JLCA NEWS ENGLISH EDITION January.2011

No.10&11

JLCA NEWS LETTER

Life-Cycle Assessment Society of Japan

Introduction

For Comprehensive Environmental Assessment Including Assessment of Environmental Impacts on Biodiversity and Water

LIME2 (Life cycle Impact assessment Method based on Endpoint modeling 2) has been developed based on the result of the second national LCA project (the LCA Project). LIME2 is an upgraded version of the Japanese version of LIME that can carry out LCIA (Life Cycle Impact Assessment) on 15 impact categories and 1,000 substances while taking into account the Japanese environmental conditions. Global warming or urban air pollution coefficients in the major areas of impact will continue to be updated even after the LCA Project, and obtained data will be included in the guidebook and published in 2010.

In addition to LCA, LIME2 can be used in a wide variety of environmental assessments such as environmental performance assessment, environmental efficiency assessment, factor assessment, and environmental accounting. Within the LIME2 Working Group (WG) part 1 established in 2007, corporate LCA administrators and LIME developers studied case examples and confirmed that new LIME2 features such as indoor air pollution assessment and uncertainty analysis were usable.

While public concern about global warming has been increasing as the concept of a carbon footprint has been disseminated, global environmental problems have been diversified. A large number of quantified assessments on biodiversity, such as the TEEB Report and the Millennium Ecosystem Assessment (MA), have been carried out, and the results will be incorporated into international environmental measures. Due to the worsening of water issues in developing countries, international water footprint standardization has begun. Resource issues involving rare metals or fossil fuels have been causing multi-country conflicts. Therefore, the necessity to carry out environmental assessment from a comprehensive perspective has increased.

In 2010, the Life Cycle Assessment Society of Japan (JLCA) established the WG part 2 consisting of corporate LCA administrators and LIME developers to discuss how LCIA should be implemented. As a result, inventory data prepared in advance by participating companies was applied to LIME2, and the group members worked together to interpret the assessment results. Concerns were particularly strong for the environmental impact on water and biodiversity, and therefore, companies that had implemented processes or chose products to reduce such impacts actively participated in this WG to use LIME2.

This report provides information on LIME2 usability and issues to be resolved in the future from the user perspective. It would be a great pleasure for us if the readers of this report were those who wish to use LCA or related methods to comprehensively view and assess a wide variety of environmental impacts on global warming, water, biodiversity, and resources such that they can incorporate the assessment results in environmental management.

Norihiro Itsubo

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Chairman, LIME2 Use Review WG, Life Cycle Assessment Society of Japan (JLCA)

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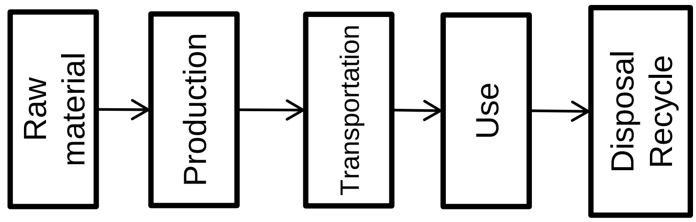
Assessment of a Steel Beverage Can ‘TULC’

Assessor: Atsuo Masaki, Environmental Department, TOYO SEIKAN KAISHA

- Purpose of assessment and characteristics of product
  - Environmental impact assessment of a steel beverage container ‘TULC’
  - Comparison with a welded can or a decorated can
  - Assessment of environmental impact of waste

  - Steel can for holding coffee or tea
  - 200 ml
  - Lighter than a welded can by 2 g (approximately 6%)
  - Reduction of as much carbon dioxide emission as possible during can production

- Functional unit and system boundary
  - Functional unit: provision of 200 ml low acid beverage to consumers
  - System boundary: material, manufacturing, transportation, use, disposal, and recycling



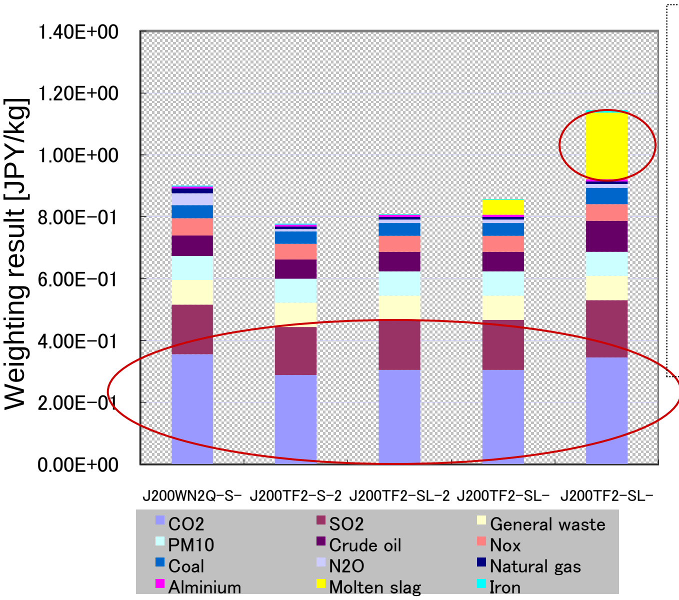
- Study method

  <Inventory analysis>
  - Foreground data: in-house measurement data
  - Background data: basic unit used in the EcoLeaf program

  <Impact analysis>
  - LIME2

- Assessment result

[Consolidated result (by life cycle substance)]



① J200WN2Q-S-2
Welded can (control)

② J200TF2-S-2
TULC (regular printed can)

③ J200TF2-SL-2
Labeled TULC (can with a gravure printing film label)

④ J200TFS-SL-88
Labeled TULC with an environmental impact of waste

⑤ J200TFS-SL-50
Labeled TULC with an environmental impact of waste and also with the recycling rate lowered from 88% to 50%

- CO_2 emission greatly influences the environmental impact
- Molten slag as a waste material is also considerable
- The recycling rate also greatly influences the environmental impact
- Effective use of resources results in reduction of environmental loads

Reduction of the environmental impact by reducing carbon dioxide emission

Limitations of this assessment: environmental impacts other than energy-based environmental impacts, such as productivity, efficiency, and human impacts, are not included in the assessment.

Power Generation Business Assessment (Environmental Impact Assessment of Power Generation)

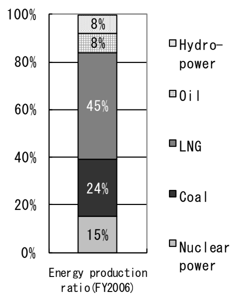
Assessors: Yasunori Kato, Environmental Department, CHUBU Electric Power, Takeshi Toramaru, JAPAN NUS

- Purpose of assessment

Assessment of the environmental impact of power generation (fuel procurement, fossil fuel consumption, and waste generation) from the following perspectives:

- Assessment of the environmental impact reducing effect of improvement of power generation efficiency
- Comparison of environmental impacts among various power generation modes

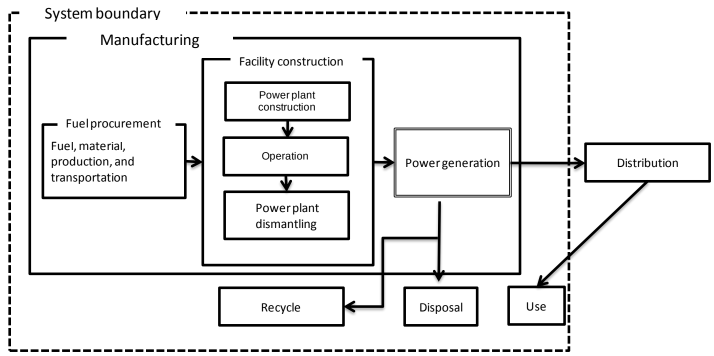
- LNG thermal power (1100ºC level CC)
- LNG thermal power (1300ºC level CC)
- Coal thermal power
- Oil thermal power
- Nuclear power
- CC: combined cycle



- Functional unit and system boundary

Functional unit: electricity at a power distribution terminal of a power plant (1 kWh)

System boundary: fuel procurement, facility construction, power generation, use, and disposal



- Study method

<Inventory analysis>

- Foreground data: measurement data
- Background data: JEMAI-LCA pro data and the Central Research Institute of Electric Power Industry Study Report (Y99009 and Y01006) *

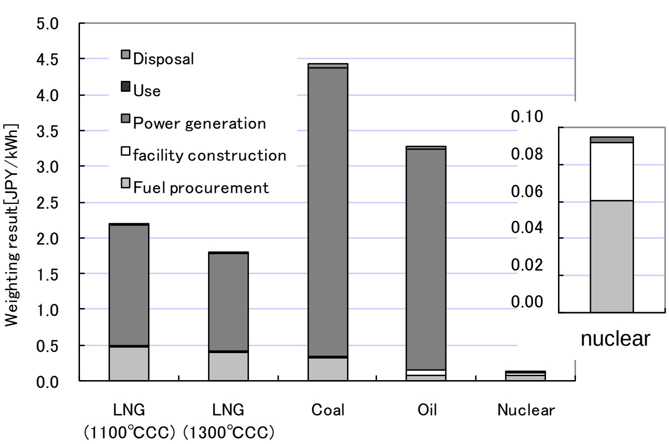
<Impact analysis>

- LIME2

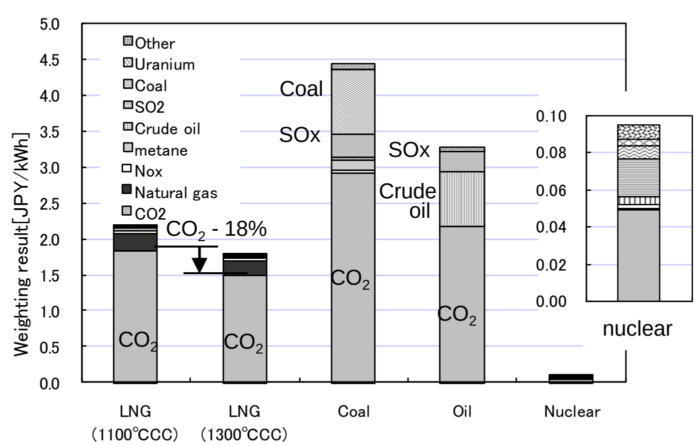
* Hiroki Hondo, Yoji Uchiyama, and Yoshie Moriizumi: "Power Generation Technology Assessment based on Life Cycle CO_2 Emission," Y99009, Central Research Institute of Electric Power Industry Study Report (2000).
Hiroki Hondo: "Nuclear Power Generation Technology Assessment based on Life Cycle CO_2 Emission," Y01006, Central Research Institute of Electric Power Industry Study Report (2001).

- Assessment

[Weighting result (by life cycle stage)]



[Weighting result (by substance)]



- Improvement of power generation efficiency (1100ºC → 1300ºC LNG thermal power) reduces the environmental impact by approximately 20% (18% in this example).
- Thermal power generation causes high social costs.

- Coal and oil thermal power have higher environmental impacts than LNG thermal power.
- CO_2 emission caused by power generation has the highest environmental impact.
- The environmental impact of nuclear power generation is extremely low.

It has been confirmed that improvement of power generation efficiency leads to reduction of the environmental impact (mainly reduction of CO_2 emissions).
The environmental impact of various modes of power generation has been compared and assessed.

Limitations of this assessment: environmental impact of the power generation facility is a reference value, and the environmental impact of radioactive waste processing (nuclear power) has not been assessed.

Environmental Impact Comparison of Toilet Care using Automatic Urine Collector

Assessor: Nobuaki Kosugi, Environmental Promotion Office, CSR Department, Unicharm Corporation

Purpose of assessment and characteristics of product

- Determination of the environmental performance of toilet care using automatic urine collector
- Extraction of processes important for the improvement of environmental impacts

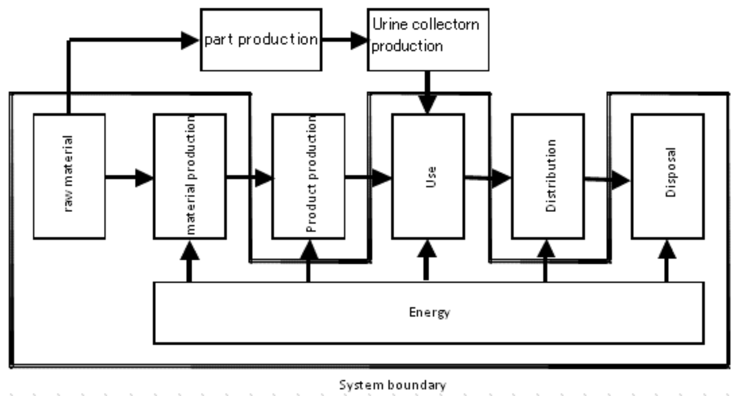
- By combining the use of tape fastening-type diapers and automatic urine collector in toilet care, the number of diaper changes needed can be reduced as urine is collected with the suction pump of the urine collector instead of being absorbed by a diaper, preventing diapers from becoming wet frequently
- Urine is disposed of into a toilet once a day
- For each day of toilet care,
  Conventional method (2 diapers / 6 pads) *
  Automatic urine collector (2 diapers / 2 pads) *
  are used respectively

* Company data

Functional unit and system boundary

Functional unit: toilet care for a one-day period

System boundary: includes the raw material production, use, and disposal stages



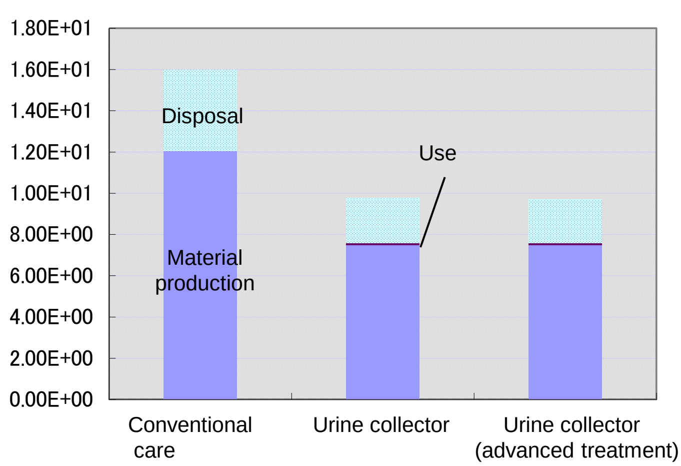
Study method

<Inventory analysis>

- Foreground data: interview survey
- Background data: data provided by Prof. Muroyama and others at Kansai University, LCA Japan Forum, and Jemai-LCA
- <Impact analysis>
- LIME2

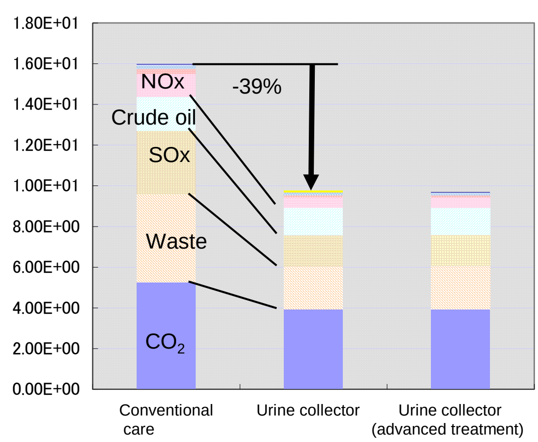
Assessment result

[Weighting result (by life cycle stage)]



- The majority of environmental impacts occur during the raw material production and disposal stages
- The impact during the use stage of the automatic urine collector is small

[Weightingresult (by substance)]



- CO_2, SOx, waste and crude oil are the major causes of impacts for all systems
- Significant reduction of environmental impacts is achieved as the result of reduced waste

The reduction of impacts during raw material production and the reduction of waste after the product use contribute to mitigating overall environmental impacts

Limitations of this assessment: the assessment does not include data on the product production and transportation stages. While the impacts associated with these stages are estimated to be small, their inclusion in the assessment needs to be considered.

Environmental Impact Comparison of Recycled Wood-Based Building Materials using Natural Adhesive

Assessor: Koshiro Nakajima, Kyoto Research & Development Laboratory, Urban Infrastructure and Environmental Products Company, Sekisui Chemical Co., Ltd.

• Purpose of assessment and characteristics of product

- Determination of the environmental performance of natural (tannin) adhesive
- Extraction of processes important for the improvement of environmental impacts
- Utilization of the assessment result for environmentally conscious designing and productivity improvement

Demolition/sorting /shredding | Shredded wood chips | Adhesive application and steam pressing

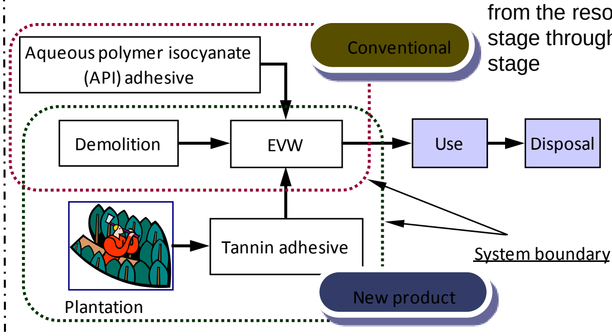
(☆ Received Nikkei Global Environmental Technology Award in 2006)

- Demolition wood waste is reprocessed as structural materials
- Achieved the quality of performance that had not been possible with conventional wood materials
  Stable quality / high strength + rigid / large cross section / utilization of lumber from forest thinning
- Newly-developed adhesive produced from mimosa bark extract (tannin)

• Functional unit and system boundary

Functional unit: having bending strength that meets the requirement for class 1 structural plywood under JAS

System boundary: from the resource extraction stage through the production stage



• Study method

<Inventory analysis>

- Foreground data: collected at the company plants or obtained from existing literature (research paper)

◆ Yukinobu Sawada, Keisuke Ando, Nobuaki Hattori, Yasuo Tamura: Inventory Analysis of Adhesives Used for Wood Based Materials, Journal of the Japan Wood Research Society, vol. 52, No. 4, p 235-240, 2006

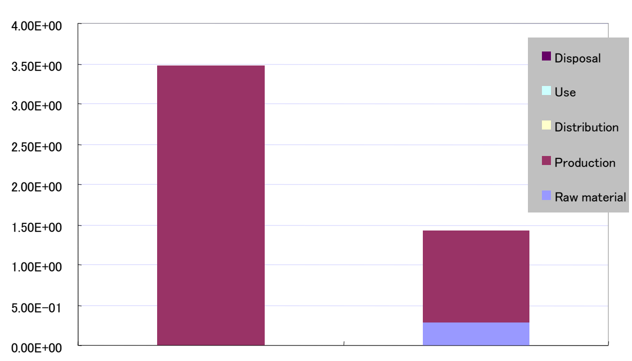
- Background data: JEMAI-Pro + data pack

<Impact analysis>

- LIME2

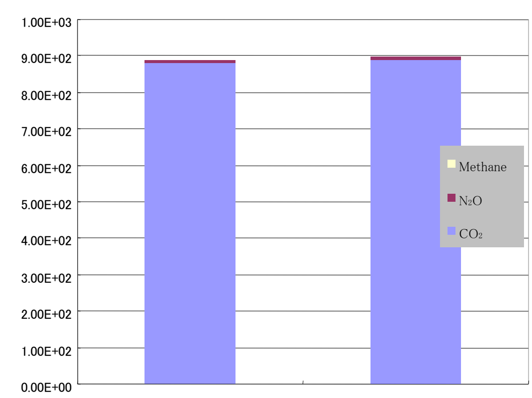
• Assessment result

[Weighting result (yen/kg)] Comparison between 1 kg of conventional product (petroleum-derived: API adhesive) and 1 kg of newly-developed natural (tannin) adhesive



- The impact of API was calculated using data provided in the above research paper. Natural adhesive has less than half the impact of API. The impact occurring in the production stage of natural adhesive is especially smaller.

[Weighting result - global warming] Comparison between 1 ton each of two recycled wood-based building materials using different types of adhesives



- Due to a larger amount of adhesive used in the natural adhesive-based building material for strength development, the impacts of both building materials are virtually of the same level. The reduction of impacts through the entire production process will be considered in the future.

Environmental impacts are reduced through the production of adhesive from natural raw materials

Limitations of this assessment: impacts occurring in the stage of overseas transportation were excluded from the scope of this assessment for the reason that LIME2 is intended for application within Japan.

Environmental Impact Comparison between Conventional and New Switchboard Products

Assessor: Masahiko Masuda, Fuji Electric Systems Co., Ltd. and Takashi Kuwabara, Fuji Electric Advanced Technology Co., Ltd.

- Purpose of assessment and characteristics of product
  - Determination of the environmental performance of conventional and new products
  - Extraction of processes important for the improvement of environmental impacts
  - Utilization of the assessment result for environmentally conscious designing
  - Assessment subjects: high voltage panels and control centers

High voltage panel

Conventional product / new product

7.2 kV panel / SLIMEC-V6

Ecoleaf registration number

BW-06-002/BW-07-003

Energy conservation: ▲16%

Weight reduction: ▲ 57%

Control center

Conventional product / new product

SM1200/SM3000

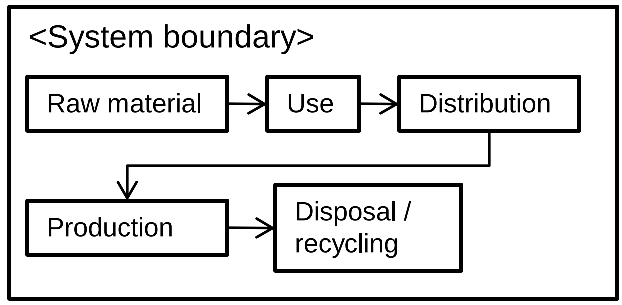
Ecoleaf registration number

BG-04-001/BG-05-002

Energy conservation: ▲ 36%

Weight reduction: ▲ 22%

- Functional unit and system boundary
  - Functional unit: high voltage panel) 2 functional units, main circuit rated current 300A
    Load factor 35%, 24 hours/day, 360 days/year, for 15 years
    Control center) 10 functional units, total control capacity 150 kW
    Load factor 70%, 4 hours/day, 360 days/year, for 15 years
  - System boundary: includes the raw material, production, transportation, use, disposal/recycling stages



- Study method

<Inventory analysis>

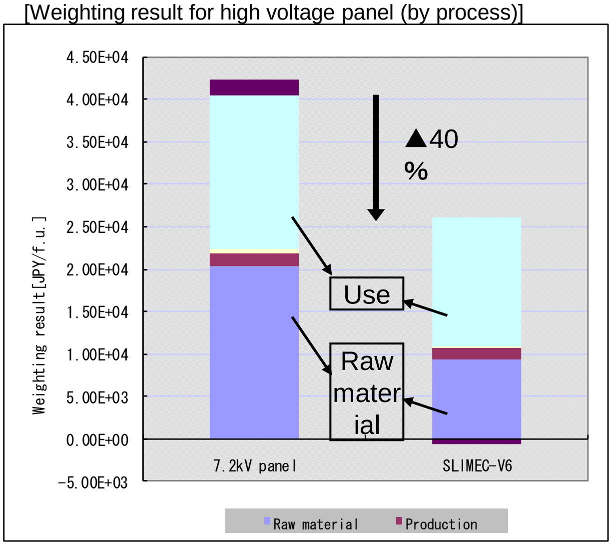
- Foreground data: actual measurement (partially research) data
- Background data: Ecoleaf environmental label common intensities

<Impact analysis>

- LIME2

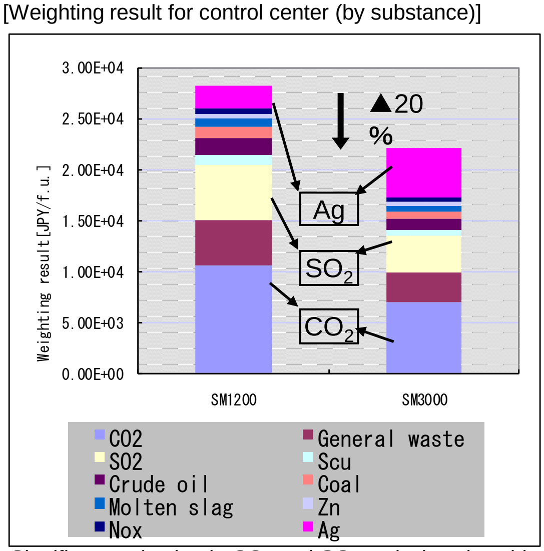
- Assessment result

[Weighting result for high voltage panel (by process)]



- Significant reduction in environmental impacts is achieved in the raw material stage as the result of the reduced product weight
- The proportions of the environmental impacts associated with the use stage and raw material stage are almost equal

[Weighting result for control center (by substance)]



- Significant reduction in CO_2 and SO_2 emissions is achieved as the result of energy conservation
- The consumption of silver has a large environmental impact

Environmental impacts associated with the raw material and use stages are reduced through energy conservation and product weight reduction

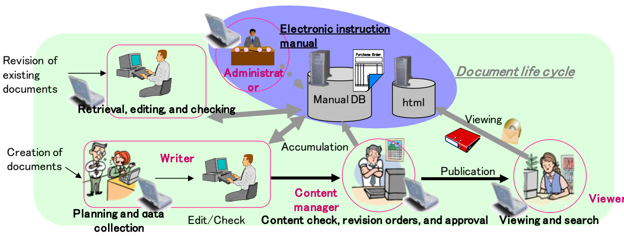
Limitations of this assessment: because switchboards are build-to-order products, this assessment result does not universally apply to all switchboard products.

Environmental Impacts Before and After Installation of a Document Digitization Solution

Assessor: Shigeharu Suzuki, Environmental Engineering Laboratories, Fujitsu Laboratories Limited

• Purpose of assessment and characteristics of product

- An ICT solution to digitize documents
- To product users, quantitative presentation of environmental improvements comparing before and after the product installation

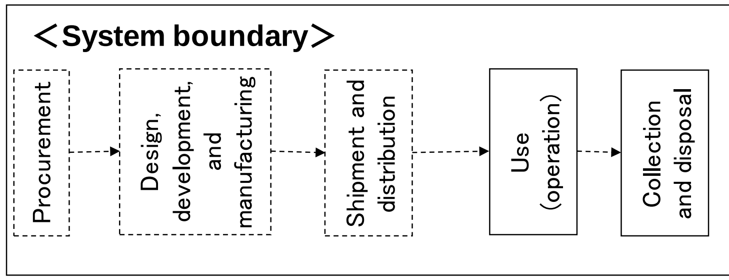


- Update status, history, and details of a document can be checked on a browser
- A document can be automatically published on a specified date
- Instruction manuals are managed in the xml format and published in the html format on a web server
- Existing Word files can be used to improve document creation efficiency

• Functional unit and system boundary

Functional unit: updating of 1,300 types of instruction manuals to be handled in a year when distributing them to 1,500 divisions

System boundary: use and disposal stages



Environmental impacts of paper consumption, object transportation/relocation, efficiency, storage space, and ICT device power consumption during the operation and disposal stages were assessed.

• Study method

<Inventory analysis>

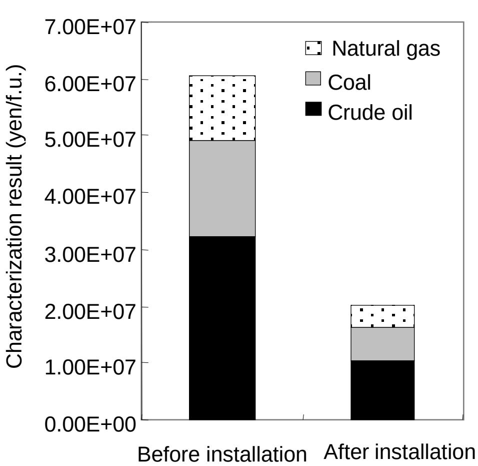
- Foreground data: solution operation measurement data obtained through customer interviews
- Background data: in-house database based on the 2000 inter-industry relations table and EcoLeaf data (for biomass paper incineration)

<Impact analysis>

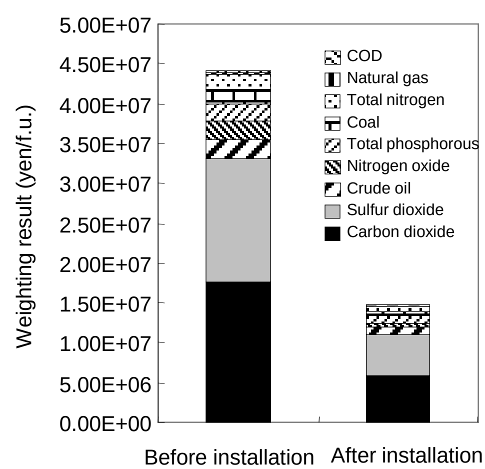
- LIME2

• Assessment result

[Weighting result (resource energy consumption)]



[Weighting result (by substance)]



- Installation of the subject solution led to a dramatic decrease of the environmental impact through reduction of paper consumption, reduction of transportation due to viewing of websites, and reduction of energy consumption (crude oil and coal) due to improved efficiency.
- CO_2 and SO_2 had large environmental impacts. Reduction of paper consumption and reduction of energy consumption through efficiency improvement would contribute to reduction of the overall environmental impact.

Installation of the subject solution resulted in a dramatic decrease in the environmental impact caused by resource energy consumption.

Limitations of this assessment: the assessment was conducted only with paper consumption and power consumption caused by the use of ICT devices such as servers and PCs during the solution operation and disposal stages, and device materials and the manufacturing stage were not included in the scope of assessment.

Environmental Impact Assessment of Lead-Free Solder used in LCD Projector

Assessor: Ayano Nishiguchi, Production Engineering Research Laboratory, Hitachi, Ltd.

●Purpose of assessment

Assess the environmental impact of a liquid crystal projector (LCD projector) that uses lead-free solder for the assembly of its printed circuit board (hereinafter referred to as "this product"). The same LCD projector, on the assumption that lead solder is used instead for its printed circuit board assembly (hereinafter referred to as a "lead solder-based product"), is referred to for comparison purposes.

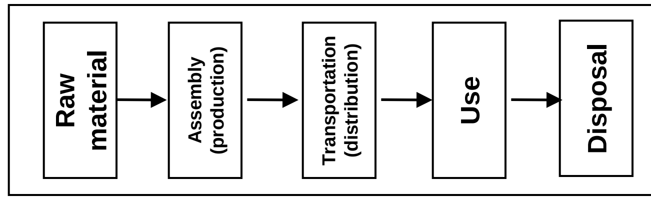
Source: Wooo World LCD projector, Hitachi, Ltd.
http://av.hitachi.co.jp/homeproj/index.html

●Characteristics of product

- Lead-free solder is used for printed circuit board assembly
- Mechanical parts are completely free of polyvinyl chloride
- Non-halogen flame retardant is used in the housing
- Transmissive 3LCD shutter projection system / digital high-definition capable / maximal brightness 1200 lm

●Functional unit and system boundary

- Functional unit: used for 3.5 hours/day, 100 days/year, for 5 years
- System boundary: includes raw material, assembly (production), transportation (distribution), use, and disposal stages



- Assessment criteria: Ecoleaf PSC for data projector (PSC ID: AG-03) published by the Japan Environmental Management Association for Industry (JEMAI)

●Survey method

- Solder composition ratio:
- Lead-free solder: SnAgCu = 96.3:3:0.5
- Lead solder: SnPb = 37:63
- Assuming a scenario that the entire amount of lead contained in the solder used in the solder-based product is released into the soil upon the product's disposal

<Inventory analysis>

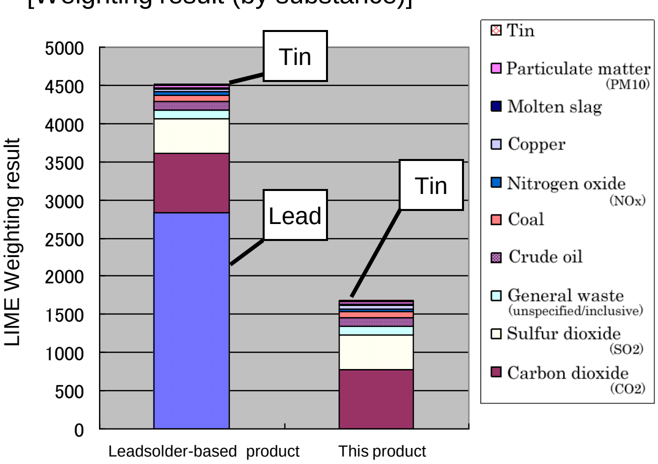
- Foreground data: actual measurement taken at the company plants
- Background data: Ecoleaf
- Assessment of lead emissions: chemical substance emission calculation sheet

<Impact analysis>

- LIME2

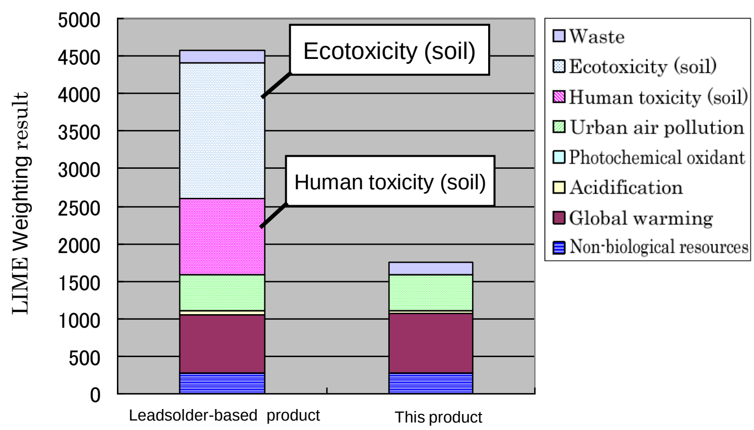
●Assessment result

[Weighting result (by substance)]



- By using lead-free solder, the total environmental impact can be reduced to 1/3.

[Weighting result (by category)]



- By using lead-free solder, the environmental impact of "ecotoxicity (39%)" and "human toxicity (22%)" in soil will be 0 (zero).

Environmental impact on humans and ecosystems will be reduced by using lead-free solder

Limitations of this assessment: data on part of the assembly (production) processes that are outsourced or components manufactured externally, such as purchased parts, are not covered in the assessment; the impact assessment of the release of lead into the soil is based on the assumption of long-term impact

Environmental Impact Assessment of Household Air Conditioner

Assessor: Yoshiyuki Hondo, Corporate Research & Development Center, Toshiba Corporation

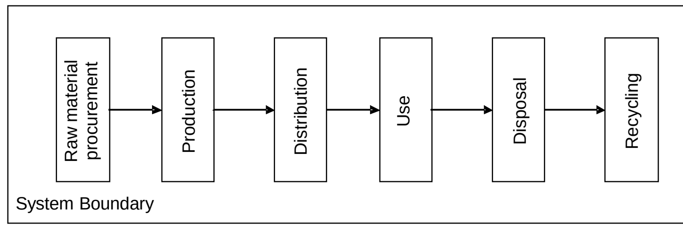
- Purpose of assessment and characteristics of product
  - Conduct a LIME2 assessment on "Daiseikai SDR Series" RAS-402SDR (released in 2006), a household air conditioner model with an environmentally conscious design. Make a comparative assessment with RAS-406YDR (released in 2000).
  - Confirm the reduction of environmental impact and calculate the factor T.

- A combination of built-in high-performance compressor and high-efficiency inverter enhances energy conservation.
- Automatic cleaning function self-cleans the inside of the unit and maintains the efficiency of the air conditioner.

- Functional unit and system boundary

Functional unit: assume the use of a household air conditioner for one life cycle of 10 years.

System boundary: includes raw material, assembly (production), transportation (distribution), use, disposal, and recycling stages



* The use conditions are set according to the calculation criteria for annual performance factor (APF)

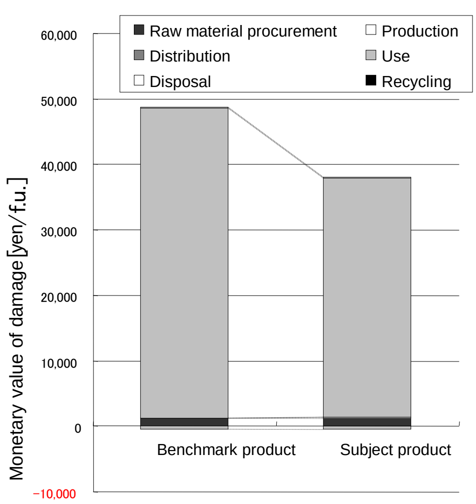
- Study method

<Inventory analysis>
- Foreground data: design data
- Background data: Easy-LCA

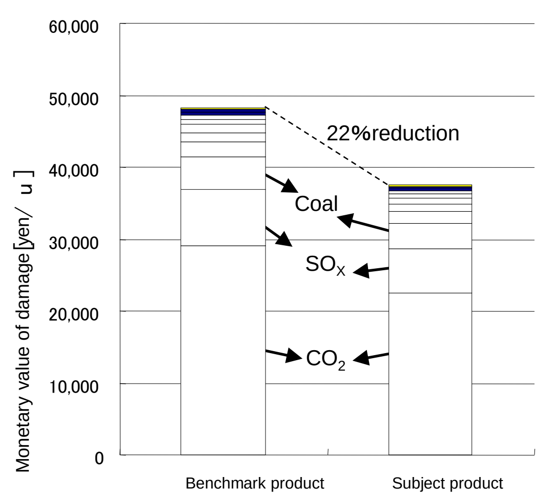
<Impact analysis>
- LIME2

- Assessment result

[Weigting result (by life cycle stage)]



[Weigting result (by substance)]



- The environmental impact at the use stage is reduced by 23% (through energy-saving design)
- The environmental impact of raw materials (at the raw material procurement stage) increased slightly (8%) (due to changes made to the composition of parts)
- The emissions of substances such as CO_2 and SOx attributable to the electricity consumption during product use have large environmental impacts

Environmental impact over the product's life cycle is reduced by 22% as the result of an energy-saving design

Limitations of this assessment: data used for the disposal and recycling stages were referenced from existing literature

Environmental Impact Analysis of Indoor Air Quality Improvement through the Use of a High-Function Building Material

Assessor: Hiroyuki Oba, Environmental Office, TOSTEM CORPORATION

Purpose of assessment and characteristics of product

- Environmental impact assessment of each life stage of an interior material
- Assessment of adsorption and decomposition of formaldehyde (CO_2 emission)
- Effectiveness and possibility of recycling

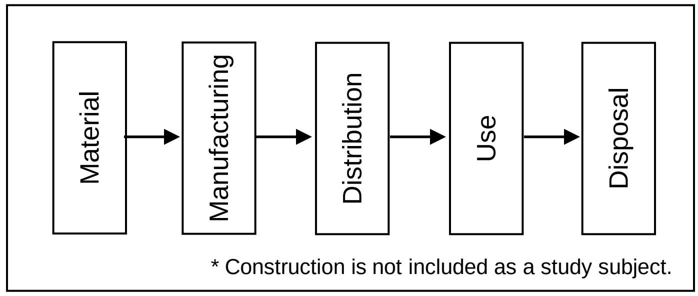
Interior material ‘MOISS’

- Humidity adjustment and deodorant functions like soil walls or trees
- Adsorption and decomposition of toxic substances by vermiculite
- No adhesive is required because wallpaper is unnecessary to finish walls
- Recyclable because of the use of natural materials as main ingredients

Functional unit and system boundary

Functional unit: 8-year use of 6 pieces of 910 x 1820 x 9.5 mm

System boundary: material, manufacturing, distribution, use, and disposal



Study method

<Inventory analysis>

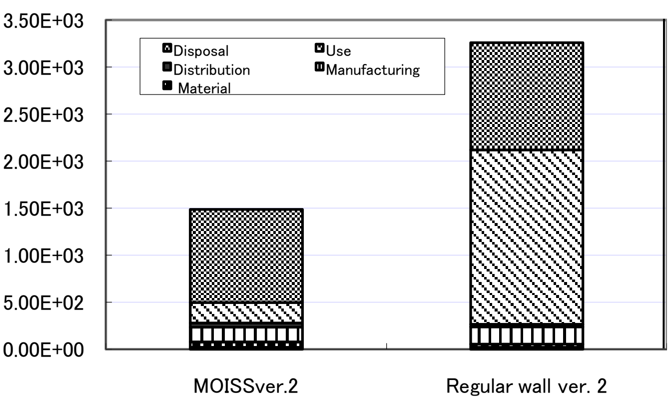
- Foreground data: data from interviews and industrial associations
- Background data: data from JEMAI-LCA Pro, LCA Japan Forum database, industrial associations

<Impact analysis>

- LIME2

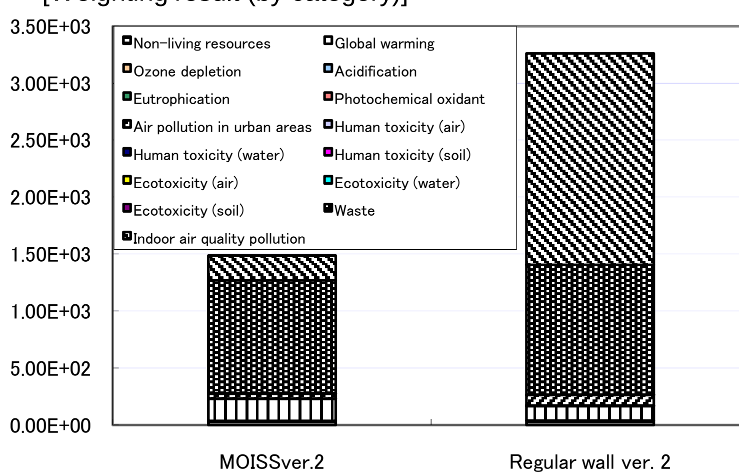
Assessment result

[Weighting result (by life cycle stage)]



- Environmental impact is high in the use stage.
- After the use stage, the disposal, manufacturing, material, and distribution stages follow in this order.

[Weighting result (by category)]



- Improvement of indoor air quality has a strong influence on the environmental impact.
- Waste, air pollution in urban areas, and global warming have high environmental impacts.

The formaldehyde adsorption and decomposition effect of MOISS has a strong effect on reduction of the environmental impact.
Waste has a high environmental impact; therefore, recycling is expected to reduce the environmental impact.

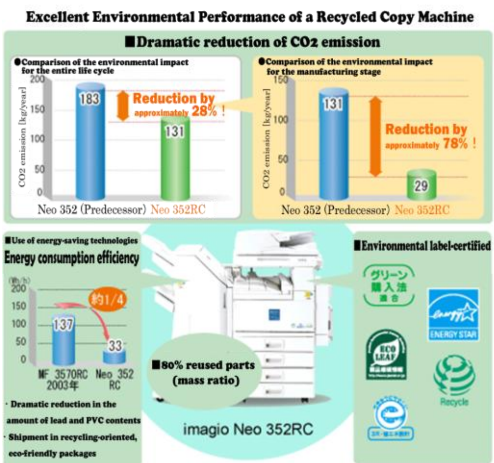
Limitations of this assessment: the effectiveness of formaldehyde adsorption and decomposition was based on the performance test value, the material process for by-product gypsum was excluded from the assessment, and the walls were disassembled and treated as industrial waste.

Comparison of Environmental Impacts between a Recycled Copy Machine (RC Machine) and a Copy Machine

Assessor: Makiko Hirai, Environmental Division, Ricoh Company, Ltd.

Purpose of assessment and characteristics of product

- Assessment of the environmental impact of a recycled copy machine (RC machine)
- Assessment of the effectiveness of recycling of parts
- Use of the evaluation result to create eco-friendly designs

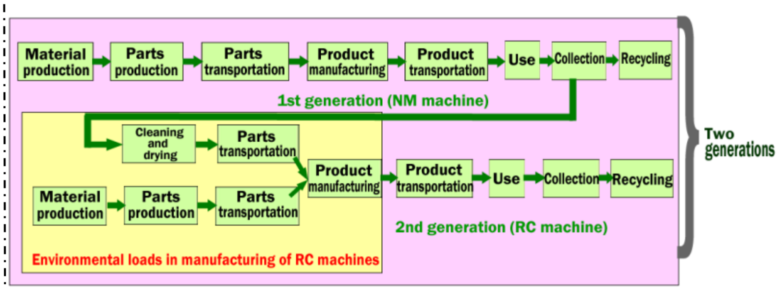


- Comparison between "2 new machines x 5 years of use" and "new and RC machines for 10 years of use (5 years of use for each)"
- Copy speed: 45 sheets/minute
- More than 80% of a unit consists of recycled parts (mass ratio)

Functional unit and system boundary

Functional unit: copy machines to be used for 10 years

System boundary: material, manufacturing, transportation, use, recycling, and disposal stages



Study method

<Inventory analysis>

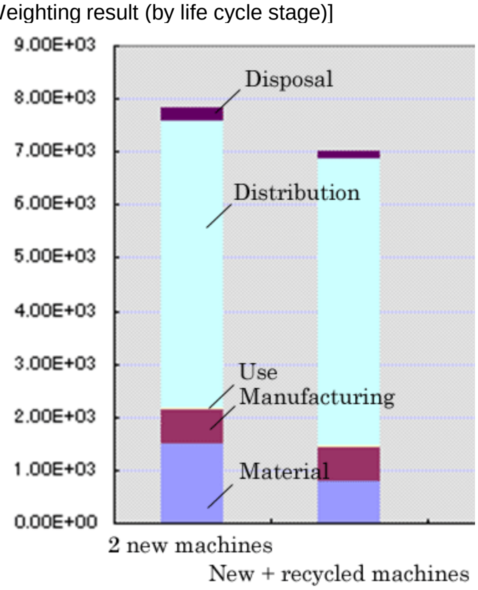
- Foreground data: corporate data
- Background data: basic unit used in the EcoLeaf program

<Impact analysis>

- LIME2

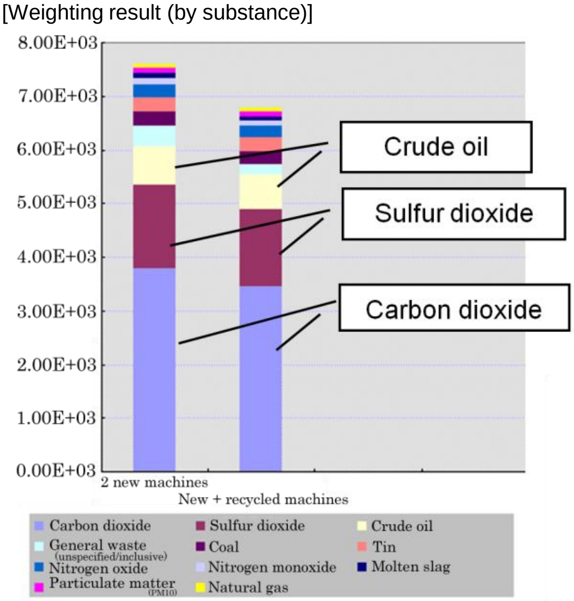
Assessment result

[Weighting result (by life cycle stage)]



- Use of an RC machine has a smaller environmental impact
- High environmental loads are observed in the product use stage

[Weighting result (by substance)]



- For both types of machines, crude oil consumption, and CO_2 and SOx emission are the major determinants of the level of environmental impact
- An RC machine emits less CO_2 than a new machine.

Reuse of parts can reduce the environmental impact of the overall copy machine materials

Limitations of this assessment: the yield ratio in remaking a new machine into an RC machine has not been taken into account. Also, it is necessary to examine how the concept of recycling should be expressed.

Sustainable Forest Management and Environmental Impact with Relation to Base Paper for Paper Cups

Evaluator: Paper Cup Working Group, Printers Association of Japan
(Toshihiko Arima, Alpha Research Institute)

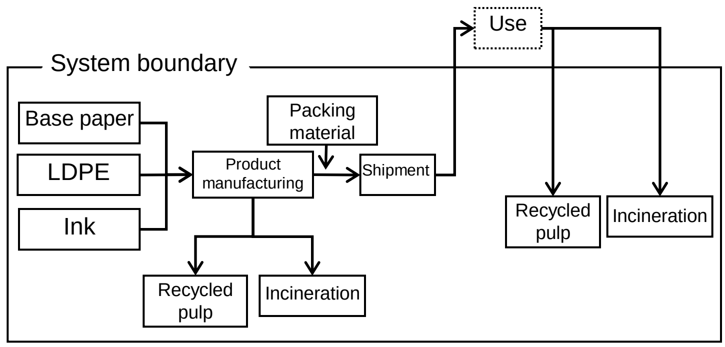
• Objective and product characteristics

- A paper cup is made of wood.
- Environmental impacts on primary production and biodiversity depend on where the wood is from and whether the wood is from a natural forest or a planted forest.
- Assessment is carried out to examine how differences in material influence Weightingresults.

- The maximum capacity of the subject paper cup is 275 ml.
- It is usually used to hold approximately 200 ml of beverage.
- Used cups are usually incinerated.
- Some are collected for material recycling.

• Functional unit and system boundary

Functional unit: One paper cup
System boundary: Manufacturing, shipment, incineration, and recycling



● Study method

<Inventory analysis>

- Priority data: data obtained in interviews
- Background data: database of the Life Cycle Assessment Society of Japan (JLCA), JEMAI-LCA Pro, and the container packaging LCA survey report

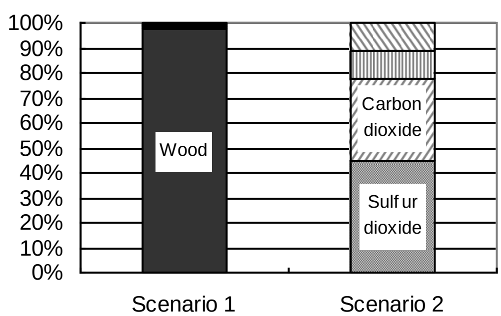
<Impact assessment>

- LIME2

• Result

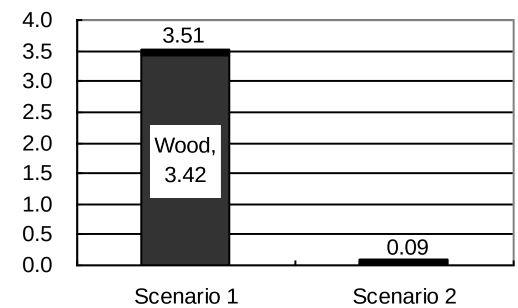
Scenario 1: Calculate environmental loads using data on countries of origin of paper in general, and the ratio between trees from natural forests and trees from planted forests.
Scenario 2: Calculate environmental loads based on the assumption that sustainable forest management has been achieved so that neither primary production nor biodiversity is affected.

[Weighting result (breakdown by substance)]



- In Scenario 1, wood accounts for most of the environmental impact.
- In Scenario 2, sulfur dioxide and carbon dioxide account for approximately 80% of the environmental impact.

[Weighting result (real number for each substance)]



- Social costs are 3.51 yen in Scenario 1 and 0.09 yen in Scenario 2. In Scenario 1, wood accounts for 3.42 yen out of 3.51 yen.
- Scenario 2 can greatly reduce environmental loads.

Environmental loads can be reduced by using wood obtained from forests that are under sustainable management.

Limitations of this assessment result: data on countries of origin of base paper for paper cups as well as the ratio between trees from natural forests and trees from planted forests has not been obtained.

Environmental Impact Assessment of Ethanol Production Using Rice Straw as a Raw Material

Evaluators: Masaharu Motoshita and Cuifen Yang, Research Institute of Science for Safety and Sustainability, National Institute of Advanced Industrial Science and Technology

● Objective and product characteristics

- To Identify important processes in ethanol production from rice straw in the aspect of environmental impacts
- To quantify the reduction of environmental impacts achieved by utilizing byproducts
- Raw material : unutilizedor low utilized rice straw
- Production method: hydrolysis with concentrated sulfuric acid
- Options: Utilization of byproduct (lignin) as a boiler fuel in the fermentation, distillation, and dehydration processes

● Functional unit

Functional unit: production of 1GJ of ethanol from rice straw

● Study method

<Inventory analysis>

- Unit process data: literature (Yang, et al, 2009)
- Background data: AIST-LCA ver. 4

<Impact assessment>

- LIME2

● System boundary

System boundary: from raw material collection to ethanol production and transportation

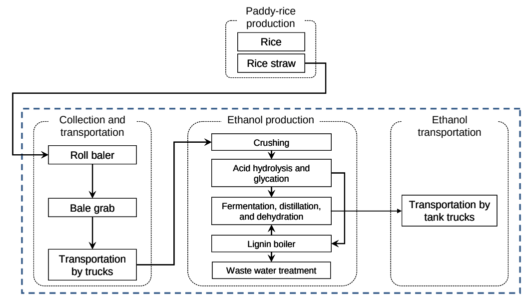


Figure 1 System boundary of Scenario 1(with a lignin-fueled boiler)

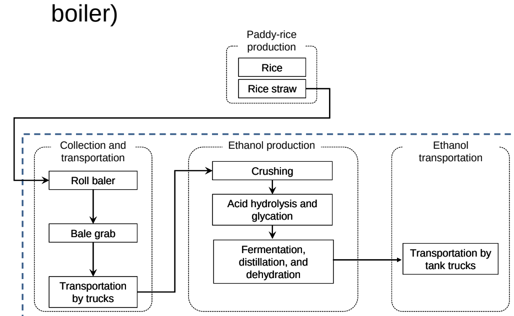
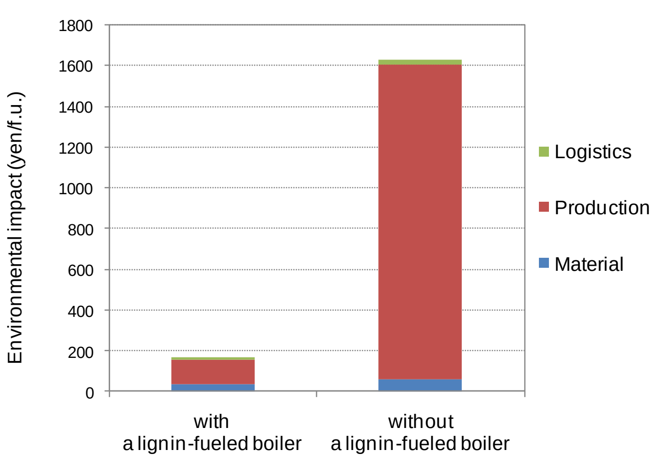


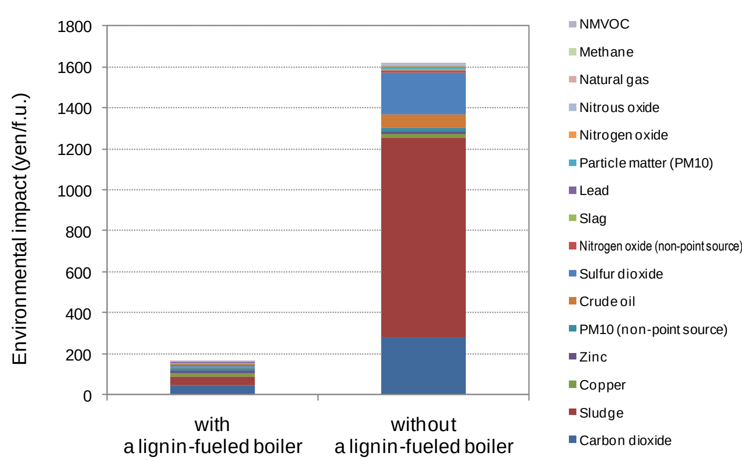
Figure 2 System boundary of Scenario 2 (without a lignin-fueled boiler)

● Result

[Weighting result (life stages)]



[Weighting result (substances)]



- Production process (mainly, due to energy consumption for fermentation, distillation, and dehydration, and waste landfill) dominate large part of total environmental impact.
- Significant improvement effect can be found in emissions of CO2 and PM10, and sludge landfill, by utilizing lignin for boiler fuel.

The utilization of the byproduct (lignin) as a fuel can hold the environmental impact to 1/10.

Limitations: The environmental load of raw material (raw straw) production is not included in the study. In case of considering it, energy and materials used in rice cropping should be allocated to rice and chaff, respectively.

Method of Filling a PET Bottle Using Lower Water Consumption

Evaluators: Ayumi Shibata and Asako Fujimori, Packaging Operations, Dai Nippon Printing Co., Ltd.

• Objective and product characteristics

For an aseptic PET bottle filling system, compare the conventional and new filling methods with water being used as the subject of assessment.

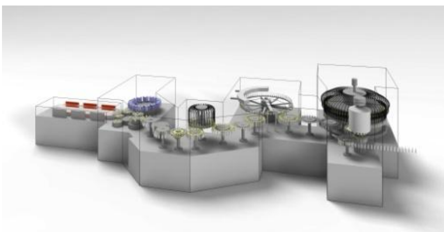


Image of an aseptic bottle filling system

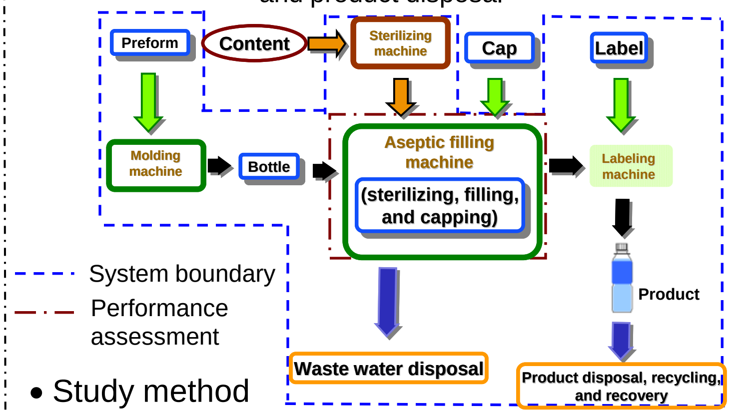
①Conventional method
This is Dai Nippon Printing's original sterilizing and filling method in which high-temperature hydrogen peroxide mists are blown into a bottle. This method very effectively sterilizes a bottle within a very short period of time.

② New method
This is the advanced version of the conventional method. With the blow-molding device being directly connected to the aseptic filling device, energy efficiency has been improved and water consumption has been reduced.

• Functional unit and system boundary

Functional unit: One-hour production (36,000 pet bottles) by a system that adds 500 ml of tea to a PET bottle

System boundary: From preform molding to content sterilization, bottle molding, filling, labeling, and product disposal



• Study method

<Inventory analysis>

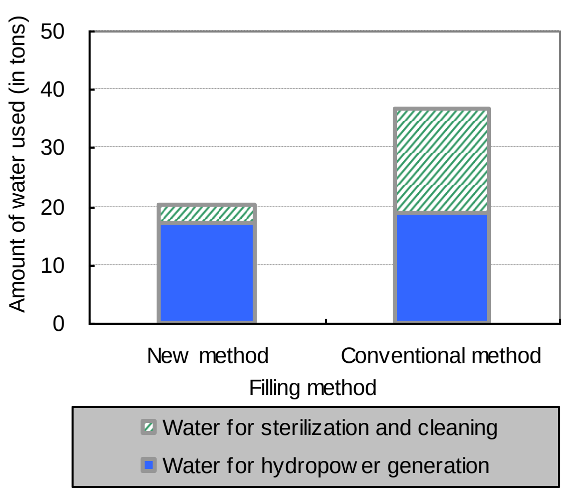
- Priority data: interviews
- Background data: JEMAI-LCA Pro, JEMAI-LCA Option Datapack, and the PET Bottle LCI Analysis Report

<Impact assessment>

- LIME2 and water consumption-induced health damage coefficients

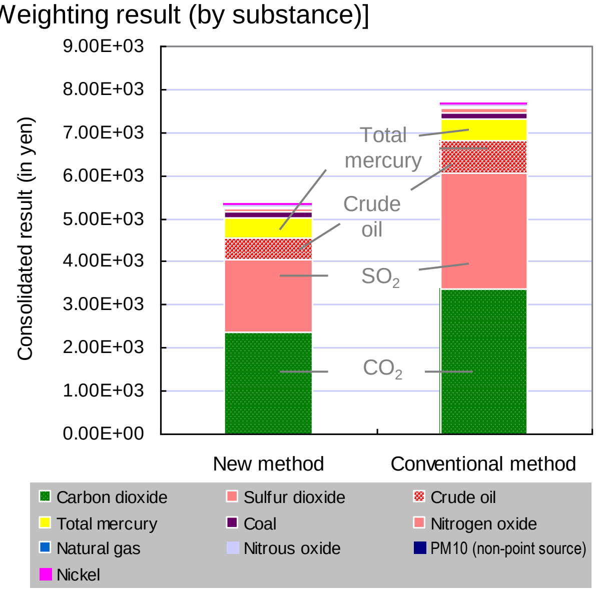
• Result

[Inventory result (water)]



Water consumption can be greatly reduced with the new method.

[Weighting result (by substance)]



The environmental impact caused by CO_2 and SO_2 in particular can be reduced with the new method. In Japan, water resource consumption has almost no environmental impact.

With the new method, it is possible to greatly reduce the amount of water used and also the damage caused by CO_2 and SO_2.

Limitations of this assessment result: A basic unit appropriate for each type of water has not been selected. Water resource consumption-induced health damage coefficients have not been established.

Environmental Impact Assessment of a Professional Golf Tournament

Evaluators: Masato Hiruma, Dentsu Communication Institute Inc., Dentsu Inc.
Hiroshi Yamaguchi, Tokyo City University

• Objective and the characteristics of study subject

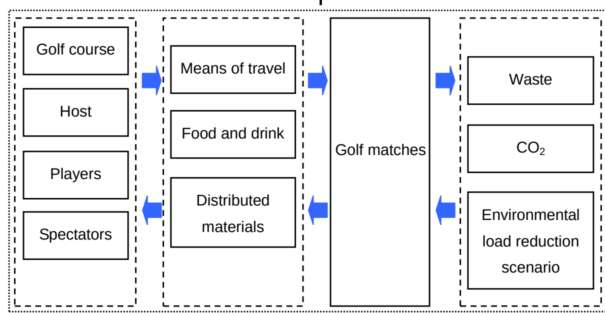
- Understanding of the overview of the environmental impact associated with a professional golf tournament
- Review of issues regarding development of a method to carry out environmental impact assessment on sports events, and examination of the method to administer the assessment

Duration and place	Duration: one week (two days for practice and four days for the tournament) Place: venue not within walking distance from the nearest station (in the northern Kanto area)
Participants	125 professional players, 100 amateur players, 20,180 spectators, 445 volunteers, and 260 tournament officials
Scope of assessment	All processes before, during, and after the tournament (details will be described below)

• Functional unit and system boundary

Functional unit: amount of environmental loads generated by a person (spectators, player, or tournament official) during the life cycle of a professional golf tournament.

System boundary: travel by people, hosting of the tournament, and waste disposal



• Study method

<Inventory analysis>

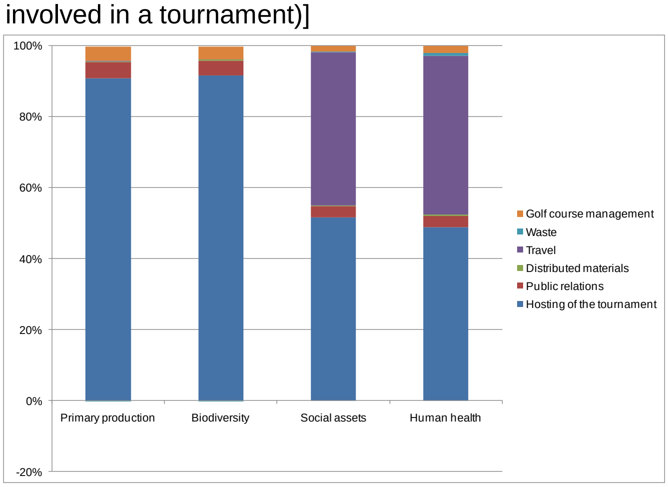
- Priority data: tournament budget list and tournament manual
- Background data: environmental load data based on input-output tables (3EID, database created by Tokyo City University, and database created by the National Institute of Advanced Industrial Science and Technology), and statistical data on travel created by the Ministry of Land, Infrastructure, Transport and Tourism and the Ministry of the Environment

<Impact assessment>

- LIME2

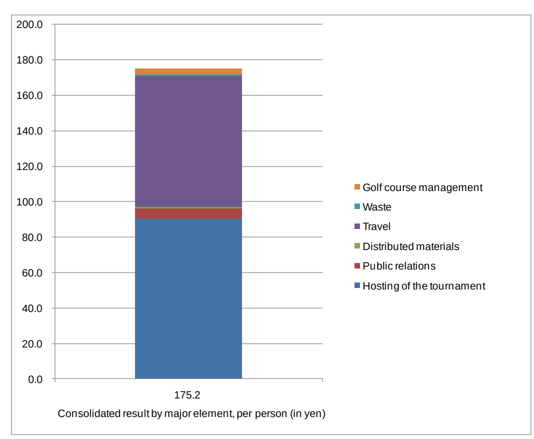
• Result

[Damage assessment result (by major elements involved in a tournament)]



- The damage caused by hosting of the tournament is high relative to other elements.
- The damage caused by travel and public relations is relatively high within the category of damage to human health.

[Weighting result (by major elements involved in a tournament)]



- According to the Weightingresult, the damage caused by one person is calculated to be approximately 175 yen (approximately 3.7 million yen for the entire tournament).
- The damage of hosting of the tournament is 91 yen (1.92 million yen for the entire tournament) and travel is 74 yen (1.56 million yen for the entire tournament)

The damage from public relations (printing) could be reduced. It may be difficult to reduce the impact from hosting of the tournament and travel.

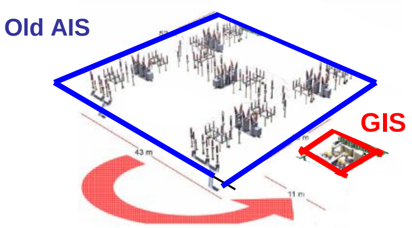
Limitations of this assessment result: The objective of this assessment is to grasp the overall environmental impact. To improve assessment accuracy, it is necessary to improve the quality of data and databases. It will also be necessary to examine the relationships among consumption or emission-induced environmental loads.

Comparison of Environmental Impact between Substations Using an SF_6 Gas Insulated Switchgear and an Air Insulated Switchgear

Evaluator: Hideki Noda, Power and Industrial Systems R&D Center, Toshiba Corporation

• Objective and product characteristics

Assuming that an outdoor substation will be built in a mountain area, compare an SF_6 gas insulated switchgear (GIS) and an old-type air insulated switchgear (AIS) to clarify the trade-off relationship between SF_6 gas leakage and the effect of substation floor area reduction to the environment due to GIS installation.



Comparison image

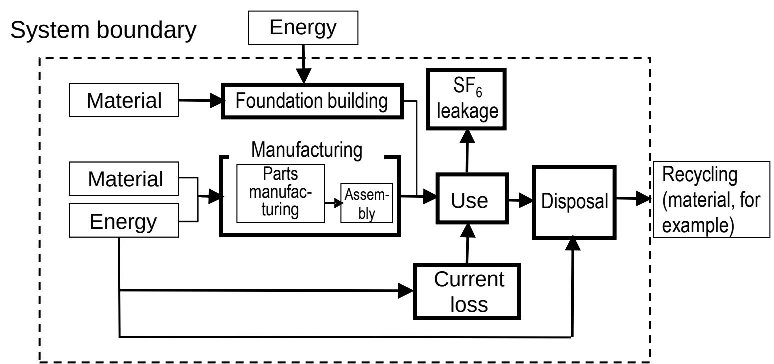
Characteristics of a GIS

- The total mass is 35% of the old-type AIS.
- The amount of concrete used to build the foundation is 6.7% of what is required for the old-type AIS.
- The substation area is 3.3% of the old-type AIS.
- It is assumed that there will be SF_6 gas leakage (0.05%/year during operation, and 1% at the time of system removal)

• Functional unit and system boundary

Functional unit: 30 years of use (load factor: 50%) of a 145-kV switchgear (4 lines and Bus Section)

System boundary: foundation building, manufacturing, current loss, SF_6 gas leakage, and disposal



• Study method

<Inventory analysis>

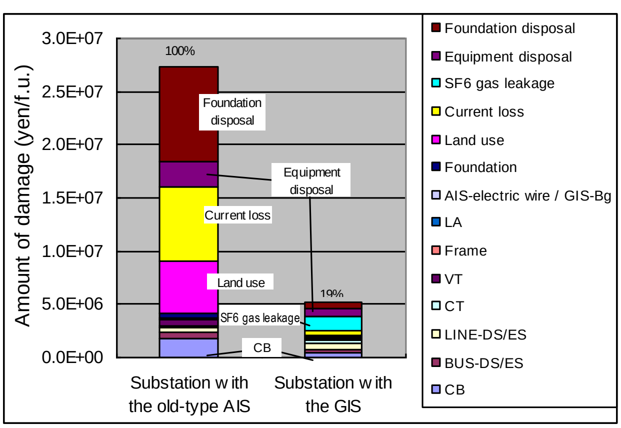
- Priority data: interviews
- Background data: input-output data (EasyLCA data)

<Impact assessment>

- LIME2

• Result

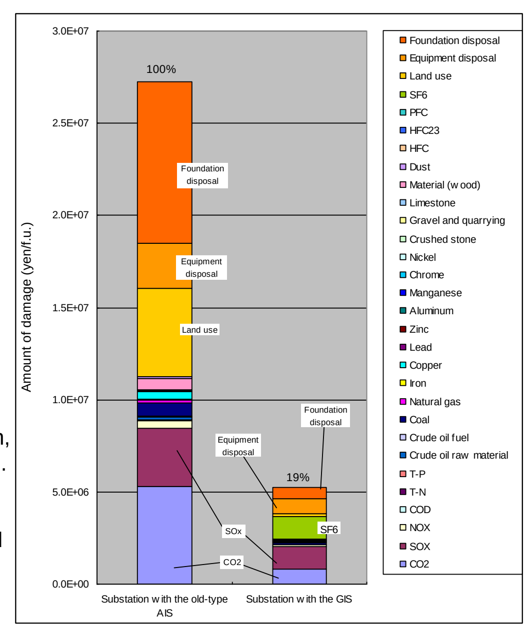
[Weighting result] (by process)



- The old-type AIS had a larger environmental impact than the GIS in terms of land use, current loss, and disposal (foundation and equipment), but it had a smaller environmental load in terms of SF_6 gas leakage.

[Weighting result] (by inventory)

- A large part of the environmental impact of the old-type AIS is the result of disposal (foundation and equipment), land use, CO_2 emission, and SOx emission.
- For the GIS, the environmental impact of SOx and SF_6 emission is prominent.



Reduction of substation area can reduce the environmental impact of land use and disposal.

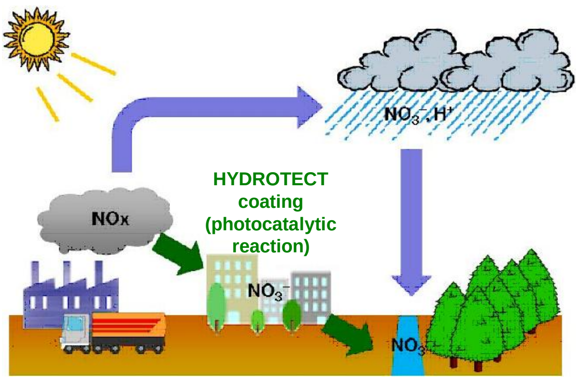
Limitations of this assessment result: data on the foundation is used as background data, and the recycling process is not included as the subject of assessment.

Environmental Impact Assessment of HYDROTECT Coating

Evaluators: Junji Kameshima, Technical Development Section, Green Building Materials Division, TOTO LTD.
Toshihiro Takagi, Research and Planning G, Research Laboratory, TOTO LTD

● Objective and product characteristics

- Understanding of environmental performance of HYDROTECT coating
- Identification of processes that are important in reduction of the environmental impact

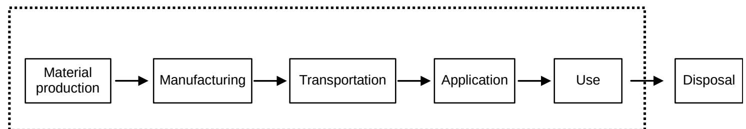


- Photocatalytic reaction of HYDROTECT coating removes NOx to purify the air.
- Highly durable HYDROTECT coating can double the life of an ordinary coating.

● Functional unit and system boundary

Functional unit: use of a 1,000 m^2 coated surface for 20 years

System boundary: material production, manufacturing, transportation, application, and use



● Study method

<Inventory analysis>

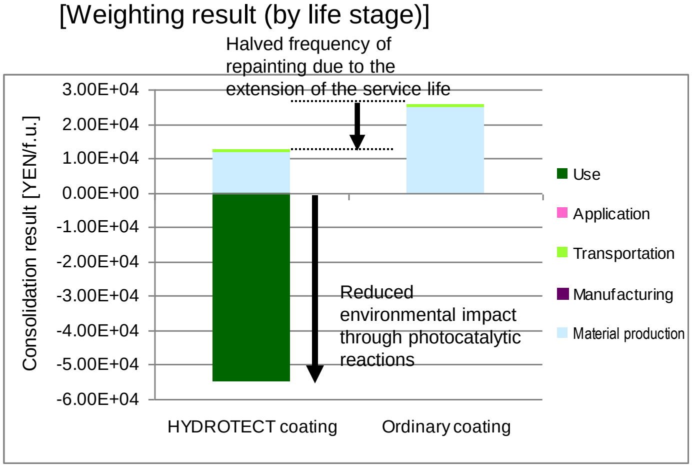
- Priority data: survey by TOTO
- Background data: data from JEMAI “LCA pro” and the Life Cycle Assessment Society of Japan (JLCA)

<Impact assessment>

- LIME2

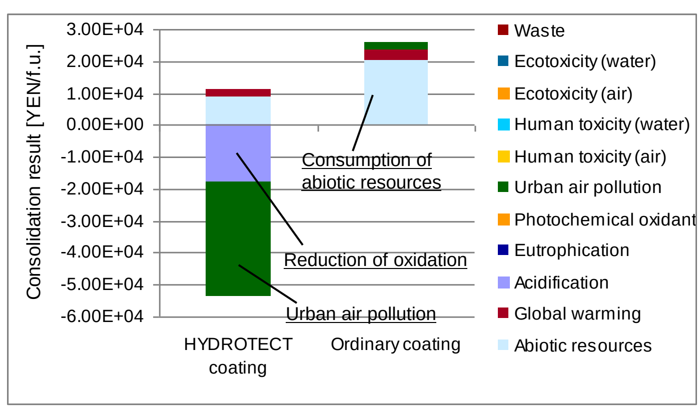
● Results

[Weighting result (by life stage)]



- HYDROTECT coating purifies the air by means of photocatalytic reactions and has a positive effect on the environment during the use phase.
- Lengthening of coating life can lead to reduction of its environmental impact.

[Weighting result (by category)]



- Most of the positive environmental effect is attributed to consumption of abiotic resources.
- HYDROTECT coating can reduce the environmental impact of urban air pollution and acidification; therefore, the bar extends to the negative side of the graph.

Lengthening of coating life can lead to reduction of its environmental impact.
HYDROTECT coating purifies the air by means of photocatalytic reactions and has a positive effect on the environment during the use phase.

Limitations of this assessment result: The inventory for photocatalytic titanium dioxide was based on white pigment data. The amount of NOx removal was obtained by converting performance test results (JIS-certified test).

Comparison of the Environmental Impact of Various Types of Containers

Evaluator: Yumi Yoshimura
Environment Department, Material Purchase and Environment Division, Toyo Seikan Kaisha, Ltd.

• Objective and product characteristics

- Environmental impact assessment of 350-ml containers: two aluminum cans (DWI can and an aTULC), a PET bottle, and a stand-up pouch
- Understanding of differences in the environmental impact among different containers
- Use of the assessment result to reduce the environmental impact

[DWI can]

- conventional aluminum can
- Requires application of a lubricant and a coating on the inner surface

[aTULC]

- Stands for Aluminum Toyo Ultimate Can
- Does not require application of a lubricant or a coating on the inner surface

[PET bottle]

- A heat-resistant bottle that can be filled with tea (a 350-ml bottle for carbonated drinks was not available)

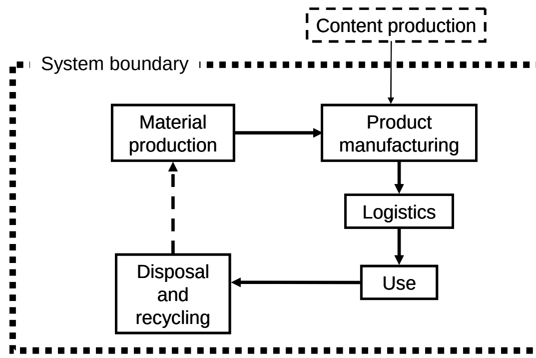
[Stand-up pouch]

- A pouch containing detergent refill (a 350-ml pouch for drinks was not available)

• Functional unit and system boundary

Functional unit: one container to be filled with 350 ml of contents, protected, and provided to a consumer

System boundary: from material production to product manufacturing, logistics, use, disposal, and recycling



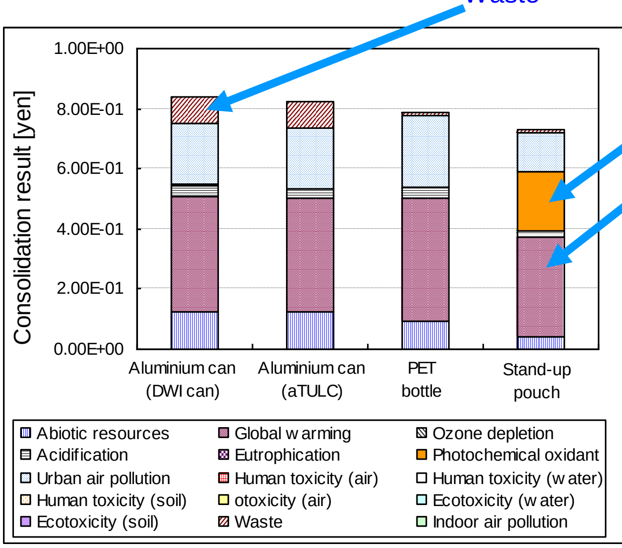
• Study method

<Inventory analysis>
- Priority data: in-house measurement data
- Background data: EcoLeaf basic unit

<Impact assessment>
- LIME2

• Result

[Weighting result (by area of impact)]



- The total value is about the same for all types of containers.
- All containers had a significant effect on global warming.
- Compared to other types of containers, the aluminum cans had a large impact on waste.
- Compared to other types of containers, the stand-up pouch had high photochemical oxidant emissions.

Different containers have different areas of impact.
It is necessary to establish different environmental impact reduction measures for different types of containers.

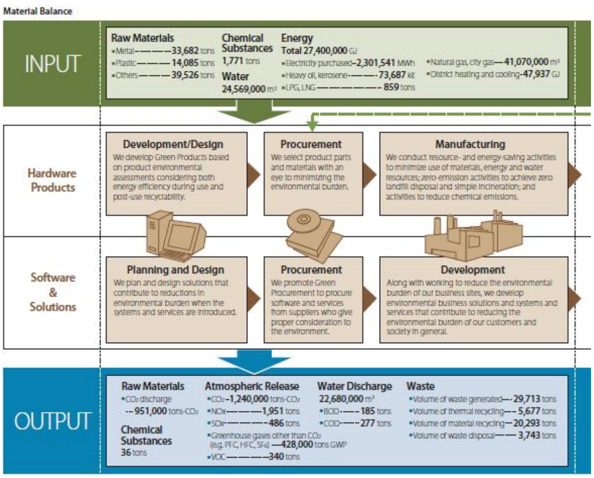
Limitations of this assessment result: Containers with different functions and characteristics were compared while the same filling process data was applied to all types of containers.

Comparison of the Environmental Impacts of Business Activities

Evaluator: Shigeharu Suzuki, Environmental Technology Lab. Fujitsu Laboratories Ltd.

● Objective and product characteristics

- Understanding of the environmental impact of business activities
- Focus on the phases up to the manufacturing phase of leading products
- Examination of chronological changes in the environmental impact and provision of information as tips to reduce the environmental impact



- Manufacturing of leading products* in the business activities of FY2007 and FY2008

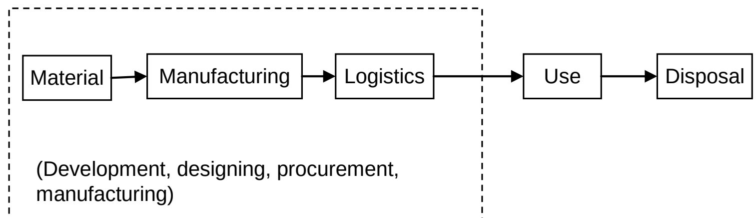
* Leading products: 15 types of product such as PCs, mobile phones, and servers

● Functional unit and system boundary

Functional unit: the life cycle of the leading products manufactured and shipped in each subject fiscal year

System boundary: from the raw material procurement (material) phase to the manufacturing and logistics phases

System boundary



● Study method

<Inventory analysis>

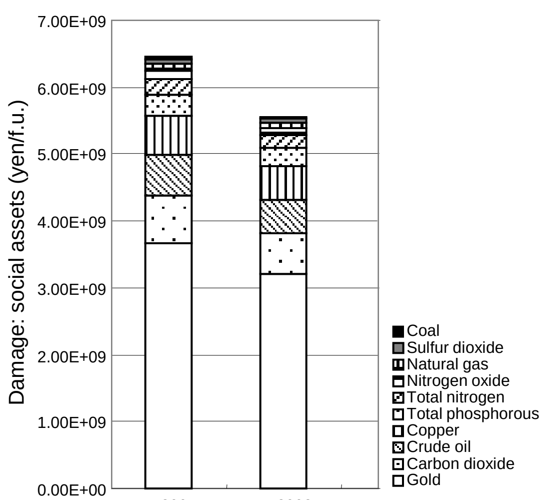
- Priority data: in-house survey results and sustainability reports
- Background data: in-house database

<Impact assessment>

- LIME2

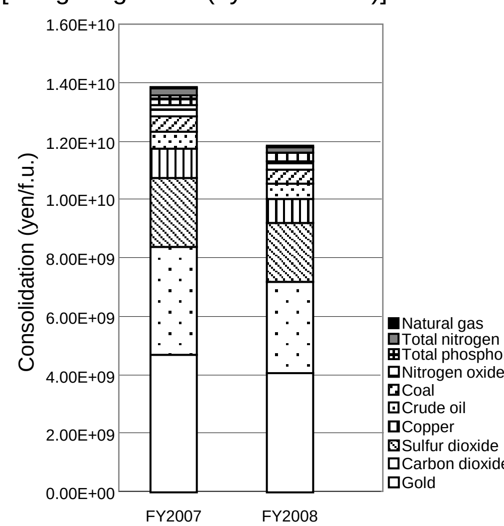
● Result

[Damage assessment (social assets)]



- The gold accounted for more than half of the damage, followed by carbon dioxide, crude oil, and copper in that order.

[Weighting result (by substance)]



- Major constituents of the weighting damage are: gold consumption that has a large impact on social assets; and carbon dioxide and sulfur dioxide emissions that have a large impact on human health and social assets.

Consumption of resources such as gold and crude oil has the largest environmental impact, and emission of carbon dioxide and sulfur dioxide has the second largest environmental impact of the subject products.

Limitations of this assessment result: The scope of assessment includes the material, manufacturing, and logistics phases, and excludes the use and disposal phases. Chemical substances are not the subjects of the assessment.

Comparison of the Environmental Impact between a Traditional Adult Diaper and the Humany Urine Suction System

Evaluator: Nobuaki Kosugi, Environment Enhancement Office, CSR Division, Unicharm Humancare Corporation

• Objective and product characteristics

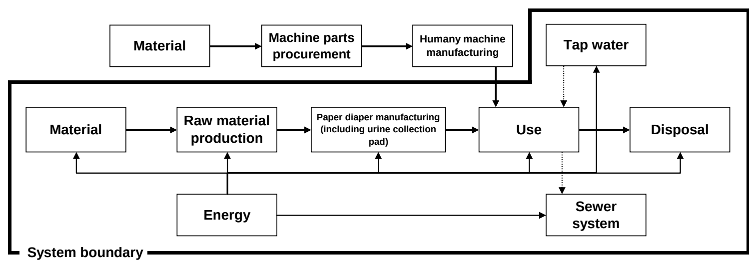
- Understanding of the environmental efficiency of Humany
- Identification of important processes and elements of the environmental impact in order to reduce

- Humany machine: mass of 2 kg, power consumption of 10 W during suction, and power consumption of 1 W while in stand-by mode
- Tank capacity: 1 liter (must be emptied out into the toilet once a day)
- Medium-sized adult diaper with side tapes: product mass of approximately 110 g (1 diaper per day)
- Humany pad: product mass of approximately 40 g (1 pad per day)
- The sensor on the pad detects urine to trigger suction by the machine

• Functional unit and system boundary

Functional unit: urine suction and collection for a day

System boundary: from the manufacturing to use and then disposal phases.
Note that, manufacturing and transportation of the Humany machine are not included.



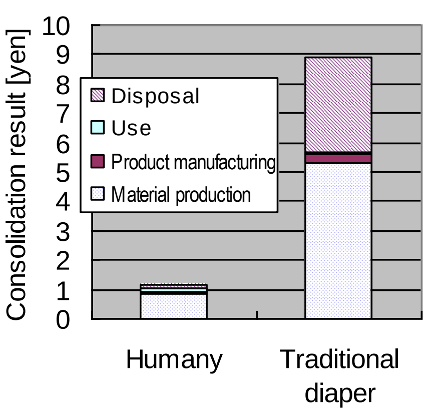
• Study method

<Inventory analysis>
- Priority data: in-house research data
- Background data: database created by the Life Cycle Assessment Society of Japan (JLCA), and JEMAI-LCA

<Impact assessment>
- LIME2

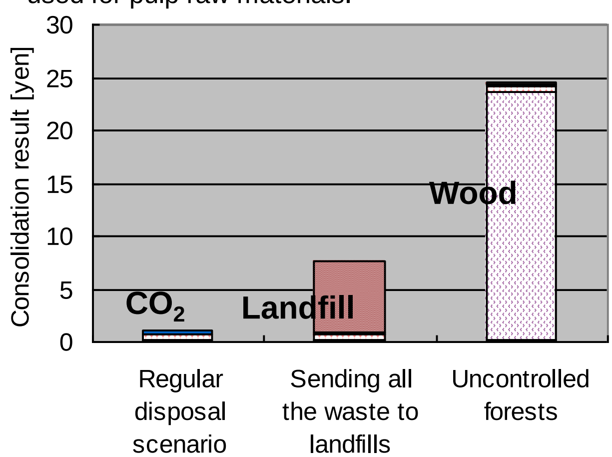
• Result

[Weighting result (by substance)]



- Use of Humany resulted in a significant reduction of the environmental loads.
- The material production and disposal phases accounted for a large part of the consolidation result.

[Weighting result (by substance)]
Comparison between the scenarios in which: all disposed products are subject to landfilling; and unmanaged forests used for pulp raw materials.



- The environmental damage in the regular mode of disposal, which was incineration, was mostly attributed to CO_2. In an attempt to reduce CO_2 emission, we replaced incineration with sending the waste to landfills, but this resulted in an increase of environmental loads.
- Environmental loads significantly increased when pulp from unmanaged forests was used.

Although CO_2 emission could be reduced by reducing the amount of resources used, by reducing environmental loads, or by using landfills as a disposal method, the overall damage increased. Management of forests for pulp production was the most important environmental impact-related issue.

Limitations of this assessment result: Since the data on product manufacturing was not used in the assessment and the raw material data was obtained from other companies, the data quality may not be consistent throughout the assessment.

Report on
Steel Beverage Can 'TULC' Assessment

May 2008

TOYO SEIKAN KAISHA, LTD.

1. General Information

1.1 Assessor

Organization: Environmental Department, Material and Environment Division, TOYO SEIKAN KAISHA
Name: Atsuo Masaki
Contact: atsuo_masaki@toyo-seikan.co.jp

1.2 Report preparation date

May 30, 2008

2. Purpose of Study

2.1 Basis of study

This study was conducted using the environmental impact assessment method called LIME2 to assess the environmental impact and understand environmental efficiency of a TULC whose environmental impact has been reduced compared to a conventional can through development of forming technologies, complete simplification of production equipment, and eliminating the use of water. A TULC with decoration called a labeled can was also assessed for an understanding of its environmental impact.

2.2 Application of study result

In this study, the study result was used to check the validity of the environmental impact assessment method. One of the most focused on parameters in deciding the validity of the method conventionally was manifestation of reduction of CO_2 emission, but in this study, LIME2 was used to comprehensively assess the environmental impact including the environmental impact of waste that LC-CO_2 could not assess.

3. Scope of Study

3.1 Subject of study and its specifications

The subjects of the study were a welded can and TULC, steel beverage cans manufactured, used, and disposed of in Japan. Each can holds 200 ml and weighs as follows:

Welded can (control):	33.7 g
TULC:	31.7 g
Labeled TULC:	32.0 g

Figure 3.1-1 shows the external view of TULC.

Figure 3.1-1 External view of a TULC

3.2 Functions and functional unit

The function of the product is limited to a basic container function, which is "to be filled with 200 ml of low acid beverage (coffee, tea, and so on), protected, and provided to consumers."

3.3 System boundary

The system boundary included stages from material production, to filling, use, disposal, and recycling. Note that the content of cans was not included in the assessment. Also, because LIME2 does not have an independent parameter for which the recycling effect could be inputted, the disposal and recycling process loads and the recycling effect were added in the assessment (Figure 3.3-1)

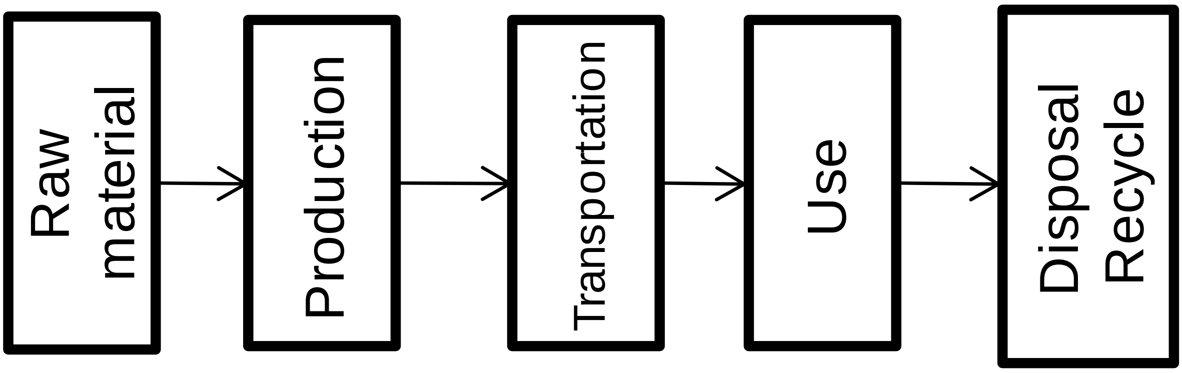


Figure 3.3-1 System boundary of a steel beverage can

3.4 Special notes (processes or items exempted from assessment, etc.)

Assessment is based on the EcoLeaf Guideline, but this does not require assessment of the environmental impact of waste in the disposal and recycling stages. In order to include assessment of the environmental impact of waste in this study, waste that was incinerated and disposed of in landfills was added as molten slag. Also, in this study, the influence of changes in the recycling rate on the amount of waste or on the overall environmental impact assessment result was studied. The recycling rate at the time of assessment was set to 88% (FY2004), and for comparison, the recycling rate in 1991, which was 50%, was also used.

4. Inventory Analysis

4.1 Foreground data

Data of materials, resources, and energy used in the can body and can lid manufacturing process was based on the measurement data obtained in FY2004 at a TOYO SEIKAN KAISHA factory.

4.2 Background data

Assuming that the material production, transportation, product use, and recycling were all EcoLeaf compliant, the EcoLeaf basic unit was used as background data. However, can molds that have not been EcoLeaf certified or cans with changed recycling rates were also specially used in this study.

4.3 Inventory analysis item and result table

Tables 4.3-1 through 4.3-5 show the subjects and results of inventory analysis for containers used in this study.

Table 4.3-1 Welded can (model: J200WN2Q-S) LCU analysis result (unit: kg/can)

I/O	Type	Selection	Material	Manufacturing	Distribution	Use	Disposal
IN	ENERGY	Crude oil	3.52E-02	6.43E-03	1.75E-03	4.02E-03	-2.53E-02
IN	ENERGY	Coal	2.42E-02	1.75E-03	1.87E-07	4.39E-04	-9.68E-03
IN	ENERGY	Natural gas	4.60E-03	7.81E-03	2.71E-05	2.74E-04	-2.23E-04
IN	MATERIAL	Uranium	1.68E-07	1.18E-07	1.27E-11	2.97E-08	-1.25E-08
IN	MATERIAL	Iron	3.00E-02				-2.51E-02
IN	MATERIAL	Aluminum	1.93E-03				
IN	MATERIAL	Nickel					
IN	MATERIAL	Chrome					
IN	MATERIAL	Manganese					
IN	MATERIAL	Mountain gravel					
IN	MATERIAL	Limestone	1.40E-03				8.43E-05
OUT	Air	Carbon dioxide	7.01E-02	4.54E-02	5.64E-03	1.46E-02	-2.45E-02
OUT	Air	Sulfur dioxide	7.24E-05	1.38E-05	6.93E-06	3.66E-06	-2.21E-05
OUT	Air	Nitrogen oxide	8.76E-05	9.54E-05	8.66E-05	2.68E-05	-2.69E-05
OUT	Air	Nitrogen monoxide	3.89E-07	2.40E-05	1.02E-07	6.04E-07	1.95E-07
OUT	Air	Methane	1.23E-08	3.16E-07	3.39E-11	7.97E-08	-1.35E-07
OUT	Air	NMVOC	2.40E-08	6.20E-07	6.66E-11	1.56E-07	-2.64E-07
OUT	Air	PM10	4.58E-05	3.39E-06	6.93E-06	3.91E-07	-1.71E-07
OUT	Water	COD	2.47E-06				-3.18E-07
OUT	Water	Total phosphorus	9.88E-08				-9.09E-09
OUT	Water	Total nitrogen	1.07E-06				-2.95E-07
OUT	General	General waste	2.42E-03	9.80E-06		2.05E-04	
OUT	General	Molten slag					
OUT	Industrial	Other sludge	1.59E-04				-3.42E-05

Table 4.3-2 TULC (model: J200TF2-S) LCU analysis result (unit: kg/can)

I/O	Type	Selection	Material	Manufacturing	Distribution	Use	Disposal
IN	ENERGY	Crude oil	3.82E-02	5.00E-03	1.75E-03	4.02E-03	-2.82E-02
IN	ENERGY	Coal	2.55E-02	1.06E-03	1.87E-07	4.39E-04	-1.07E-02
IN	ENERGY	Natural gas	4.63E-03	1.67E-03	2.71E-05	2.74E-04	-2.06E-04
IN	MATERIAL	Uranium	1.73E-07	7.20E-08	1.27E-11	2.97E-08	-7.92E-09
IN	MATERIAL	Iron	3.29E-02				-2.80E-02
IN	MATERIAL	Aluminum	1.93E-03				
IN	MATERIAL	Nickel					
IN	MATERIAL	Chrome					
IN	MATERIAL	Manganese					
IN	MATERIAL	Mountain gravel					
IN	MATERIAL	Limestone	1.46E-03				9.41E-05
OUT	Air	Carbon dioxide	7.37E-02	2.31E-02	5.64E-03	1.46E-02	-2.69E-02
OUT	Air	Sulfur dioxide	7.69E-05	9.48E-06	6.93E-06	3.66E-06	-2.42E-05
OUT	Air	Nitrogen oxide	9.18E-05	6.71E-05	8.66E-05	2.68E-05	-2.98E-05
OUT	Air	Nitrogen monoxide	1.82E-07	4.00E-06	1.02E-07	6.04E-07	1.82E-07
OUT	Air	Methane	7.19E-09	1.93E-07	3.39E-11	7.97E-08	-1.34E-07
OUT	Air	NMVOC	1.41E-08	3.77E-07	6.66E-11	1.56E-07	-2.63E-07
OUT	Air	PM10	4.56E-05	3.15E-06	6.93E-06	3.91E-07	-1.72E-07
OUT	Water	COD	2.52E-06				-3.56E-07
OUT	Water	Total phosphorus	1.01E-07				-1.02E-08
OUT	Water	Total nitrogen	4.09E-06				-3.29E-07
OUT	General	General waste	2.37E-03	9.80E-06		2.05E-04	
OUT	General	Molten slag					
OUT	Industrial	Other sludge	1.70E-04				-3.82E-05

Table 4.3-3　Labeled TULC (model: J200TF2-SL) LCU analysis result (unit: kg/can)

I/O	Type	Selection	Material	Manufacturing	Distribution	Use	Disposal
IN	ENERGY	Crude oil	3.89E-02	5.40E-03	1.75E-03	4.02E-03	-2.89E-02
IN	ENERGY	Coal	2.57E-02	1.35E-03	1.87E-07	4.39E-04	-1.10E-02
IN	ENERGY	Natural gas	4.68E-03	2.47E-03	2.71E-05	2.74E-04	-2.04E-04
IN	MATERIAL	Uranium	1.78E-07	9.12E-08	1.27E-11	2.97E-08	-7.15E-09
IN	MATERIAL	Iron	3.33E-02				-2.88E-02
IN	MATERIAL	Aluminum	1.93E-03				
IN	MATERIAL	Nickel	5.14E-12				
IN	MATERIAL	Chrome	9.38E-11				
IN	MATERIAL	Manganese	1.34E-09				
IN	MATERIAL	Mountain gravel	2.97E-09				
IN	MATERIAL	Limestone	1.47E-03				9.65E-05
OUT	Air	Carbon dioxide	7.53E-02	2.72E-02	5.64E-03	1.46E-02	-2.75E-02
OUT	Air	Sulfur dioxide	7.86E-05	1.12E-05	6.93E-06	3.66E-06	-2.47E-05
OUT	Air	Nitrogen oxide	9.43E-05	7.15E-05	8.66E-05	2.68E-05	-3.05E-05
OUT	Air	Nitrogen monoxide	2.95E-07	6.30E-06	1.02E-07	6.04E-07	1.85E-07
OUT	Air	Methane	8.58E-09	2.44E-07	3.39E-11	7.97E-08	-1.35E-07
OUT	Air	NMVOC	1.68E-08	4.77E-07	6.66E-11	1.56E-07	-2.65E-07
OUT	Air	PM10	4.57E-05	3.25E-06	6.93E-06	3.91E-07	-1.74E-07
OUT	Water	COD	2.55E-06				-3.65E-07
OUT	Water	Total phosphorus	1.03E-07				-1.04E-08
OUT	Water	Total nitrogen	4.17E-06				-3.38E-07
OUT	General	General waste	2.38E-03	9.80E-06		2.05E-04	
OUT	General	Molten slag	7.63E-08				
OUT	Industrial	Other sludge	1.73E-04				-3.91E-05

Table 4.3-4 LCI analysis result of labeled TULC with an environmental impact of waste

(unit: kg/can)

I/O	Type	Selection	Material	Manufacturing	Distribution	Use	Disposal
IN	ENERGY	Crude oil	3.89E-02	5.40E-03	1.75E-03	4.02E-03	-2.89E-02
IN	ENERGY	Coal	2.57E-02	1.35E-03	1.87E-07	4.39E-04	-1.10E-02
IN	ENERGY	Natural gas	4.68E-03	2.47E-03	2.71E-05	2.74E-04	-2.04E-04
IN	MATERIAL	Uranium	1.78E-07	9.12E-08	1.27E-11	2.97E-08	-7.15E-09
IN	MATERIAL	Iron	3.33E-02				-2.88E-02
IN	MATERIAL	Aluminum	1.93E-03				
IN	MATERIAL	Nickel	5.14E-12				
IN	MATERIAL	Chrome	9.38E-11				
IN	MATERIAL	Manganese	1.34E-09				
IN	MATERIAL	Mountain gravel	2.97E-09				
IN	MATERIAL	Limestone	1.47E-03				9.65E-05
OUT	Air	Carbon dioxide	7.53E-02	2.72E-02	5.64E-03	1.46E-02	-2.75E-02
OUT	Air	Sulfur dioxide	7.86E-05	1.12E-05	6.93E-06	3.66E-06	-2.47E-05
OUT	Air	Nitrogen oxide	9.43E-05	7.15E-05	8.66E-05	2.68E-05	-3.05E-05
OUT	Air	Nitrogen monoxide	2.95E-07	6.30E-06	1.02E-07	6.04E-07	1.85E-07
OUT	Air	Methane	8.58E-09	2.44E-07	3.39E-11	7.97E-08	-1.35E-07
OUT	Air	NMVOC	1.68E-08	4.77E-07	6.66E-11	1.56E-07	-2.65E-07
OUT	Air	PM10	4.57E-05	3.25E-06	6.93E-06	3.91E-07	-1.74E-07
OUT	Water	COD	2.55E-06				-3.65E-07
OUT	Water	Total phosphorus	1.03E-07				-1.04E-08
OUT	Water	Total nitrogen	4.17E-06				-3.38E-07
OUT	General	General waste	2.38E-03	9.80E-06		2.05E-04	
OUT	General	Molten slag	7.63E-08				3.55E-03
OUT	Industrial	Other sludge	1.73E-04				-3.91E-05

Table 4.3-5 LCI analysis result of labeled TULC with an environmental impact and also with the recycling rate lowered from 88% to 50% (unit: kg/can)

I/O	Type	Selection	Material	Manufacturing	Distribution	Use	Disposal
IN	ENERGY	Crude oil	4.15E-02	5.40E-03	1.75E-03	4.02E-03	-1.93E-02
IN	ENERGY	Coal	2.67E-02	1.35E-03	1.87E-07	4.39E-04	-7.30E-03
IN	ENERGY	Natural gas	4.71E-03	2.47E-03	2.71E-05	2.74E-04	-7.58E-05
IN	MATERIAL	Uranium	1.82E-07	9.12E-08	1.27E-11	2.97E-08	3.41E-09
IN	MATERIAL	Iron	3.59E-02				-1.94E-02
IN	MATERIAL	Aluminum	1.93E-03				
IN	MATERIAL	Nickel	5.14E-12				
IN	MATERIAL	Chrome	9.38E-11				
IN	MATERIAL	Manganese	1.34E-09				
IN	MATERIAL	Mountain gravel	2.97E-09				
IN	MATERIAL	Limestone	1.56E-03				6.52E-05
OUT	Air	Carbon dioxide	7.78E-02	2.72E-02	5.64E-03	1.46E-02	-1.73E-02
OUT	Air	Sulfur dioxide	8.06E-05	1.12E-05	6.93E-06	3.66E-06	-1.59E-05
OUT	Air	Nitrogen oxide	9.68E-05	7.15E-05	8.66E-05	2.68E-05	-1.96E-05
OUT	Air	Nitrogen monoxide	2.74E-07	6.30E-06	1.02E-07	6.04E-07	1.94E-07
OUT	Air	Methane	8.29E-09	2.44E-07	3.39E-11	7.97E-08	-6.92E-08
OUT	Air	NMVOC	1.62E-08	4.77E-07	6.66E-11	1.56E-07	-1.36E-07
OUT	Air	PM10	4.57E-05	3.25E-06	6.93E-06	3.91E-07	-6.03E-08
OUT	Water	COD	2.62E-06				-2.46E-07
OUT	Water	Total phosphorus	1.03E-07				-1.04E-08
OUT	Water	Total nitrogen	4.23E-06				-2.28E-07
OUT	General	General waste	2.38E-03	9.80E-06		2.05E-04	
OUT	General	Molten slag	7.63E-08				1.57E-02
OUT	Industrial	Other sludge	1.82E-04				-2.64E-05

5. Impact Assessment

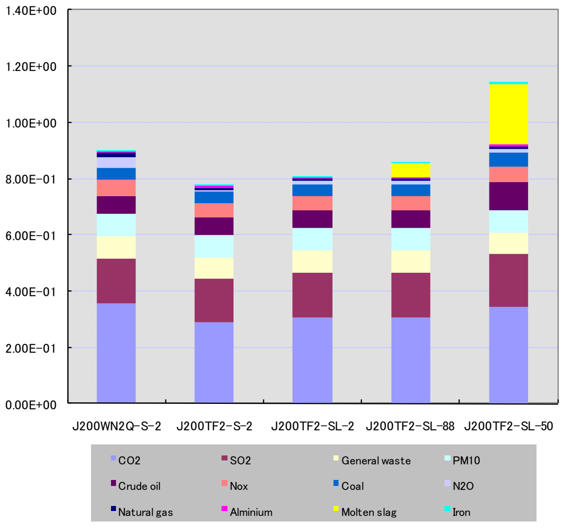
5.1 Assessment steps and subject areas of influence

For impact assessment, the Life-cycle Impact Assessment Method based on Endpoint Modeling 2 (LIME2) was used to assess weighting steps. Table 5.1-1 shows the target areas of environmental impact.

Table 5.1-1 Areas of environmental impact to be assessed

	Weighting
Resource consumption (energy)	○
Resource consumption (mineral)	○
Global warming	○
Urban air pollution	○
Ozone layer depletion	
Acidification	○
Eutrophication	○
Photochemical oxidant creation	○
Human toxicity	
Ecotoxicity	
Indoor air quality	
Noise	
Waste	○
Land use	

5.2 Result of impact assessment (weighting)



① J200WN2Q-S-2
Welded can (control)

② J200TF2-S-2
TULC (regular printed can)

③ J200TF2-SL-2
Labeled TULC

④ J200TFS-SL-88
Labeled TULC with an environmental impact of waste

⑤ J200TFS-SL-50
Labeled TULC with an environmental impact of waste and also with the recycling rate lowered from 88% to 50%

Figure 5.2-1 Weighting result (by substance)

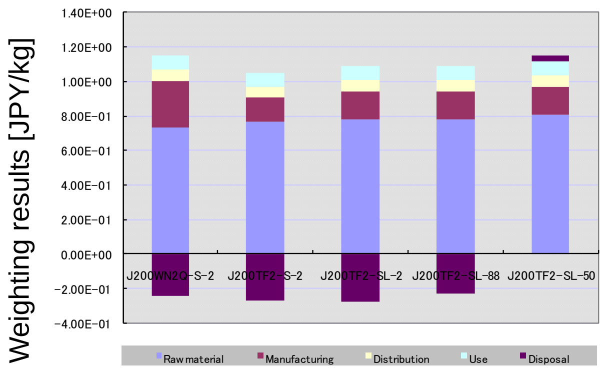


Figure 5.2-2 Weighting result (by process)

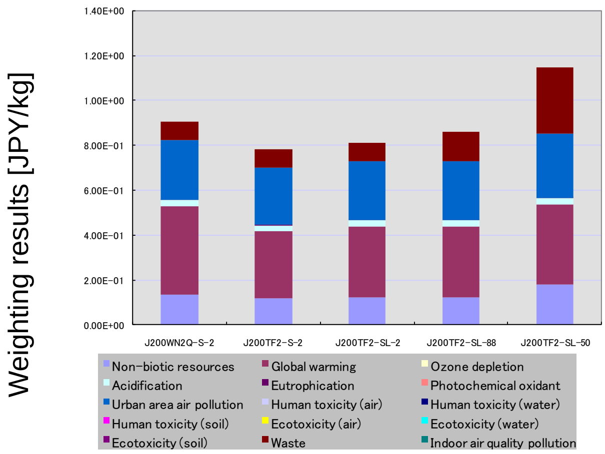


Figure 5.2-3 Weighting result (by category)

Figure 5.2-1 shows the weighting result by substance. While the environmental impact of carbon dioxide emission was significant, the environmental impact of the newly added substance 'molten slag' was also considerable. It had a large impact particularly when the lower recycling rate was applied.

Figure 5.2-2 shows the environmental impact of each process. Saving energy in the manufacturing process directly leads to reduction of the environmental loads. If the recycling rate is low, the environmental loads in the recycling and disposal process are too high to lower the environmental impact.

Figure 5.2-3 shows the environmental impact by category. Global warming and waste were the two areas of impact greatly influenced by the container type and recycling rate and had large environmental impacts. Urban area air pollution caused by NOx and SOx also had a high environmental impact.

6. Conclusion

6.1 Summary of study result

In this study, the environmental impact of the entire lifecycle (material production, product manufacturing, transportation, use, disposal, and recycling) of a conventional welded can and TULC was assessed, with both subjects being steels cans commonly used to contain coffee, and the TULC was developed for the purpose of reducing environmental loads. These types of cans hardly had any differences in the level of environmental impact as a social cost, but the result was still correlated with LC-CO_2 assessment results. Considering the number of beverage containers used, it is necessary to reduce environmental loads even though the reduction is minimal, and the study clearly showed that TULC had environmental advantages over the conventional steel can. Note, however, the level of environmental loads was slightly but clearly higher for labeled TULC than the regular TULC.

In this study, the environmental impact that could not be examined by the LC-CO_2 method was studied. This is because the recycling rate was 88%, and although the amount of waste was small, its environmental impact could not be ignored. Also, there was a significant environmental impact when the recycling rate was lowered to 50%. Although recycling itself generates environmental loads, it is necessary to improve the recycling rate as much as possible while effectively using resources and maintaining a good balance of generation and reduction of environmental loads.

6.2 Limitations and future challenges

The study clearly showed that the amount of energy use was the major determinant of the assessment result. The scope of the product assessment covered the environmental impacts of all processes and also included the environmental impact of waste; therefore, the study results should have high validity. In future studies, it is necessary to examine how environmental impacts such as productivity or human influence, which are not generated by energy, should be assessed.

Report on
Power Generation Business Assessment

May 2008

CHUBU Electric Power

1. General Information

1.1 Assessor

Organization: Environmental Management Group, Environment Department, Environment and Location Division, CHUBU Electric Power
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Organization: Nagoya Office, JAPAN NUS
Name: Takeshi Toramaru
Contact: toramaru@janus.co.jp

1.2 Report preparation date

May 31, 2008

2. Purpose of Study

2.1 Basis of study

Assessment of the environmental impact of power generation (fuel procurement, fossil fuel consumption, and waste generation) from the following perspectives:

- Environmental impact comparison among modes of power generation (LNG thermal power, coal thermal power, oil thermal power, and nuclear power generation)
- Assessment of the environmental impact reduction effect of improvement in power generation efficiency
  (LNG thermal power (1100ºC level CC) and LNG thermal power (1300ºC level CC) generation)

3. Scope of Study

3.1 Subject of study and its specifications

The subjects of this study were the power plants that used the following major power generation modes to generate power:

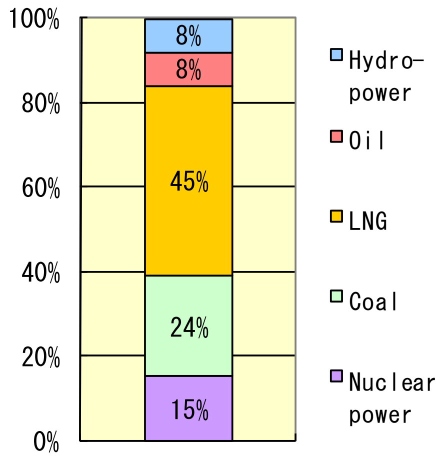
- LNG thermal power (1100ºC level CC) generation
- LNG thermal power (1300ºC level CC) generation
- Oil thermal power generation
- Coal thermal power generation
- Nuclear power generation

* CC: combined cycle power generation

[Reference information]

CHUBU Electric Power provides power to Aichi, Gifu (excluding some parts), Mie (excluding some parts), Nagano, and Shizuoka (areas west of the Fuji River) and, as of the end of March 2007, owns power generation facilities as listed below. The graph on the right shows the energy production ratio in FY2006.

Thermal power generation:	22.3696 million kW (11 locations)
Hydro-electric power generation:	5.22 million kW (182 locations)
Nuclear power generation:	4.884 million kW (1 location)
Total:	32.473 million kW (194 locations)



Energy production ratio(FY2006)

3.2 Functions and functional unit

A functional unit means 1 kWh of electricity at a power distribution terminal of a power plant (LNG thermal power, coal thermal power, oil thermal power, and nuclear power plants).

3.3 System boundary

A system includes fuel procurement, and construction, operation, and dismantling of a power plant (Figure 3.2-1).

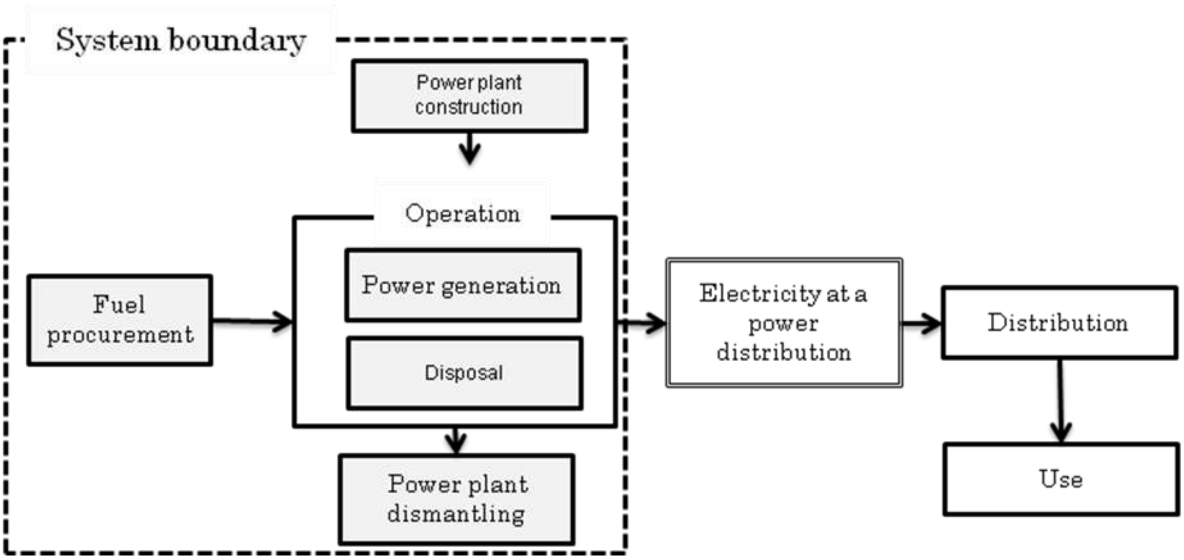


Figure 3.2-1 Power generation business system and its boundary

3.4 Special notes

- A power plant was assumed to operate for 30 years.
- Sulfur oxide (SOx) was considered as SO_2 in the assessment.
- In the assessment, all waste generated during the course of power plant operation was assumed to be used in landfills except for what would be recycled.

4. Inventory Analysis

4.1 Foreground data

Our past records were referred to for obtaining data on fuel for power generation, amount of power generated, material required for power plant operation, emissions (CO_2, SOx, and NOx) caused by power generation, and the amount of waste generation.

4.2 Background data

Data by Hondo, et al [1)] and Hondo [2)] was used to obtain information on fuel procurement and facility construction. Other data was obtained from JEMAI-LCA pro (Japan Environmental Management Association for Industry).

4.3 Inventory analysis item and result table

Tables 4.3-1 through 4.3-5 show subject items of inventory analysis for each power generation facility and also lists of analysis results.

Table 4.3-1 LCI analysis result for LNG thermal power generation
(1100ºC level combined cycle)

[Unit: kg/kWh]

			Fuel procurement	Construction and dismantling	Operation	
					Power generation	Disposal
Consumption load	Depleted resources	Coal	2.02E-07	7.25E-04	3.15E-06	2.27E-09
		Crude oil (fuel)	1.89E-03	1.37E-04	2.38E-04	1.32E-08
		Natural gas	2.90E-02	1.71E-05	1.65E-01	1.30E-09
		Uranium	1.37E-11	1.63E-09	2.13E-10	1.54E-13
		Iron		7.40E-04		
		Nickel		1.51E-08		
		Chrome		2.75E-07		
		Manganese		3.93E-06		
		Mountain gravel		7.58E-05		
		Lime stone		1.21E-03		
Environmental emission load	Outdoor atmosphere	CO_2	1.07E-01	2.82E-03	4.64E-01	5.22E-08
		SOx	2.81E-06	9.51E-07	8.61E-08	2.63E-11
		NOx	1.35E-04	1.76E-06	1.12E-04	4.77E-11
		CH_4	4.01E-04	4.33E-09	5.72E-10	7.55E-12
		PM10	1.95E-06	4.38E-07	4.02E-09	8.90E-13
	Water	COD			2.24E-07	
	Soil	General waste (estimated fixed value if amount is unknown)			7.80E-06	2.48E-05
		Molten slag		2.24E-04		

Table 4.3-2 LCI analysis result for LNG thermal power generation (1300ºC level combined cycle)

[Unit: kg/kWh]

			Fuel procurement	Construction and dismantling	Operation: Power generation	Operation: Disposal
Consumption load	Depleted resources	Coal	1.71E-07	4.42E-04	1.25E-06	4.92E-10
		Crude oil (fuel)	1.60E-03	8.90E-05	1.19E-04	2.87E-09
		Natural gas	2.45E-02	1.06E-05	1.40E-01	2.82E-10
		Uranium	1.16E-11	1.00E-09	8.47E-11	3.32E-14
		Iron		4.44E-04		
		Nickel		9.03E-09		
		Chrome		1.65E-07		
		Manganese		2.35E-06		
		Mountain gravel		5.03E-05		
		Lime stone		8.00E-04		
Environmental emission load	Outdoor atmosphere	CO_2	9.07E-02	1.76E-03	3.77E-01	1.13E-08
		SOx	2.38E-06	5.95E-07	4.12E-08	5.70E-12
		NOx	1.14E-04	1.12E-06	6.54E-05	1.03E-11
		CH_4	3.39E-04	2.66E-09	2.27E-10	8.87E-14
		PM10	1.65E-06	2.79E-07	1.93E-09	1.92E-13
	Water	COD			3.59E-08	
	Soil	General waste (estimated fixed value if amount is unknown)			2.98E-06	5.38E-06
		Molten slag		1.34E-04		

Table 4.3-3 LCI analysis result for coal thermal power generation

[Unit: kg/kWh]

			Fuel procurement	Construction and dismantling	Operation	
					Power generation	Disposal
Consumption load	Depleted resources	Coal	3.04E-04	5.44E-04	3.62E-01	1.57E-07
		Crude oil (fuel)	6.38E-03	1.03E-04	6.17E-04	9.12E-07
		Natural gas	2.46E-04	1.28E-05	1.34E-05	8.97E-08
		Uranium	2.06E-08	1.22E-09	9.08E-10	1.06E-11
		Iron		5.61E-04		
		Nickel		1.14E-08		
		Chrome		2.08E-07		
		Manganese		2.97E-06		
		Mountain gravel		5.40E-05		
		Lime stone		8.60E-04	5.09E-03	
Environmental emission load	Outdoor atmosphere	CO_2	2.40E-02	2.10E-03	8.89E-01	3.59E-06
		SOx	2.29E-05	7.09E-07	1.33E-04	1.81E-09
		NOx	4.76E-05	1.32E-06	6.75E-05	3.29E-09
		CH_4	2.01E-03	3.23E-09	2.43E-09	2.82E-11
		PM10	3.21E-06	3.24E-07	2.58E-06	6.13E-11
	Water	COD			1.24E-07	
	Soil	General waste (estimated fixed value if amount is unknown)			7.00E-06	1.71E-03
		Molten slag		1.69E-04		

Table 4.3-4 LCI analysis result for oil thermal power generation

[Unit: kg/kWh]

			Fuel procurement	Construction and dismantling	Operation	
					Power generation	Disposal
Consumption load	Depleted resources	Coal	1.88E-07	2.59E-03	7.15E-06	9.87E-08
		Crude oil (fuel)	1.76E-03	4.82E-04	2.49E-01	5.75E-07
		Natural gas	2.74E-05	6.11E-05	5.52E-06	5.65E-08
		Uranium	1.28E-11	5.80E-09	4.84E-10	6.67E-12
		Iron		2.65E-03		
		Nickel		5.39E-08		
		Chrome		9.84E-07		
		Manganese		1.41E-05		
		Mountain gravel		2.65E-04		
		Lime stone		4.22E-03		
Environmental emission load	Outdoor atmosphere	CO_2	1.25E-02	9.99E-03	6.56E-01	2.27E-06
		SOx	2.61E-06	3.38E-06	1.23E-04	1.14E-09
		NOx	1.27E-05	6.23E-06	4.65E-05	2.07E-09
		CH_4	3.42E-11	1.54E-08	1.30E-09	1.78E-11
		PM10	1.55E-06	1.55E-06	1.67E-06	3.86E-11
	Water	COD			3.43E-07	
	Soil	General waste (estimated fixed value if amount is unknown)			1.96E-05	1.08E-03
		Molten slag		8.01E-04		

Table 4.3-5 LCI analysis result for nuclear power generation

[Unit: kg/kWh]

			Fuel procurement	Construction and dismantling	Operation	
					Power generation	Disposal
Consumption load	Depleted resources	Coal	1.73E-03	1.12E-03	1.89E-07	1.12E-04
		Crude oil (fuel)	1.96E-04	1.81E-04	2.13E-07	1.11E-04
		Natural gas	7.63E-04	3.33E-05	9.48E-08	2.25E-05
		Uranium	5.63E-07	3.58E-09	2.70E-06	2.87E-09
		Iron		1.06E-03		6.09E-05
		Nickel		2.16E-08		1.24E-09
		Chrome		3.94E-07		2.26E-08
		Manganese		5.63E-06		3.23E-07
		Mountain gravel		1.55E-04		1.44E-05
		Lime stone		2.46E-03		2.29E-04
Environmental emission load	Outdoor atmosphere	CO_2	1.07E-02	4.53E-03	1.47E-06	8.04E-04
		SOx	7.96E-06	1.57E-06	1.12E-09	4.24E-07
		NOx	7.89E-06	2.88E-06	8.90E-10	7.99E-07
		CH_4	6.21E-08	9.53E-09	3.43E-11	7.68E-09
		PM10	6.71E-07	7.84E-07	4.82E-11	1.22E-07
	Water	COD			1.16E-08	
	Soil	General waste (estimated fixed value if amount is unknown)			5.33E-07	
		Molten slag		3.20E-04		1.84E-05

5. Impact Assessment

5.1 LCIA steps and impact categories used in assessment

The impact assessment was conducted using the Japanese-design "Life Cycle Impact Assessment Method based on Endpoint Modeling" (LIME2) through its three steps consisting of characterization, damage assessment and weighting. The impact categories covered in each step of the assessment are listed in Table 5.1-1.

Table 5.1-1 LCIA steps and environmental impact categories used in assessment

	Characterization	Damage assessment	Weighting
Resource consumption (energy)	○	○	○
Resource consumption (mineral)	○	○	○
Global warming	○	○	○
Urban air pollution	-	○	○
Ozone layer depletion			
Acidification	○	○	○
Eutrophication	○	○	○
Photochemical oxidant creation	○	○	○
Human toxicity			
Ecotoxicity			
Indoor air quality	-		
Noise	-		
Waste	○	○	○
Land use			

5.2 Result of impact assessment

5.2.1 Characterization

Figures 5.2-1 and 5.2-2 show characterization of each mode of power generation in terms of global warming and acidification, respectively.

As shown in Figure 5.2-1, when compared with LNG thermal power generation (1100°C level CC), the global warming effect was reduced by 16% in LNG thermal power generation (1300ºC level CC). Coal thermal power generation had the strongest impact on global warming, followed by oil thermal power and LNG thermal power generation. Nuclear power generation had a low impact on global warming (approximately 3% of LNG thermal power generation (1300ºC level CC), the type of thermal power generation that had the lowest impact on global warming) as there is no CO_2 emission at the time of power generation.

As shown in Figure 5.2-2, when compared to the use of LNG thermal power (1100ºC level CC), the acidification effect was reduced by 27% when LNG thermal power (1300ºC level CC) was used to generate power. Coal thermal power generation had the strongest impact on acidification, followed by LNG thermal power (1100ºC level CC), oil thermal power, and LNG thermal power (1300ºC level CC) generation in this order.

Nuclear power generation had a low impact on acidification (approximately 14% of LNG thermal power generation (1300ºC level CC), the type of thermal power that had the lowest impact on acidification) because there is no NOx or SO_x emission at the time of power generation.

Since there is no SOx emission at the time of power generation using LNG thermal power, acidification was mainly caused by NOx. Meanwhile, when power was generated using coal or oil thermal power, acidification was attributed to both SOx (SO_2) and NOx, and between them, SOx (SO_2) had a particularly strong impact on acidification.

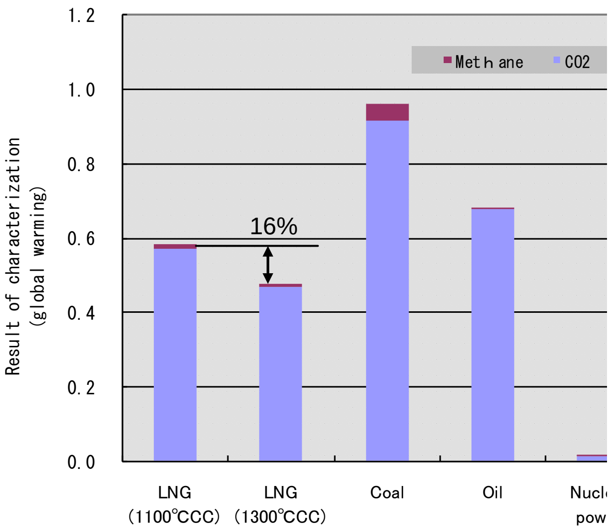


Figure 5.2-1 Result of characterization (global warming)

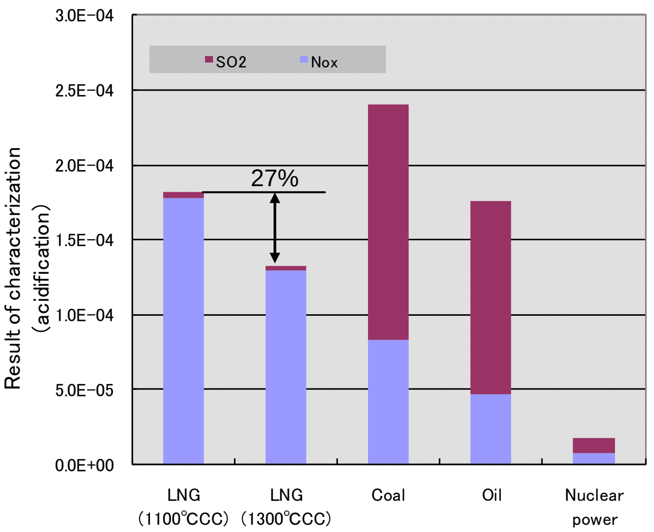


Figure 5.2-2 Result of characterization (acidification)

5.2.2 Damage assessment

Figures 5.2-3 through 5.2-6 show the assessment result of damage (by substance) to 4 areas of protection.

In the area of human health (Figure 5.2-3), coal thermal power generation had a stronger adverse effect than oil thermal power generation, but in the area of social assets (Figure 5.2-4), the result was the other way around. This is because, while CO_2 influences human health more than social assets, crude oil consumption has a stronger impact on social assets than human health. In the areas of primary production (Figure 5.2-5) and biodiversity (Figure 5.2-6), coal thermal power generation had a prominent impact.

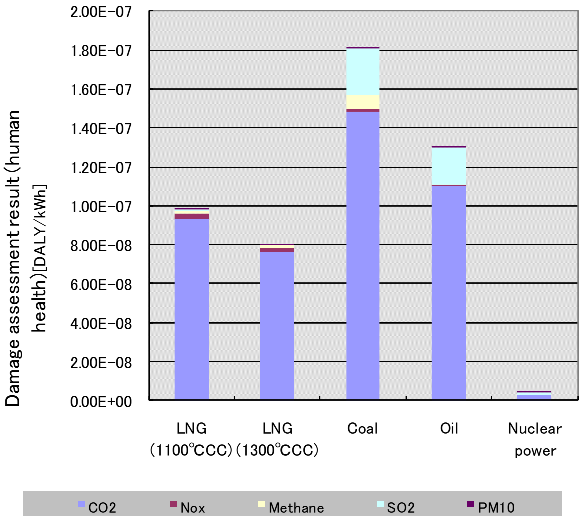


Figure 5.2-3 Damage assessment result (human health)

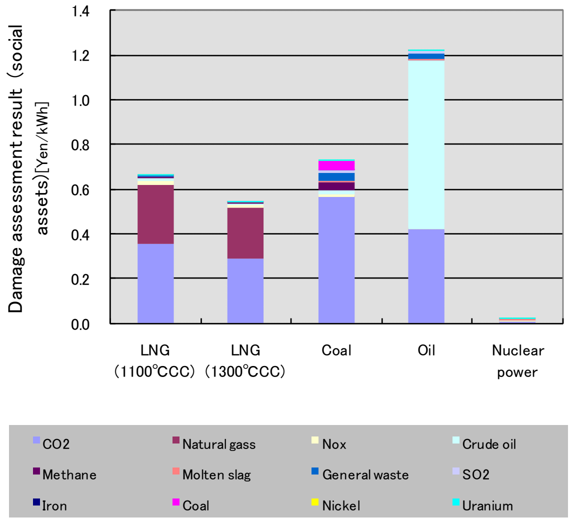


Figure 5.2-4 Damage assessment result (social assets)

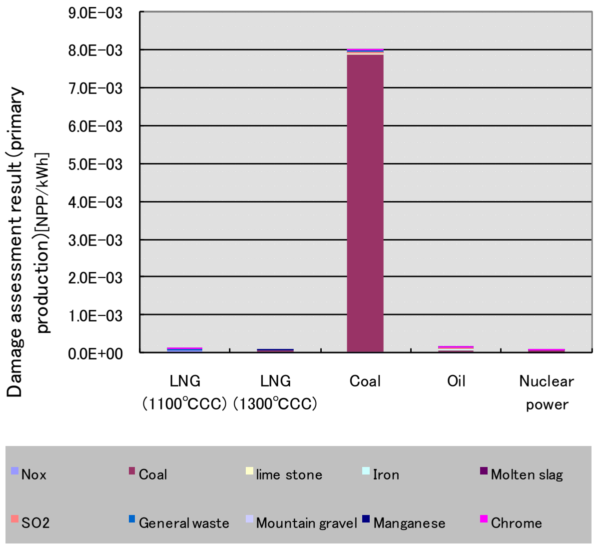


Figure 5.2-5 Damage assessment result (primary production)

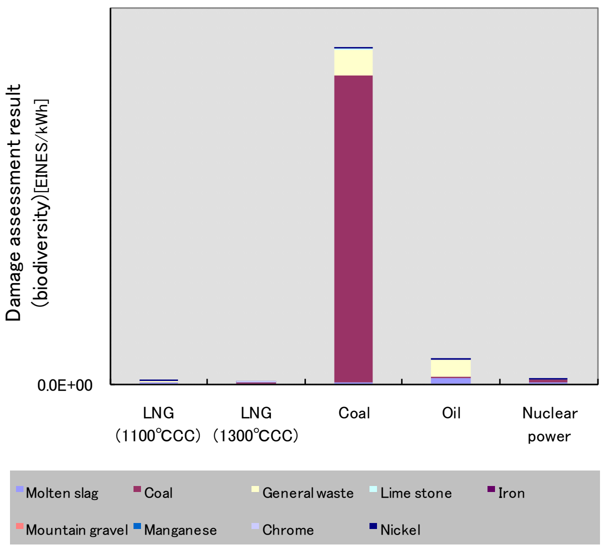
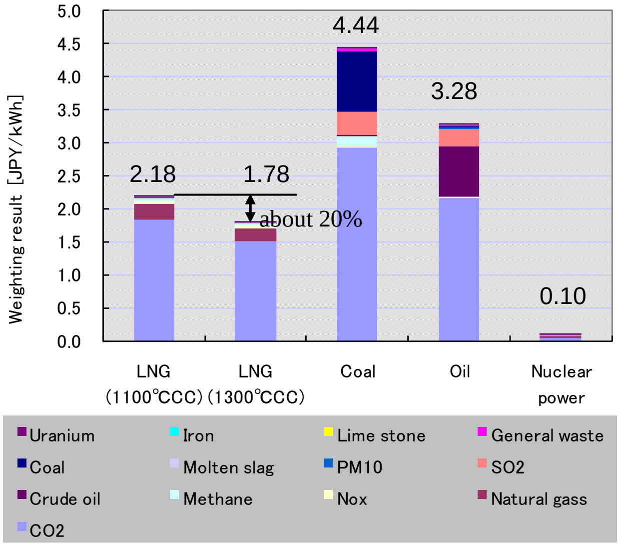


Figure 5.2-6 Damage assessment result (biodiversity)

5.2.3 Weighting

Figure 5.2-7 shows the consolidated study result (by substance) for each mode of power generation.

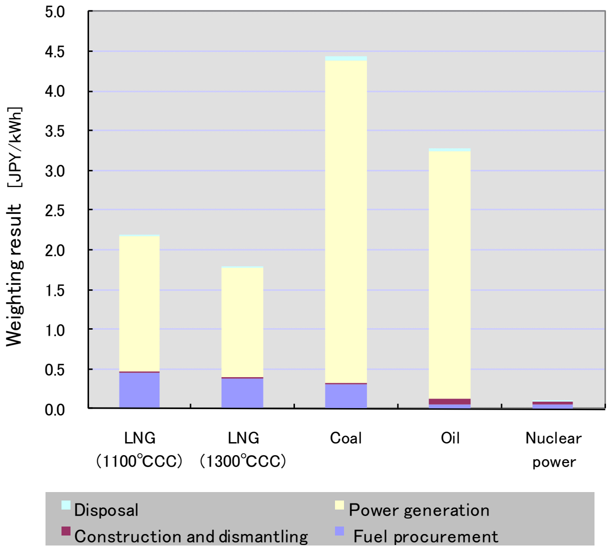


Consolidated social cost, or environmental impact, of each mode of power generation was: approximately 2.18 yen/kWh for LNG thermal power generation (1100ºC level CC); approximately 1.78 yen/kWh for LNG thermal power generation (1300ºC level CC); approximately 4.44 yen/kWh for coal thermal power generation; approximately 3.28 yen/kWh for oil thermal power generation; and approximately 0.10 yen/kWh for nuclear power generation. Also, the value for LNG thermal power generation (1300ºC level CC) was lower than that of LNG thermal power generation (1100ºC level CC) by approximately 20%.

Substances that had a high environmental impact were CO_2 and fuels (coal, crude oil, and natural gas), and there was also an environmental impact of SOx (SO_2) emissions caused by coal and oil combustion.

For the environmental impact of each mode of power generation, Figure 5.2-8 shows the impact on power generation-related processes, and Figure 5.2-9 shows the impact on the areas of influence. For the power generation-related processes, the environmental impact of thermal power generation was predominately attributed to the actual power generation process (accounting for approximately 80 to 90%). Meanwhile, nuclear power generation had a relatively high environmental effect during the fuel procurement process (CO_2 emission due to the use of overseas power).

For the areas of influence, thermal power generation had significant impacts on global warming (mostly attributed to CO_2 emission) and consumption of non-living resources (mostly attributed to fuel consumption). Furthermore, coal and oil thermal power generation had an impact on air pollution in urban areas (mostly attributed to SOx emission).



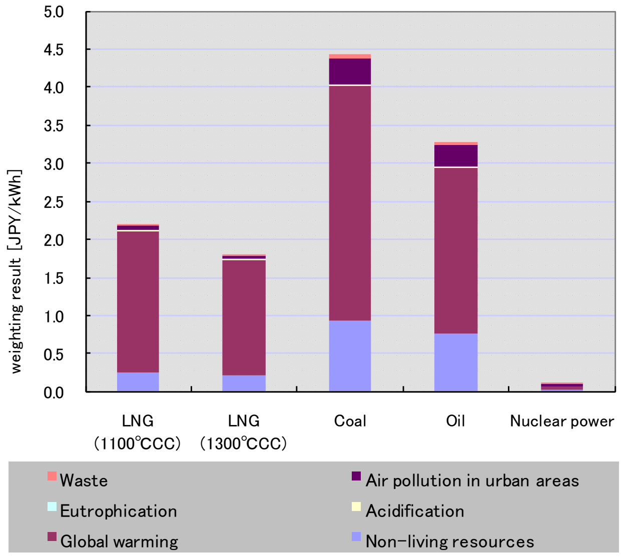


Figure 5.2-8 Weighting result (by process)

Figure 5.2-9 Weighting result (by area of influence)

6. Conclusion

6.1 Summary of study result

The environmental impact of the power generation business was assessed for each of the major modes of power generation (LNG thermal power, coal thermal power, oil thermal power, and nuclear power generation) while taking into account the business life cycle (fuel procurement, power plant construction, operation, and demolition). This study also confirmed that, through the comparison of the environmental impact between LNG thermal power generation (1100ºC level CC) and LNG thermal power generation (1300ºC level CC), improvement of power generation efficiency resulted in reduction of the environmental impact.

The weighting environmental impact of each mode of power generation was: approximately 2.18 yen/kWh for LNG thermal power generation (1100ºC level CC); approximately 1.78 yen/kWh for LNG thermal power generation (1300ºC level CC); approximately 4.44 yen/kWh for coal thermal power generation; approximately 3.28 yen/kWh for oil thermal power generation; and approximately 0.10 yen/kWh for nuclear power generation. The environmental impact of nuclear power generation in comparison with the others was thus significant. Also, this result confirmed that improvement of LNG thermal power generation efficiency (1100ºC level CC → 1300ºC level CC) could reduce the environmental impact by approximately 20%.

The size of an environmental impact (or a social cost) was, assuming that the electricity rate was 20 yen/kWh, approximately 10% of the charge in LNG thermal power generation (1100ºC level CC), approximately 9% of the charge in LNG thermal power generation (1300ºC level CC), approximately 22% in coal thermal power generation, approximately 16% in oil thermal power generation, and approximately 0.5% in nuclear power generation. Also, the weighting social cost (obtained from the FY2006 power production ratios, excluding hydro-electric power generation) was approximately 2.43 yen/kWh, which was approximately 12% of the electricity charge.

When the weighting result was reviewed in terms of process and area of impact, the environmental impact of the thermal power generation phase (mostly global warming, followed by air pollution in urban areas and consumption of non-living resources) accounted for a large part of the total power generation-related environmental impact.

In the power generation business, CO_2 emission during power generation had a large impact on global warming; therefore, introduction of nuclear power or high efficiency LNG thermal power to reduce CO_2 emission during power generation would be the most effective measures to reduce the environmental impact.

6.2 Limitations of study result

For the assessment in this study, FY2006 power plant performance data of CHUBU Electric Power was used as a model case. The scope of assessment covered important processes in the power generation business; therefore, study results should have high validity.

Also, because it was difficult to obtain detailed background data on fuel procurement, power plant construction, and power plant dismantling (amount of material used in facilities), estimated values were obtained from the studies by Hondo et al[1) 2)]. This should not affect the assessment results as, when the power generation business was summarized, the environmental impact was observed predominantly in the power generation phase.

References

1) Hiroki Hondo, et al: "Power Generation Technology Assessment based on Life Cycle CO_2 Emission: Re-estimation Using the Latest Data and the Influence of Differences in Preconditions," Study Report Y99009, Socio-Economic Research Center, Central Research Institute of Electric Power Industry (2000).
2) Hiroki Hondo: "Nuclear Power Generation Technology Assessment based on Life Cycle CO_2 Emission," Study Report Y01006, Socio-Economic Research Center, Central Research Institute of Electric Power Industry (2001).

Report on "Environmental Impact Comparison of Toilet Care using an Automatic Urine Collector"

May 2008

Unicharm Corporation

1. General Information

1.1 Assessor

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1.2 Report preparation date

May 30, 2008

2. Purpose of Study

2.1 Basis of study

Identify environmental impacts associated with toilet care for a one-day period, and determine the environmental load of toilet care that uses the automatic urine collector currently under joint development with Hitachi, Ltd. compared with conventional toilet care using only disposable paper diapers.

2.2 Application of study result

In addition to determining the environmental impacts of conventional toilet care using disposable diapers and urine collection pads (hereinafter referred to as "conventional toilet care system") and toilet care using the automatic urine collector and pads specially designed for the use with the automatic urine collector (hereinafter referred to as "toilet care system using an automatic urine collector"), clarify processes that are important for improving the environmental impacts and provide information for improvements to be made in the designing process. Also, use the result broadly as a means of communication, such as to convey information to help customers in selecting products.

3. Scope of Study

3.1 Subject of study and its specifications

Toilet care for a one-day period using tape fastening-type adult disposable diapers that are manufactured, used and disposed of within Japan, the automatic urine collector, and pads specially designed for the use with the automatic urine collector; conventional toilet care for a one-day period using tape fastening-type adult disposable diapers and urine collection pads.

3.2 Functions and functional unit

"Toilet care" in this report refers to toilet assistance provided to individuals who have difficulty using the toilet by themselves due to sickness, injury or old age and require some form of help. In this study, toilet care required for such an individual in a one-day period was specified as the functional unit, and an analysis was performed on the environmental impacts of disposable diapers and pads used for providing the required care.

A conventional toilet care system uses a combination of disposable diapers and urine collection pads. The system is designed so that only the urine collection pad needs to be changed each time the patient urinates, reducing the number of diaper changes required and thus helping reduce the burdens on caregivers as well as on the environment.

Unicharm is currently developing a toilet care system using an automatic urine collector jointly with Hitachi, Ltd. to further reduce the burdens on caregivers and impacts on the environment. While disposable diapers are also used in the toilet care system using an automatic urine collector as in the conventional system, the new system involves a urine collection pad with an attached sensor and pipe that is connected to a pump. When the sensor detects urine, it sends a signal to start the small pump, which suctions the urine through the pipe and into a tank.

The functional unit of each system is:

- Conventional toilet care system: for a one-day period
  Tape fastening-type adult disposable diapers × 2 / urine collection pads x 6
- Toilet care system using an automatic urine collector: for a one-day period
  Tape fastening-type adult disposable diapers × 2 / specially designed pads x 2 / automatic urine collector

The study covers the entire life cycle of each system. For the toilet care system using an automatic urine collector, the assessment was conducted on the assumption that tape fastening-type adult disposable diapers and pads designed for the use with the automatic urine collector are incinerated for disposal after use. Collected urine is disposed of into a toilet once a day. "Products" refers to products manufactured by Unicharm and includes three items: tape fastening-type adult disposable diapers, urine collection pads, and pads designed for the use with the automatic urine collector.

3.3 System boundary

The system boundary encompasses the raw material extraction, production, use and disposal stages (Figure 3.2-1).

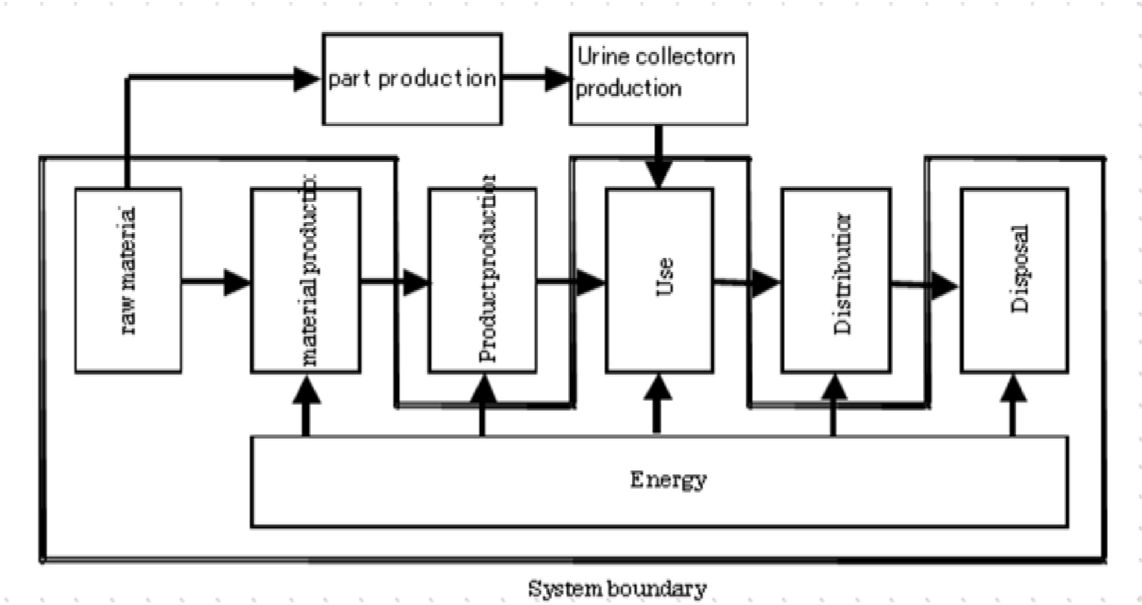

Figure 3.2-1　Schematic diagram of system boundary

3.4 Special notes (processes or items exempted from assessment, etc.)

While the assessment took into consideration the environmental load of the automatic urine collector during its use stage, environmental impacts associated with the production and disposal of the urine collector are not covered in this assessment.

Due to the high confidentiality of information on the manufacturing technology of pads used with the automatic urine collector, which is still under review at the present time, we have decided not to release data related to the assembly stage of products (tape fastening-type adult disposable diapers, pads designed for the use with the automatic urine collector, and urine collection pads) in this report. For this reason, the product production stage was excluded from the scope of the assessment in order to adjust the system boundary to be the same for both toilet care systems.

Similarly, the transportation stage was excluded from the assessment of both systems for the purpose of adjusting the system boundary, as the shipping volumes and transportation distances are not determined at this time.

4. Inventory Analysis

4.1 Foreground data

Data used in this assessment are actual measurements taken on representative materials, which were referenced from the results of studies on the environmental impact of materials conducted with the material suppliers and subsidiaries of Unicharm in 2002 and 2004. Data on the energy consumption of the automatic urine collector were obtained with the cooperation of Hitachi, Ltd.

4.2 Background data

For the incineration disposal stage, the assessment was conducted using data on general waste (mainly plastic waste) incinerators obtained from the database compiled by the Japan LCA Forum. Data on the advanced wastewater treatment process were provided by Professor Muroyama and others 1), and all other background data were sourced from Jemai-LCA Pro.

4.3 Inventory analysis item and result table

Table 4.3-1, 4.3-2 and 4.3-3 represent the list of items covered in the inventory analyses and the analysis results for the conventional toilet care system, the toilet care system using an automatic urine collector, and the toilet care system using an automatic urine collector combined with advanced wastewater treatment. The unit for all three cases is specified as usage for a one-day period.

Table 4.3-1 Result of LCI analysis of conventional toilet care system (unit: kg/day)

			Production		Distribution	Use	Disposal
			Raw material	Product			
Impact of resource consumption	Exhaustible resources	Coal	6.41E-02	-	-	0.00E+00	1.80E-03
		Crude oil (for fuel)	5.62E-01	-	-	0.00E+00	1.06E-03
		Natural gas	4.31E-02	-	-	0.00E+00	8.37E-04
		U content of an ore	2.09E-06	-	-	0.00E+00	1.58E-07
	Renewable resources	Wood	-	-	-	-	-
		Water	-	-	-	-	-
Impact of emission/discharge to the environment	To atmosphere	CO2	1.63E+00	-	-	0.00E+00	1.36E-02
		SOx	1.12E-03	-	-	0.00E+00	3.40E-04
		NOx	4.75E-03	-	-	0.00E+00	7.63E-04
		PM10	1.11E-04	-	-	0.00E+00	6.60E-05
	To water system	COD	5.59E-03	-	-	0.00E+00	0.00E+00
		T-P	0.00E+00	-	-	0.00E+00	0.00E+00
		T-N	0.00E+00	-	-	0.00E+00	0.00E+00
	To soil system	Unspecified solid waste	4.60E-02	-	-	0.00E+00	9.65E-02
		Sludge	2.66E-04	-	-	0.00E+00	0.00E+00

Table 4.3-2 Result of LCI analysis of toilet care system using an automatic urine collector

(unit: kg/day)

			Production		Distribution	Use	Disposal
			Raw material	Product			
Impact of resource consumption	Exhaustible resources	Coal	3.56E-02	-	-	5.18E-03	1.23E-03
		Crude oil (for fuel)	3.50E+00	-	-	9.61E-04	6.50E-04
		Natural gas	3.00E-02	-	-	2.41E-03	6.07E-04
		U content of an ore	1.61E-06	-	-	4.56E-07	1.08E-07
	Renewable resources	Wood	-	-	-	-	-
		Water	-	-	-	-	-
Impact of emission/discharge to the environment	To atmosphere	CO_2	1.59E+00	-	-	2.38E-02	8.73E-03
		SOx	7.56E-04	-	-	3.76E-06	1.82E-04
		NOx	2.35E-03	-	-	9.91E-06	4.08E-04
		PM10	4.57E-05	-	-	0.00E+00	3.51E-05
	To water system	COD	2.42E-03	-	-	0.00E+00	6.00E-05
		T-P	0.00E+00	-	-	0.00E+00	7.44E-06
		T-N	0.00E+00	-	-	0.00E+00	8.46E-05
	To soil system	Unspecified solid waste	1.89E-02	-	-	0.00E+00	5.14E-02
		Sludge	2.24E-04	-	-	0.00E+00	0.00E+00

Table 4.3-3 Result of LCI analysis of toilet care system using an automatic urine collector (combined with advanced wastewater treatment system) (unit: kg/day)

			Production		Distribution	Use	Disposal
			Raw material	Product			
Impact of resource consumption	Exhaustible resources	Coal	3.48E-02	-	-	5.18E-03	1.31E-03
		Crude oil (for fuel)	4.47E-01	-	-	9.61E-04	6.85E-04
		Natural gas	2.97E-02	-	-	2.41E-03	6.11E-04
		U content of an ore	1.55E-06	-	-	4.56E-07	1.15E-07
	Renewable resources	Wood	-	-	-	-	-
		Water	-	-	-	-	-
Impact of emission/discharge to the environment	To atmosphere	CO_2	1.19E+00	-	-	2.38E-02	1.00E-02
		SOx	5.28E-04	-	-	3.76E-06	1.81E-04
		NOx	2.03E-03	-	-	9.91E-06	4.08E-04
		PM10	4.57E-05	-	-	0.00E+00	3.51E-05
	To water system	COD	2.42E-03	-	-	0.00E+00	3.18E-05
		T-P	0.00E+00	-	-	0.00E+00	3.00E-07
		T-N	0.00E+00	-	-	0.00E+00	3.42E-05
	To soil system	Unspecified solid waste	1.89E-02	-	-	0.00E+00	5.14E-02
		Sludge	2.24E-04	-	-	0.00E+00	0.00E+00

5. Impact Assessment

5.1 LCIA steps and impact categories used in assessment

The impact assessment was conducted using the Japanese-design "Life Cycle Impact Assessment Method based on Endpoint Modeling" (LIME2) through its three steps consisting of characterization, damage assessment and weighting. The impact categories covered in each step of the assessment are listed in Table 5.1-1.

Table 5.1-1 LCIA steps and environmental impact categories used in assessment

	Characterization	Damage assessment	Weighting
Resource consumption (energy)	○	○	○
Resource consumption (mineral)	○	○	○
Global warming	○	○	○
Urban air pollution	-	○	○
Ozone layer depletion			
Acidification	○	○	○
Eutrophication	○	○	○
Photochemical oxidant creation			
Human toxicity			
Ecotoxicity			
Indoor air quality	-		
Noise	-		
Waste	○	○	○
Land use			

5.2 Result of impact assessment

5.2.1 Characterization

The characterization results of the environmental impacts of the conventional toilet care system, the toilet care system using an automatic urine collector, and the toilet care system using an automatic urine collector combined with advanced wastewater treatment are laid out in Figure 5.2-1, 5.2-2 and 5.2-3 respectively for the categories of resource consumption, waste and eutrophication. In the category of energy resource consumption, most impacts are associated with material production as well as crude oil consumption attributable to the materials used, and the result indicates that changing from the conventional toilet care system to the toilet care system using an automatic urine collector would have a considerable effect in reducing the impacts. For the toilet care system using an automatic urine collector, there was a concern over the potential negative impacts associated with the treatment of high-concentration wastewater due to the fact that all urine collected in an entire day would be disposed of in a toilet at once. Advanced wastewater treatment was therefore incorporated into the impact assessment as a comparison to determine the impact of wastewater treatment; however, the result indicates that there is little difference in impacts between the treatment methods. The most significant effect of the system change is apparent in the impact category of waste, and it is attributable to the reduced quantity of pads used in the toilet care. While the category of eutrophication shows the least difference between the impacts of the systems, the result indicates that advanced wastewater treatment significantly reduces the emissions of phosphorus, reducing the environmental impact as the result.

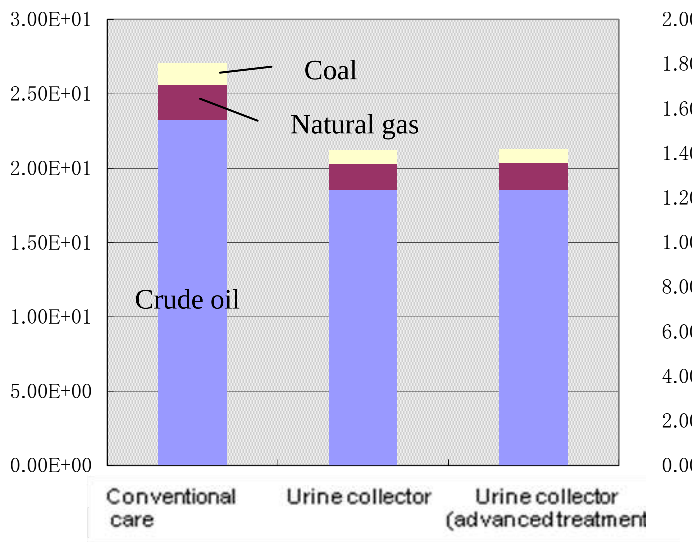

Figure 5.2-1 Characterization result (energy resource consumption)

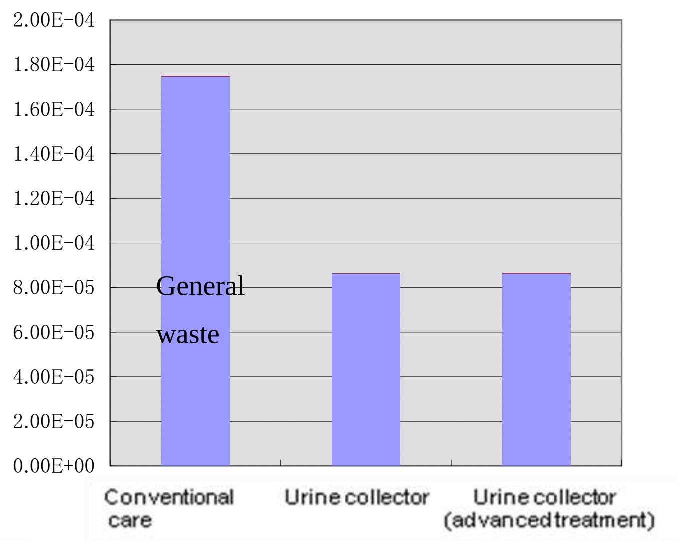

Figure 5.2-2 Characterization result (waste)

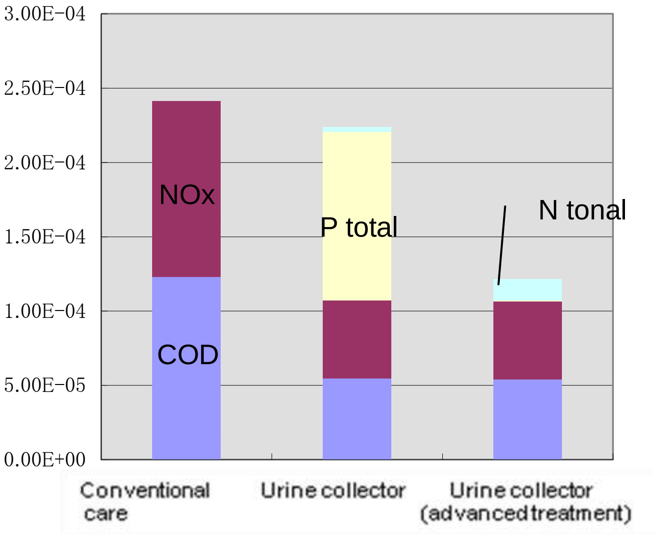

Figure 5.2-3 Characterization result (eutrophication)

5.2.2 Damage assessment

The results of the damage assessment (breakdown by substance) for four safeguard subjects are laid out in Figure 5.2-4 through 5.2-7. While CO_2 emissions constitute the largest impact on human health, a significant impact reduction effect is achieved by reduced SO_x emissions as the result of the reduction in energy consumption. Most of the impact on biodiversity is attributable to general waste in association with the disposal of waste in landfills. For social welfare and primary production, crude oil has a sizable impact in addition to CO_2 and waste, and four substances including these three and SO_x are major contributors to the environmental impacts overall.

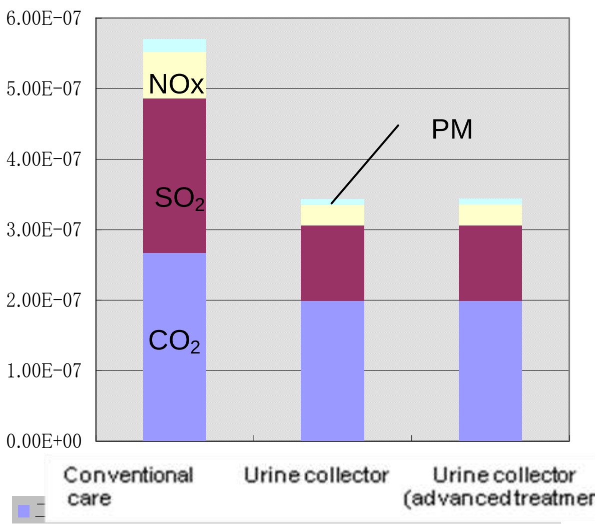

Figure 5.2-4 Result of damage assessment (human health) (unit: DAILY/day)

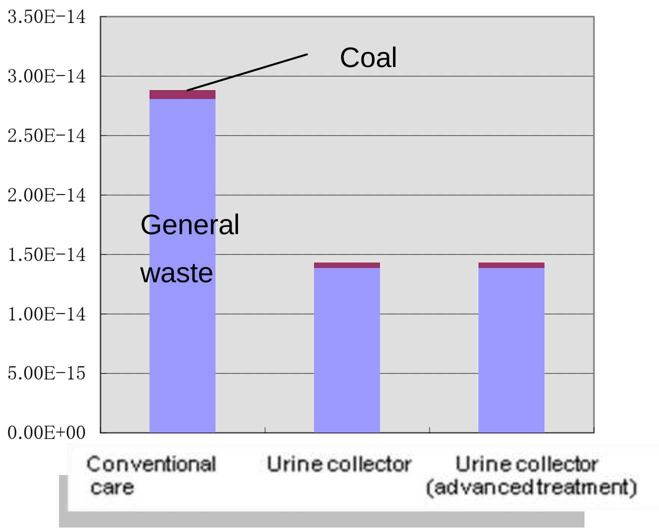

Figure 5.2-5 Result of damage assessment (biodiversity) (unit: EINES/day)

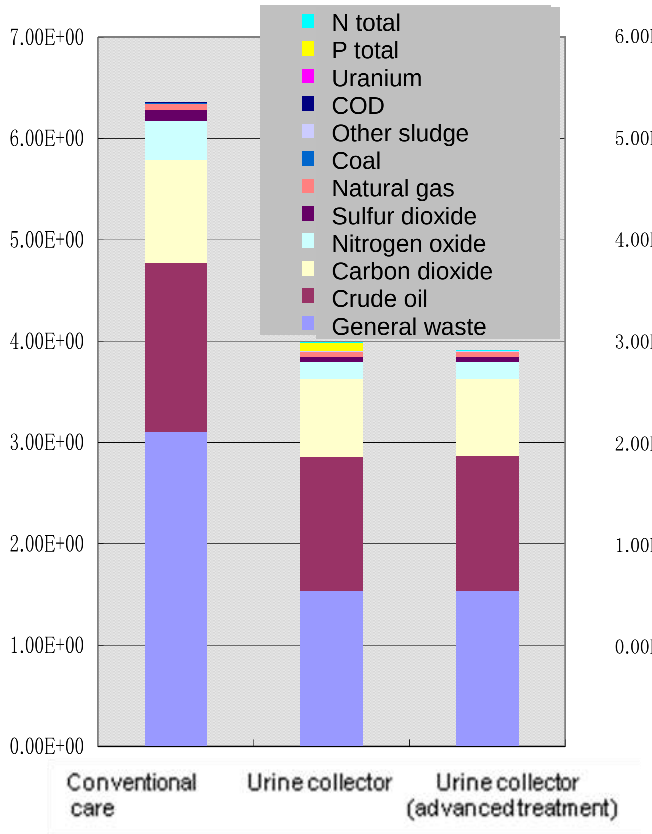

Figure 5.2-6 Result of damage assessment (social welfare) (unit: YEN/day)

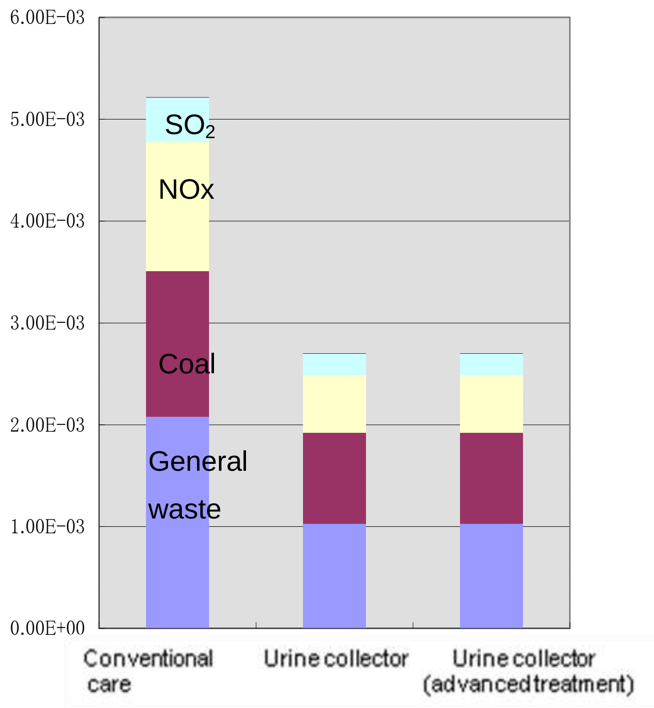

Figure 5.2-7 Result of damage assessment (primary production) (unit: kg/day)

Figure 5.2-8 and 5.2-9 represent the breakdown of the result by process for the safeguard subjects of human health and biodiversity, which yielded distinctive results in the damage assessment. The impacts on human health occur mostly in the raw material production stage, and it is assumed that the major causes of the damage are the emissions of CO_2 and SO_x generated due to energy consumption in association with the production of raw materials. The damage to biodiversity is largely associated with the disposal stage, which leads to an assumption that the impacts occur due to the disposal of incineration ash in landfills after waste is incinerated. The impact category of eutrophication, which indicated an impact reduction effect of advanced wastewater treatment in the characterization result, is found to have only a small effect on overall impacts in the result of this damage assessment.

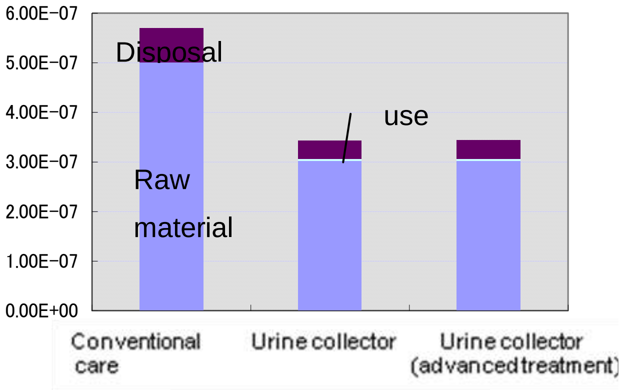

Figure 5.2-8 Result of damage assessment by process (human health) (unit: DAILY/day)

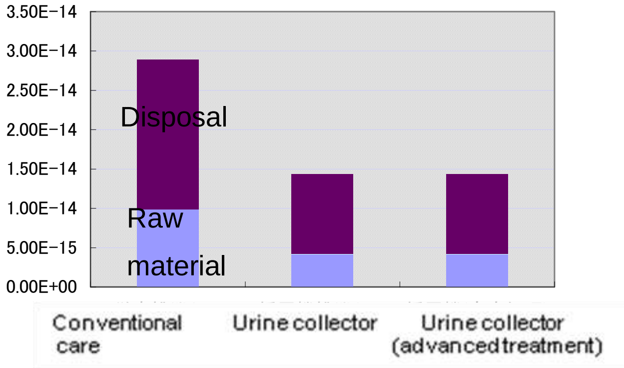

Figure 5.2-9 Result of damage assessment by process (biodiversity) (unit: EINES/day)

5.2.3 Weighting

The result of consolidating (by substance) for the three toilet care systems is shown in Figure 5.2-10. Items that comprise large portions of the total life-cycle environmental impact are the emissions of CO_2, SO_x, waste and crude oil, which is practically consistent for all three systems. Of these four substances, the result indicates that the most significant effect in reducing the environmental impacts comes from the reduction of waste emissions.

Figure 5.2-11 and 5.2-12 respectively represent the breakdown of the result by process and by impact category. The breakdown by process in Figure 5.2-11 indicates that the raw material production and disposal stages account for the most of the environmental impacts of all systems. The reduction of materials used is resulting in reduced waste emissions, and the significant reduction in the environmental impacts is achieved through the reduced raw material use. The result also confirms that only small environmental impacts occur in the use stage of the toilet care system using an automatic urine collector compared with its overall life cycle impacts, and there is only a little difference in the system's environmental impacts between the use with or without the advanced wastewater treatment. From the result of consolidating by impact category, it is observed that major environmental impacts associated with the toilet care systems are global warming, urban air pollution, waste and non-biological resources consumption.

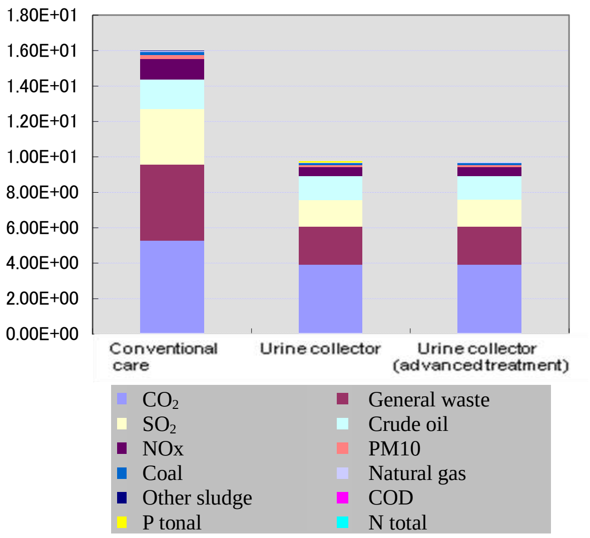

Figure 5.2-10 weighting result by substance (unit: YEN/day)

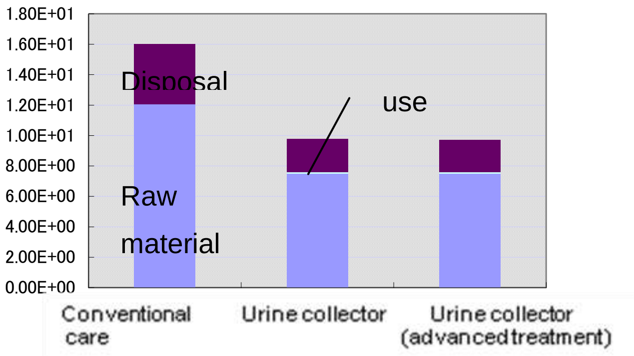

Figure 5.2-11 weighting result by process (unit: YEN/day)

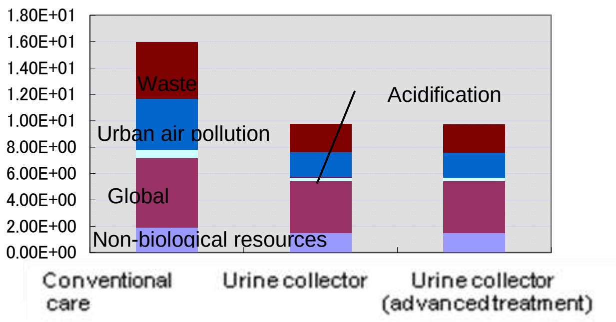

Figure 5.2-12 weighting result by impact category (unit: YEN/day)

6. Conclusion

6.1 Summary of study result

The assessment was conducted on the environmental impacts over the life cycle (raw material production, use (average toilet care for a one-day period), and disposal) of three types of toilet care systems: conventional toilet care system using disposable diapers, toilet care system using an automatic urine collector, and toilet care system using an automatic urine collector combined with advanced wastewater treatment. The environmental impacts in terms of social costs are calculated to be approximately 16 yen for the conventional toilet care system, 9.8 yen for the toilet care system using an automatic urine collector, and 9.7 yen for the toilet care system using an automatic urine collector combined with advanced wastewater treatment.

The assessment result confirmed that most of the environmental impacts associated with toilet care would occur in the raw material production stage and the disposal stage after use. The emissions of CO_2 and SOx, disposal of waste in landfills and the consumption of crude oil would be the main causes of the impacts, and major environmental impacts that would likely result from these causes are global warming, urban air pollution, waste and non-biological resource consumption.

Considering the single-use nature of disposable diapers that are thrown away after one-time use, reducing the environmental impacts in the raw material production stage by reducing the amount of raw materials used would also lead to the reduction of environmental impacts in the disposal stage.

For toilet care using the automatic urine collector, reducing the use of raw materials through steps taken in the use stage, such as the use of a pump to suction urine to reduce the number of diaper changes needed, would provide a tradeoff between the use and raw material production stages. From the perspective of environmental assessment, this would result in the reduction of environmental load as it reduces the use of raw materials in the raw material production stage, which is deemed to be responsible for the largest share of the total environmental impact.

The environmental impact of the use of advanced wastewater treatment was incorporated into the assessment of the toilet care system using an automatic urine collector, out of concern over the impact of disposing of wastewater with higher than normal levels of contamination in a toilet by flushing down all urine collected in an entire day at once. However, the results found that the impact of the disposal with a frequency as low as once a day would be minimal over the entire environmental impacts, and the effect of advanced wastewater treatment in reducing environmental impacts would also be small in the equivalent of about 0.1 yen in monetary value.

With regard to the stages excluded from the scope of this assessment (product production and transportation), it can be assumed through consulting data from past studies that the environmental impacts of the toilet care system using an automatic urine collector compared with that of the conventional toilet care system would also be smaller in these stages. Taking into consideration all these aspects, the utility of the toilet care system using an automatic urine collector in the environmental context has been confirmed.

6.2 Limitations and future challenges

The completeness of the assessment and the validity of the assessment result are deemed adequate in view of the fact that the assessment covers important processes (raw material production, use and disposal) that are responsible for over 90% of the environmental load according to the results of past life cycle assessments on disposable diapers. However, considering the circumstance that the production method of the products used in the toilet care system using an automatic urine collector differs greatly from that of the conventional toilet care system, the assessment of the processes excluded from the scope of this assessment (product production and transportation) as well as the analysis of the assessment result should also be conducted once the production technology has been established and the scenario for the transportation stage has been developed.

Acknowledgments

We extend our sincere appreciation to Mr. Tanaka of Hitachi, Ltd. for his cooperation in obtaining inventory data on the automatic urine collector, all concerned members of the LCA Japan Forum for providing us with this opportunity, members of the study committee office of the Japan Environmental Management Association for Industry for undertaking coordination work behind the scenes, members of the LIME2 study working group for sharing various views with us, Professor Norihiro Itsubo of the Faculty of Environmental and Information Studies, Tokyo City University for leading the working group and providing us with generous instructions, and Mr. Masaharu Motoshita of the Research Institute of Science for Safety and Sustainability, the National Institute of Advanced Industrial Science and Technology for assisting us in preparing this report and with our inquiries on LCA in general.

References

1) Katsuhiko Muroyama et al. (2006): Life Cycle Inventory Analysis for an Advanced Municipal Wastewater Treatment Plant. Research Paper, Organization for Research and Development of Innovative Science and Technology, vol. 21, P178-185

Report on
"Environmental Impact Comparison between Synthetic and Natural Adhesives for Wood-Based Materials"

May 2008

Sekisui Chemical Co., Ltd.

1. General Information

1.1 Assessor

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1.2 Report preparation date

May 30, 2008

2. Purpose of Study

2.1 Basis of study

Through a LCA, assess the environmental impacts of a conventional petroleum-derived synthetic adhesive for wood-based materials and a newly developed adhesive produced from natural raw materials, and determine the environmental performance of the adhesives.

2.2 Application of study result

Determine the environmental performance of a newly developed adhesive produced from natural raw materials. Clarify processes that are important for improving the environmental impacts and provide information for improvements to be made in the designing and production processes.

3. Scope of Study

3.1 Subject of study and its specifications

Adhesive for wood-based materials that is produced, used and disposed of within Japan (weight: 1 kg).

3.2 Functions and functional unit

"Recycled engineered wood (trade name: Sekisui Chemical "EcoValue Wood")" is assumed as the subject wood-based material for this assessment, with the requirement to meet the following two criteria as the functional unit:

(1) Quality standard for adhesion-molded wood-based framing materials
(2) Standard strength for SPF No. 2 grade

In other words, the function was defined to allow the development of certain quality variations and prescribed adhesive strength when the adhesive is used for wood-based materials.

3.3 System boundary

The assessment covers the resource extraction stage through the production stage (Figure 3.2-1).

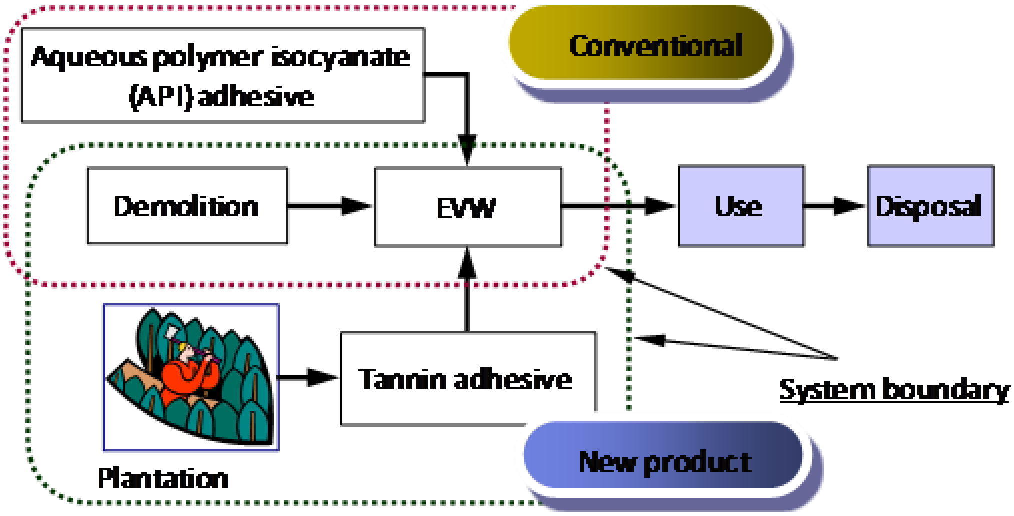

Figure 3.2-1 Adhesive and wood-based building material product system and system boundary

3.4 Special notes (processes or items exempted from assessment, etc.)

For the conventional synthetic adhesive, this environmental assessment uses literature data [1] on inventory analyses covering up to the production stage. The system boundary is therefore specified as the resource extraction stage through the production stage.

The assessment does not factor in the environmental impacts occurring in the overseas transportation stage for the reason that LIME2 is intended for application within Japan.

4. Inventory Analysis

4.1 Foreground data

The result of a research conducted by Sawada et al. [1] was used for the assessment of the conventional petroleum-derived synthetic adhesive (API: aqueous polymer isocyanate). Data based on actual measurements taken at the company plants were used for the adhesive produced from natural raw materials (tannin adhesive). "Recycled engineered wood (trade name: Sekisui Chemical "EcoValue Wood")" was assumed as the subject wood-based material for the assessment, and data collected at the company plants were used for the foreground data.

4.2 Background data

The database and optional "data pack" [3] of LCA software "JEMAI-Pro" [2] provided by the Japan Environmental Management Association for Industry were used in this assessment.

4.3 Inventory analysis item and result table

Table 4.3-1 and 4.3-2 represent the list of items covered in the inventory analyses and the analysis results of the API adhesive (1 kg) and tannin adhesive (1 kg).

Table 4.3-1 Result of LCI analysis of API adhesive (unit: kg/kg)

	No.	Name	Unit	Production Total
Resources	1	Al	kg	5.05E-07
	2	Cu	kg	1.05E-07
	3	PB	kg	3.85E-09
	4	U	kg	2.66E-06
	5	Zn	kg	2.14E-08
	6	silica sand	kg	3.12E-08
	7	Coal for fuel	kg	4.18E-02
	8	Coal for material	kg	1.47E-07
	9	Crude oil	kg	4.76E-01
	10	Natural gas	kg	2.85E-02
	11	Lime stone	kg	6.63E-05
Air	1	CO2	kg	8.97E-01
	2	As	kg	2.52E-09
	3	CH4	kg	4.36E-05
	4	Cd	kg	2.08E-10
	5	Cr	kg	4.59E-09
	6	Hg	kg	3.04E-09
	7	N2O	kg	3.73E-05
	8	NMHC	kg	5.55E-06
	9	NOx	kg	4.28E-04
	10	NOx(mobile emission source)	kg	6.31E-05
	11	Ni	kg	5.15E-09
	12	PM10(mobile emission source)	kg	4.62E-06
	13	Pb	kg	1.21E-08
	14	SO2	kg	8.50E-04
	15	SOx	kg	7.18E-05
	16	Dust	kg	1.01E-04
	17	Dust(mobile emission source)	kg	1.35E-05
Water	1	As	kg	5.02E-12
	2	BOD	kg	1.02E-04
	3	Cd	kg	7.52E-13
	4	Cr	kg	1.50E-11
	5	Hg	kg	5.02E-13
Industrial	1	Rubble(landfill)	kg	1.56E-10
	2	Low level radioactive waste	kg	1.86E-06
	3	Plastic waste(landfill)	kg	7.88E-11
	4	Industrial/landfill waste	kg	6.23E-09
	5	Slag(landfill)	kg	2.02E-07

Note) The values were calculated based on literature [1)] data.

Table 4.3-2 Result of LCI analysis of tannin adhesive (unit: kg/kg)

	No.	Name	Unit	Total	Raw material Powdered tannin production	Production Adhesive production
Resources	1	Al	kg	4.97E-07		4.97E-07
	2	Cu	kg	1.03E-07		1.03E-07
	3	PB	kg	3.79E-09		3.79E-09
	4	U	kg	7.97E-07	2.56E-11	7.97E-07
	5	Zn	kg	2.10E-08		2.10E-08
	6	silica sand	kg	3.07E-08		3.07E-08
	7	Coal for fuel	kg	2.37E-02	1.09E-06	2.37E-02
	8	Coal for material	kg	1.45E-07		1.45E-07
	9	Crude oil	kg	9.43E-02	2.61E-02	6.83E-02
	10	Natural gas	kg	3.60E-02	3.60E-04	3.57E-02
	11	Lime stone	kg	5.08E-06		5.08E-06
Air	1	CO2	kg	3.69E-01	8.29E-02	2.87E-01
	2	As	kg	7.51E-10		7.51E-10
	3	CH4	kg	7.46E-06	2.84E-11	7.46E-06
	4	Cd	kg	6.21E-11		6.21E-11
	5	Cr	kg	1.37E-09		1.37E-09
	6	Hg	kg	9.07E-10		9.07E-10
	7	N2O	kg	1.93E-05	1.35E-06	1.79E-05
	8	NMHC	kg	1.66E-06		1.66E-06
	9	NOx	kg	1.42E-04	2.39E-05	1.18E-04
	10	NOx(mobile emission source)	kg	7.91E-05	3.41E-05	4.49E-05
	11	Ni	kg	1.54E-09	5.80E-05	1.54E-09
	12	PM10(mobile emission source)	kg	6.55E-06		4.16E-06
	13	Pb	kg	3.60E-09		3.60E-09
	14	SO2	kg	1.45E-04		1.42E-04
	15	SOx	kg	2.82E-05	1.27E-06	2.69E-05
	16	Dust	kg	2.54E-05		2.27E-05
	17	Dust(mobile emission source)	kg	9.70E-09		9.70E-09
	18	Hydrocarbon	kg	1.81E-05		1.28E-05
Water	1	As	kg	4.93E-12		4.93E-12
	2	BOD	kg	6.74E-06		6.74E-06
	3	Cd	kg	7.40E-13		7.40E-13
	4	Cr	kg	1.48E-11		1.48E-11
	5	Hg	kg	4.93E-13		4.93E-13
Industrial	1	Rubble(landfill)	kg	1.54E-10		1.54E-10
	2	Low level radioactive waste	kg	5.57E-07		5.57E-07
	3	Plastic waste(landfill)	kg	7.75E-11		7.75E-11
	4	Industrial/landfill waste	kg	6.13E-09		6.13E-09
	5	Slag(landfill)	kg	1.99E-07		1.99E-07

5. Impact Assessment

5.1 LCIA steps and impact categories used in assessment

The impact assessment was conducted using the Japanese-design "Life Cycle Impact Assessment Method based on Endpoint Modeling" (LIME2) through its three steps consisting of characterization, damage assessment and weighting.　The impact categories covered in each step of the assessment are listed in Table 5.1-1.

Table 5.1-1　LCIA steps and environmental impact categories used in assessment

	Characterization	Damage assessment	Weighting
Resource consumption (energy)	○	○	○
Resource consumption (mineral)	○	○	○
Global warming	○	○	○
Urban air pollution	-	○	○
Ozone layer depletion			
Acidification	○	○	○
Eutrophication	○	○	○
Photochemical oxidant creation	○	○	○
Human toxicity			
Ecotoxicity			
Indoor air quality	-		
Noise	-		
Waste			
Land use	*	*	*

*:　Not covered in the LIME calculation sheet

-:　No coefficients by LIME

5.2 Result of impact assessment

5.2.1 Characterization

The characterization results of the environmental impacts of the API adhesive and tannin adhesive in the categories of resource (energy) consumption and acidification are laid out in Figure 5.2-1 and 5.2-2. While the consumption of natural gas associated with the tannin adhesive has a larger impact in the category of energy consumption, there is little difference in the total impacts between the two types of adhesives. In the acidification category, the emission of nitrogen oxide during the production of ingredients for the API adhesive is resulting in a significant impact, of which environmental load amounts to more than twice that of the tannin adhesive. Similar results were obtained for other impact categories such as global warming and eutrophication, which indicated that the API adhesive has more than twice the load of the tannin adhesive. The result of characterization in the mineral consumption category confirmed that the environmental load of the tannin adhesive, which is made of natural raw materials, is approximately 1/3 of that of the API adhesive. These results suggest the superiority of tanning adhesive in environmental performance.

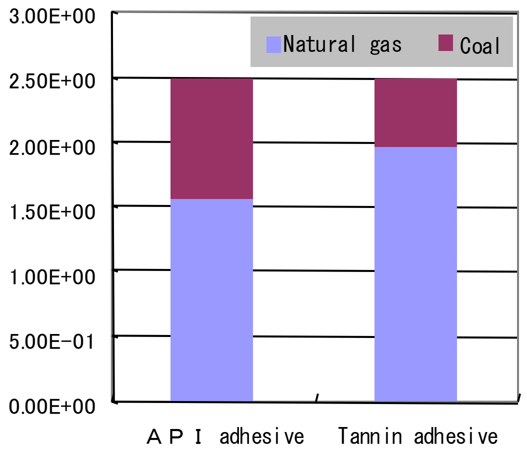

Figure 5.2-1 Characterization result (energy consumption)

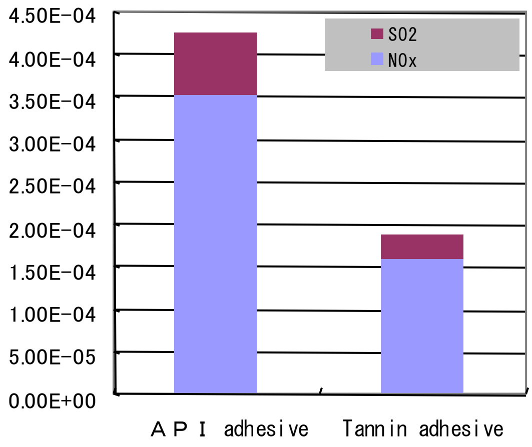

Figure 5.2-2 Characterization result (acidification)

5.2.2 Damage assessment

The results of the damage assessment (breakdown by substance) for four safeguard subjects are laid out in Figure 5.2-3 through 5.2-6. The amounts of impacts on human health and social welfare shown in the results indicate large differences of more than two times between the two adhesives. A similar tendency can also be observed in the results for primary production and biodiversity, where the tannin adhesive is found to be superior to the API adhesive. The reason for such differences can be attributable to the production of synthetic ingredients for the API adhesive, which involves larger impacts compared to using tannin made of natural ingredients.

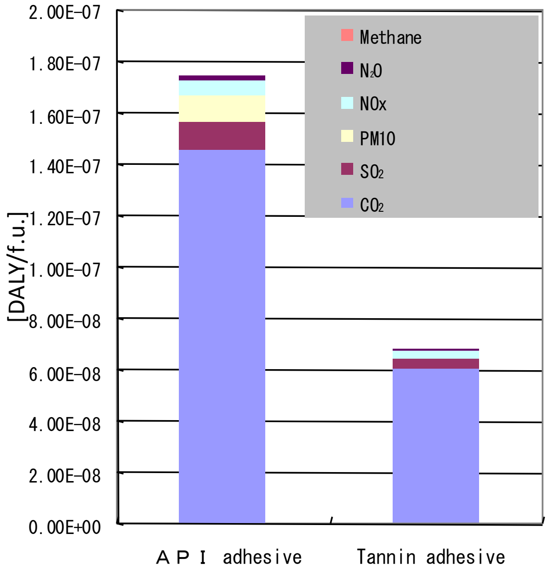

Figure 5.2-5 Result of damage assessment (primary production)

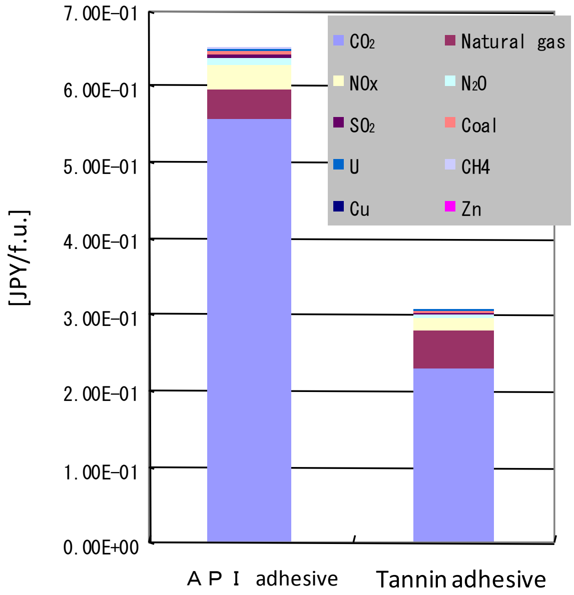

Figure 5.2-6 Result of damage assessment (biodiversity)

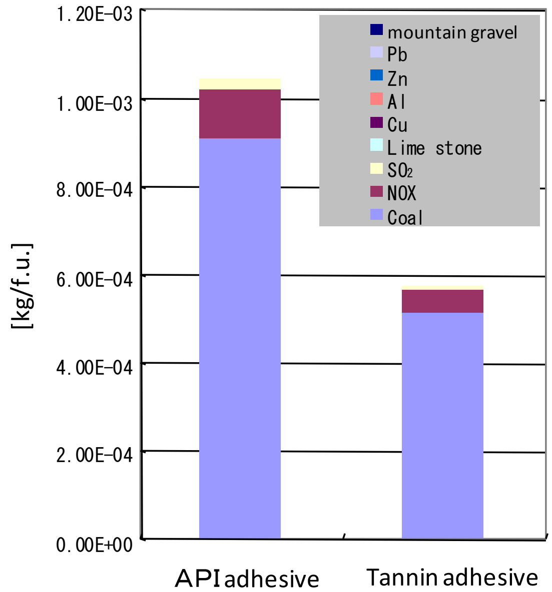

Figure 5.2-3 Result of damage assessment (human health)

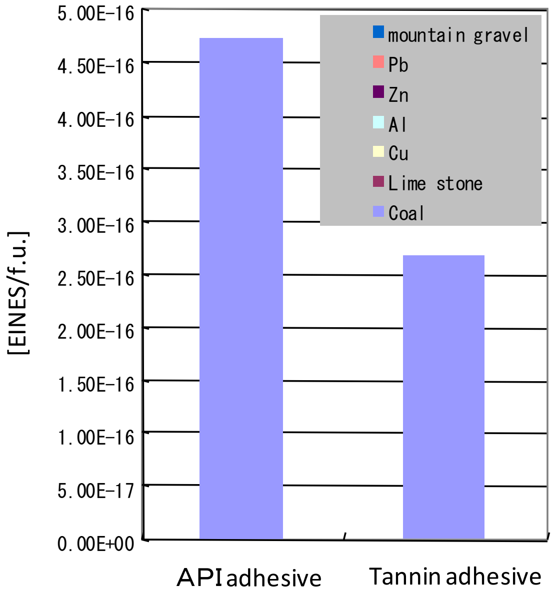

Figure 5.2-4 Result of damage assessment (social welfare)

Figure 5.2-7 and 5.2-8 represent the breakdown of the results by process for human health, in which a large difference was confirmed between the impacts of the API adhesive and tannin adhesive, and for primary production, which presented a smaller difference. For the tannin adhesive, the "raw material" stage includes the plantation of mimosa trees operated overseas and the production of powdered tannin. From the result, it can be estimated that the environmental impact of the tannin adhesive on human health would remain at around 1/4 of that of the API adhesive given that the adhesives are produced in manufacturing plants within Japan. For the impact on primary production, as the impact occurring during the production of the tannin power is very small and the amount of power input during production of adhesives is about the same for both types of adhesives, the difference is assumed to be attributable to synthetic ingredients.

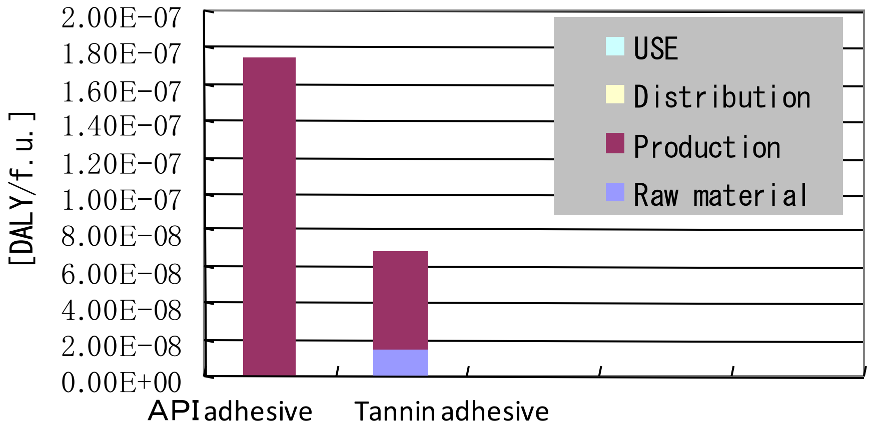

Figure 5.2-7 Damage to human health by process

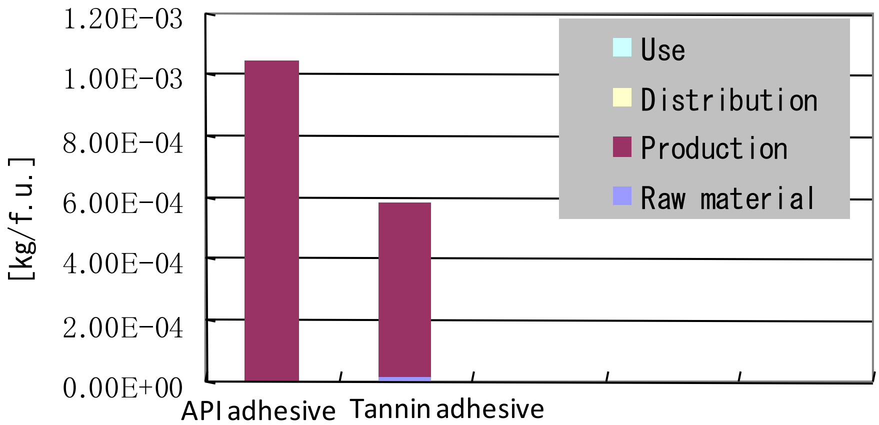

Figure 5.2-8 Damage to primary production by process

5.2.3 Weighting

The weighting result (by substance) for the API adhesive and tannin adhesive is shown in Figure 5.2-9. For both types of adhesives, the emissions of CO_2 is the largest contributor to the environmental impact occurring during the resource extraction stage through the production stage. An aspect of the synthetic-based API adhesive shown in the result that is different from the tannin adhesive is that its environmental impact includes sizable portions resulting from the emissions of SO_2 and PM10.

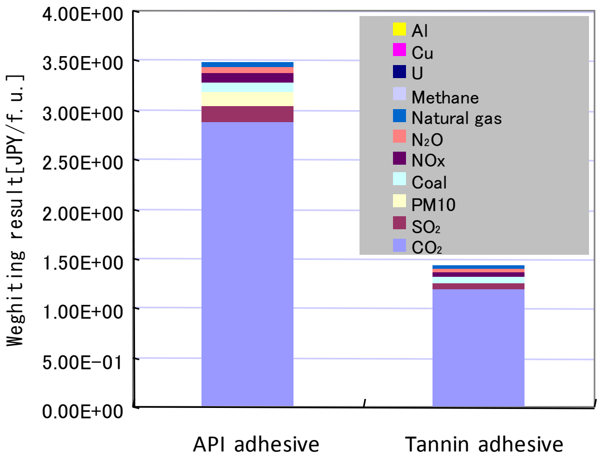

Figure 5.2-9 weighting result (by substance)

Figure 5.2-10 and 5.2-11 respectively represent the breakdown of the weighting result by process and by impact category. The result by process in Figure 5.2-10 indicates that the impact of the tannin adhesive associated with overseas plantation operation (= raw material) is very small, and it is because the process is mainly carried out through manual labor combined with the use of a private power generation facility. The breakdown by impact category illustrates that dominant environmental impacts are global warming, urban air pollution and non-biological resource consumption.

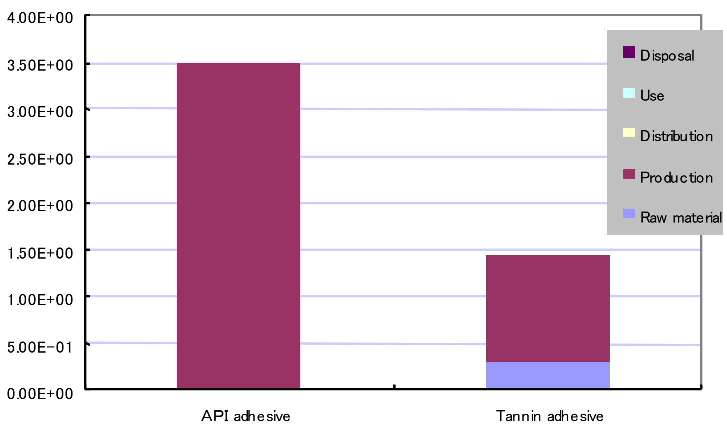

Figure 5.2-10 weighting result (by process)

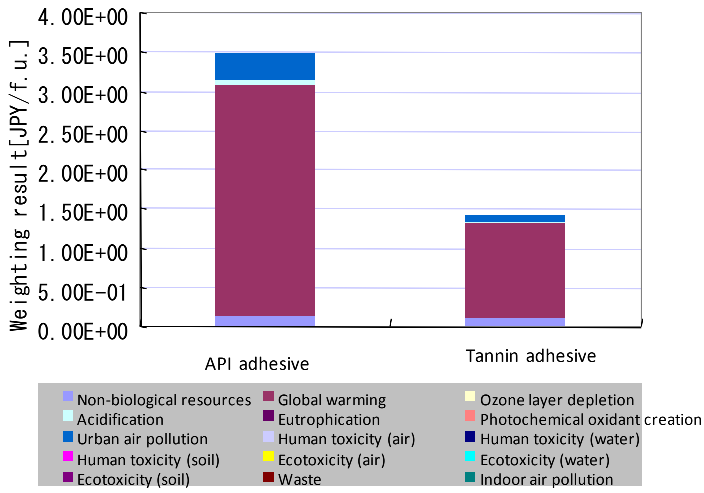

Figure 5.2-11 weighting result (by impact category)

6. Conclusion

6.1. Summary of study result

The assessment was conducted on the environmental impacts of API adhesive and tannin adhesive covering from their resource extraction stage to the production stage. The environmental impacts in terms of social costs are calculated to be approximately 3.5 yen for the API adhesive (1 kg) and 1.4 yen for the tannin adhesive (1 kg). As a commercial API adhesive (1 kg) is currently around 350 yen, the social cost of the adhesive for wood-based materials is estimated to be about 1% of its life cycle (from resource extraction to production) cost.

The assessment result confirmed that most of the environmental impacts associated with the adhesive occur during the production of synthetic ingredients. The emissions of CO_2 and CH_4, and the consumption of crude oil are the main causes of the impacts, and major environmental impacts that are expected to result from these causes are global warming, urban air pollution and non-biological resource consumption.
In order to lessen the environmental impacts of adhesives for wood-based materials, an effective solution would be to change the use of synthetic ingredients to natural raw materials to reduce the emissions of substances that can cause environmental loads. Compared with the aqueous polymer isocyanate adhesive (synthetic-based) that is becoming more commonly used in recent years due to its characteristic that it does not contain formaldehyde, the assessment result indicated that switching to the tannin adhesive (natural-based) has the potential to reduce the environmental impacts by half.

6.2 Limitations and future challenges

The scope of this assessment was specified in accordance with the system boundary used in the reference literature, and included only limited processes (from resource extraction to production of adhesive). For this reason, the validity of the assessment result is considered limited. While the environmental loads that occur in the overseas transportation stage of natural raw materials grown in plantations were excluded from the scope of this assessment for the reason that LIME2 is intended for application within Japan, the inclusion of the overseas transportation stage should be considered in the future. Since we have not conducted studies on the emissions of chemical substances during the use of wood-based materials and the generation of chemical substances during the waste incineration, the effects that these factors could have on the assessment result are unknown under the present circumstances, and the completeness of the scope of the assessment with regard to chemical substances may not be sufficient.

Many plants manufacturing wood-based materials recently started to introduce wood chip boilers to utilize mill ends for further energy conservation and reduction of environmental impacts. The LCIA covering the life cycle of such systems should be considered in the next step.

References

1) Yukinobu Sawada, Keisuke Ando, Nobuaki Hattori, Yasuo Tamura (2006): Inventory Analysis of Adhesives Used for Wood Based Materials. Journal of the Japan Wood Research Society, vol. 52, No. 4, p 235-240
2) Japan Environmental Management Association for Industry (2005): LCA software "JEMAI-LCA Pro ver. 2.1.2"
3) Japan Environmental Management Association for Industry (2006): LCA software "JEMAI-LCA Pro optional data pack"

Report on Environmental Impact Comparison of "Metal-Enclosed Switchgear (High Voltage Panel)" and "Low Voltage Motor Control Center" Switchboards

May 2008

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Fuji Electric Advanced Technology Co., Ltd.

1. General Information

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1.2 Report preparation date

May 23, 2008

2. Purpose of Study

2.1 Basis of study

Determine the effects of energy conservation and weight reduction on lowering the environmental impacts (loads) of new products compared to conventional products, by assessing the life cycle environmental impacts of the products using the LIME2 method.

2.2 Application of study result

Determine the environmental performance of a conventional product and a new product for each of two switchboard models: "metal-enclosed switchgear (high voltage panel)" and "low voltage motor control center." Clarify processes that are important for improving the environmental impacts and provide information for improvements to be made in the designing process.

3. Scope of Study

3.1 Subject of study and its specifications

3.1.1 Metal-enclosed switchgear (high voltage panel)

A device connected to a high voltage circuit with a frequency of 60 Hz or lower and rated voltage of 3.6 kV/7.2 kV, and consisting of switching equipment, control, measurement, protection, adjustment, internal connection, auxiliaries, grounded metal enclosure box and support structure.
Definition based on the Japan Electrical Manufacturers' Association (JEMA) standard: JEM 1425.
Hereinafter referred to as "high voltage panel."
The main specifications of the conventional and new products are laid out in Table 3.1-1.

Table 3.1-1 High voltage panel) main specifications of conventional and new products

	Conventional product: 7.2 kV panel	New product: SLIMEC-V6
Ecoleaf registration number	BW-06-002	BW-07-003
Number of functional units mounted per unit area	2 units	2 units
Rated current of main circuit of functional unit	300A	300A
Rated short-time withstand current of main circuit of functional unit	12.5 kA	12.5 kA
Compliant standard/type code	JEM 1425/MW	JEM 1425/CW
Ingress protection rating	IP2X	IP2X
Dimension (W x H x D)	700 x 2350 x 1800 mm	600 x 2350 x 700 mm
Total mass	607.0 kg	260.2 kg
Exterior appearance		
Key improvements made to new product (Priority theme in new product development was reduction of panel depth)	The total mass of the entire panel was significantly reduced through the reduction of the panel depth achieved as the result of downsized internal equipment and the progress of conductor processing technologies. Improvement was made in reducing the energy consumption of the entire panel through the introduction of energy-efficient equipment. Energy conservation (reduction of power consumption): ▲16% Weight reduction (reduction of product mass): ▲ 57%	

3.1.2 Low voltage motor control center

A switching control device connected to a low voltage circuit with an alternating current frequency of 50 Hz or 60 Hz and voltage of 600V or lower, and used to centrally connect and disconnect, control and protect motor and lighting loads.

Definition based on the Japan Electrical Manufacturers' Association (JEMA) standard: JEM 1195. Hereinafter referred to as "control center."

The main specifications of the conventional and new products are laid out in Table 3.1-2.

Table 3.1-2 Control center) main specifications of conventional and new products

	Conventional product: SM1200	New product: SM3000
Ecoleaf registration number	BG-04-001	BG-05-002
Number of functional units mounted per unit area	10 units	10 units
Connection method for main and control circuits	BB method (Direct connection)	BB method (Direct connection)
Dimension (W x H x D)	630 x 2350 x 600 mm	630 x 2350 x 600 mm
Total mass	382.4 kg	296.4 kg
Exterior appearance		
Key improvements made to new product (Priority theme in new product development was high-density mounting of units)	The total mass of the entire panel was reduced as the result of the reduced panel size achieved through the high-density mounting of functional units (a maximum of 40 units can be mounted on the front and back surfaces of the new product, where the conventional product allows the mounting of 14 units maximum). Improvement was made in reducing the energy consumption of the entire panel through the introduction of energy-efficient equipment and reduction of energy loss by shortening the power lines of the main circuit. Energy conservation (reduction of power consumption): ▲36% Weight reduction (reduction of product mass): ▲ 22%	

3.2 Functions and functional unit

3.2.1 High voltage panel

The number of functional units mounted per unit area: 2 units, rated current of main circuit: 300A.

The calculations factored in the power consumption of the high voltage panel only, based on the average load factor of 35% at the rated current of the main circuit of the functional unit for 24 hours a day, 360 days a year (downtime of 5 days for maintenance) for 15 years.

3.2.2 Control center

The number of functional units mounted per unit area: 10 units, total control capacity: 150 kW.
The calculations factored in the power consumption of the control center only, based on the assumption that internal equipment units at 70% of the maximum capacity feeds the load for 4 hours a day, 360 days a year (downtime of 5 days for maintenance), for 15 years.

3.3 System boundary

The assessment covers the raw material production, assembly (product production), transportation, use, and disposal/recycling stages (same for both high voltage panel and control center). See Figure 3.3-1.

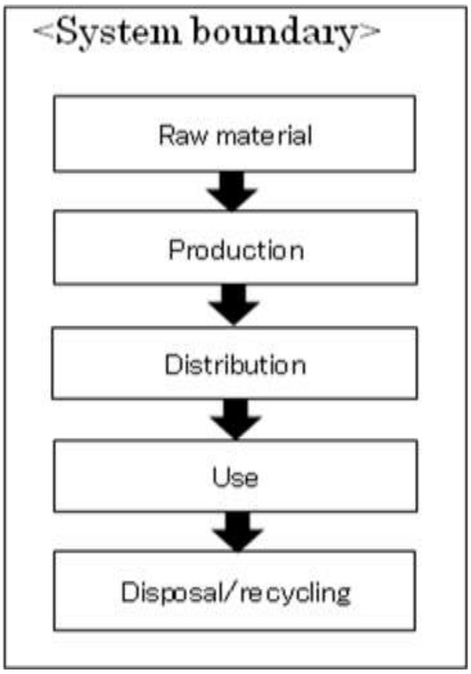

Figure 3.3-1 System boundary of switchboard

3.4 Special notes

Given the fact that switchboards have long life spans of over 15 years and products become properties of clients, information obtainable regarding their disposal and recycling processes is usually limited and it is difficult to accurately determine how products are disposed of in practice. Under these circumstances, we have carried out calculations for the disposal/recycling stage based on the following scenario (same scenario was applied to both high voltage panel and control center) formulated after conducting interviews with industrial waste disposal operators and research through the Internet and related literature.

Iron and copper that can be dismantled manually using general-purpose tools are collected and shredded, and included in the calculation as a deduction at the recovery rate of 80% [1)] (recycling effect). The remaining 20% and other components with the exception of instruction documents are shredded and disposed of in a landfill as industrial waste. Instruction documents (wood pulp-based paper) are deducted at a 40% recovery rate [2)] (recycling effect). The remaining 60% is incinerated as general waste, and the incineration ash is disposed of in a landfill as industrial waste.

4. Inventory Analysis

4.1 Foreground data

Actual measurements taken at the company plants or provided by contractors (partially research data).

4.2 Background data

Common intensities for Ecoleaf environmental label [4] administered by the Japan Environmental Management Association for Industry (JEMAI) [3] are used.

4.3 Inventory analysis item and result table

Table 4.3-1 through Table 4.3-4 represent the list of items covered in the inventory analyses and the results of the analyses of conventional and new high voltage panel products as well as conventional and new control center products.
All of the above products have registered Ecoleaf environmental labels [4], and the inventory analysis results are published on the JEMAI website [5] (Note that the data on the disposal/recycling stage shown in the tables are the combined values of the disposal and recycling effects).

Table 4.3-1 High voltage panel: 7.2 kV panel (conventional product) LCI data

					unit	Rwa material	Production	Distribution	Use	Disposal/Recycling
Inventry analyses	Impact by resource consumption	Exhaoustible resources	Energy resources	Coal	kg	4.48E+02	3.48E+01	1.38E−03	3.94E+02	−2.30E+02
				Crude oil (for fuel)	kg	1.24E+02	4.13E+01	1.29E+01	4.46E+02	5.96E+00
				LNG	kg	2.52E+01	1.85E+01	2.00E−01	1.97E+02	3.72E+00
				U content of an ore	kg	2.39E−03	2.36E−03	9.36E−08	2.67E−02	4.98E−04
			Mineral resources	Crude oil (for material)	kg	4.31E+01	0	0	0	0
				Fe content of an ore	kg	4.86E+02	0	0	0	−2.95E+02
				Cu content of an ore	kg	2.29E+01	0	0	0	−8.39E+00
				Al content of an ore	kg	1.07E+00	0	0	0	0
				Ni content of an ore	kg	1.15E−01	0	0	0	−6.00E−03
				Cr content of an ore	kg	3.23E−01	0	0	0	−1.09E−01
				Mn content of an ore	kg	2.60E+00	0	0	0	7.08E−02
				Pb content of an ore	kg	2.00E+00	0	0	0	−6.82E−01
				Sn content of an ore	kg	4.03E−02	0	0	0	0
				Zn content of an ore	kg	2.05E+01	0	0	0	−6.70E+00
				Au content of an ore	kg	0	0	0	0	0
				Ag content of an ore	kg	2.49E−02	0	0	0	0
				Silica sand	kg	1.28E+01	0	0	0	−3.89E+00
				Halite	kg	4.65E+01	0	0	0	6.62E−03
				Limestone	kg	1.02E+02	0	0	0	−4.78E+01
				soda ash	kg	6.35E−02	0	0	0	0
		Renewable resources		wood	kg	2.10E+00	0	0	0	−1.74E−01
				water	kg	4.47E+04	2.64E+04	1.04E+00	2.98E+05	3.56E+03
	Emission to the environment	To air		CO2	kg	1.62E+03	2.77E+02	4.17E+01	3.06E+03	−5.54E+02
				SOx	kg	8.70E−01	2.14E−01	5.12E−02	2.34E+00	−1.40E−01
				NOx	kg	1.17E+00	2.57E−01	6.40E−01	1.85E+00	−2.27E−01
				N2O	kg	8.96E−02	3.12E−03	7.52E−04	3.35E−02	−1.03E−02
				CH4	kg	6.33E−03	6.30E−03	2.50E−07	7.13E−02	1.34E−03
				CO	kg	2.58E−01	7.57E−02	2.56E−01	4.53E−01	−9.19E−02
				NMVOC	kg	1.24E−02	1.23E−02	4.92E−07	1.40E−01	2.62E−03
				CxHy	kg	5.02E−02	2.53E−03	1.29E−02	7.29E−03	−1.35E−02
				dust	kg	2.07E−01	1.63E−02	5.12E−02	1.00E−01	−7.65E−02
		To water		BOD	kg	–	–	–	–	–
				COD	kg	–	–	–	–	–
				N total	kg	–	–	–	–	–
				P total	kg	–	–	–	–	–
				SS	kg	–	–	–	–	–
		To soil		Unspecified solid waste	kg	8.41E+00	3.25E−06	0	0	2.95E+02
				Slag	kg	2.10E+02	0	0	0	−9.31E+01
				Sludge	kg	2.30E+00	0	0	0	0
				Low level radio-active waste	kg	1.67E−03	1.65E−03	6.56E−08	1.86E−02	3.48E−04

Table 4.3-2 High voltage panel: SLIMEC-V6 (new product) LCI data

					unit	Rwa material	Production	Distribution	Use	Disposal/Recycling
Inventry analyses	Impact by resource consumption	Exhaoustible resources	Energy resources	Coal	kg	1.83E+02	2.57E+01	8.30E-04	3.31E+02	-1.04E+02
				Crude oil (for fuel)	kg	4.39E+01	3.25E+01	7.75E+00	3.74E+02	2.62E+00
				LNG	kg	1.04E+01	1.29E+01	1.20E-01	1.66E+02	1.65E+00
				U content of an ore	kg	9.27E-04	1.74E-03	5.62E-08	2.24E-02	2.27E-04
			Mineral resources	Crude oil (for material)	kg	1.72E+01	0	0	0	0
				Fe content of an ore	kg	1.97E+02	0	0	0	-1.32E+02
				Cu content of an ore	kg	1.34E+01	0	0	0	-6.76E+00
				Al content of an ore	kg	6.02E-01	0	0	0	0
				Ni content of an ore	kg	1.24E-02	0	0	0	-2.68E-03
				Cr content of an ore	kg	8.47E-02	0	0	0	-4.89E-02
				Mn content of an ore	kg	1.05E+00	0	0	0	3.16E-02
				Pb content of an ore	kg	1.13E+00	0	0	0	-5.49E-01
				Sn content of an ore	kg	1.37E-02	0	0	0	0
				Zn content of an ore	kg	1.07E+01	0	0	0	-5.40E+00
				Au content of an ore	kg	2.90E-05	0	0	0	0
				Ag content of an ore	kg	1.80E-02	0	0	0	0
				Silica sand	kg	6.78E+00	0	0	0	-2.59E+00
				Halite	kg	2.31E+01	0	0	0	2.50E-03
				Limestone	kg	3.95E+01	0	0	0	-2.14E+01
				soda ash	kg	7.58E-02	0	0	0	0
		Renewable resources		wood	kg	3.49E+00	0	0	0	-1.74E-01
				water	kg	1.58E+04	2.03E+04	6.24E-01	2.51E+05	9.84E+02
	Emission to the environment	To air		CO_2	kg	6.56E+02	2.04E+02	2.50E+01	2.57E+03	-2.51E+02
				SO_x	kg	3.91E-01	1.57E-01	3.07E-02	1.96E+00	-8.77E-02
				NO_x	kg	4.61E-01	1.84E-01	3.84E-01	1.56E+00	-1.07E-01
				N_2O	kg	3.62E-02	2.38E-03	4.51E-04	2.81E-02	-4.61E-03
				CH_4	kg	2.44E-03	4.64E-03	1.50E-07	5.99E-02	6.14E-04
				CO	kg	1.07E-01	5.37E-02	1.53E-01	3.81E-01	-4.22E-02
				NMVOC	kg	4.78E-03	9.09E-03	2.95E-07	1.17E-01	1.20E-03
				C_xH_y	kg	1.96E-02	1.77E-03	7.75E-03	6.13E-03	-6.06E-03
				dust	kg	8.19E-02	1.16E-02	3.07E-02	8.40E-02	-3.47E-02
		To water		BOD	kg	–	–	–	–	–
				COD	kg	–	–	–	–	–
				N total	kg	–	–	–	–	–
				P total	kg	–	–	–	–	–
				SS	kg	–	–	–	–	–
		To soil		Unspecified solid waste	kg	6.56E-01	3.11E-02	0	0	1.11E+02
				Slag	kg	9.48E+01	0	0	0	-4.31E+01
				Sludge	kg	1.29E+00	0	0	0	0
				Low level radio-active was	kg	6.48E-04	1.21E-03	3.94E-08	1.56E-02	1.59E-04

Table 4.3-3 Control center: SM1200 (conventional product) LCI data

					unit	Rwa material	Production	Distribution	Use	Disposal/Recycling
Inventry analyses	Impact by resource consumption	Exhaoustible resources	Energy resources	Coal	kg	2.68E+02	2.39E+01	8.30E-04	3.27E+02	-1.75E+02
				Crude oil (for fuel)	kg	8.73E+01	3.53E+01	7.75E+00	3.69E+02	4.30E+00
				LNG	kg	1.87E+01	3.75E+01	1.20E-01	1.63E+02	2.74E+00
				U content of an ore	kg	1.52E-03	1.62E-03	5.62E-08	2.21E-02	3.78E-04
			Mineral resources	Crude oil (for material)	kg	2.88E+01	0	0	0	0
				Fe content of an ore	kg	2.87E+02	0	0	0	-2.21E+02
				Cu content of an ore	kg	1.72E+01	0	0	0	-1.12E+01
				Al content of an ore	kg	9.59E-01	0	0	0	0
				Ni content of an ore	kg	9.67E-02	0	0	0	-4.50E-03
				Cr content of an ore	kg	2.29E-01	0	0	0	-8.21E-02
				Mn content of an ore	kg	1.54E+00	0	0	0	5.32E-02
				Pb content of an ore	kg	1.45E+00	0	0	0	-9.11E-01
				Sn content of an ore	kg	4.56E-04	0	0	0	0
				Zn content of an ore	kg	1.46E+01	0	0	0	-8.95E+00
				Au content of an ore	kg	0	0	0	0	0
				Ag content of an ore	kg	8.99E-02	0	0	0	0
				Silica sand	kg	9.33E+00	0	0	0	-4.31E+00
				Halite	kg	1.67E+01	0	0	0	2.97E-03
				Limestone	kg	6.75E+01	0	0	0	-3.60E+01
				soda ash	kg	1.21E-01	0	0	0	0
		Renewable resources		wood	kg	6.74E-01	0	0	0	-2.52E-01
				water	kg	3.03E+04	1.81E+04	6.24E-01	2.47E+05	1.65E+03
	Emission to the environment	To air		CO2	kg	1.01E+03	1.87E+02	2.50E+01	2.54E+03	-4.22E+02
				SOx	kg	5.75E-01	1.42E-01	3.07E-02	1.94E+00	-1.47E-01
				NOx	kg	7.65E-01	1.15E-01	3.84E-01	1.54E+00	-1.79E-01
				N2O	kg	6.60E-02	3.66E-03	4.51E-04	2.77E-02	-7.78E-03
				CH4	kg	4.02E-03	4.32E-03	1.50E-07	5.91E-02	1.02E-03
				CO	kg	1.62E-01	2.77E-02	1.53E-01	3.75E-01	-7.10E-02
				NMVOC	kg	7.86E-03	8.46E-03	2.95E-07	1.16E-01	2.00E-03
				CxHy	kg	3.32E-02	7.24E-04	7.75E-03	6.04E-03	-1.02E-02
				dust	kg	1.30E-01	6.15E-03	3.07E-02	8.29E-02	-5.83E-02
		To water		BOD	kg	-	-	-	-	-
				COD	kg	-	-	-	-	-
				N total	kg	-	-	-	-	-
				P total	kg	-	-	-	-	-
				SS	kg	-	-	-	-	-
		To soil		Unspecified solid waste	kg	1.10E+01	1.01E-04	0	0	1.32E+02
				Slag	kg	1.33E+02	0	0	0	-7.23E+01
				Sludge	kg	2.06E+00	2.30E+00	0	0	0
				Low level radio-active was	kg	1.06E-03	1.13E-03	3.94E-08	1.54E-02	2.64E-04

Table 4.3-4　Control center: SM3000 (new product) LCI data

					unit	Rwa material	Production	Distribution	Use	Disposal/Recycling
Inventry analyses	Impact by resource consumption	Exhaoustible resources	Energy resources	Coal	kg	2.24E+02	1.45E+01	8.30E-04	2.10E+02	-1.50E+02
				Crude oil (for fuel)	kg	5.34E+01	1.83E+01	7.75E+00	2.37E+02	3.70E+00
				LNG	kg	1.20E+01	1.88E+01	1.20E-01	1.05E+02	2.38E+00
				U content of an ore	kg	1.20E-03	9.81E-04	5.62E-08	1.42E-02	3.19E-04
			Mineral resources	Crude oil (for material)	kg	1.33E+01	0	0	0	0
				Fe content of an ore	kg	2.45E+02	0	0	0	-1.92E+02
				Cu content of an ore	kg	9.33E+00	0	0	0	-5.96E+00
				Al content of an ore	kg	1.10E-01	0	0	0	0
				Ni content of an ore	kg	2.73E-02	0	0	0	-3.91E-03
				Cr content of an ore	kg	1.21E-01	0	0	0	-7.14E-02
				Mn content of an ore	kg	1.30E+00	0	0	0	4.61E-02
				Pb content of an ore	kg	9.46E-01	0	0	0	-4.85E-01
				Sn content of an ore	kg	1.99E-02	0	0	0	0
				Zn content of an ore	kg	1.05E+01	0	0	0	-4.76E+00
				Au content of an ore	kg	0	0	0	0	0
				Ag content of an ore	kg	1.89E-01	0	0	0	0
				Silica sand	kg	6.80E+00	0	0	0	-2.68E+00
				Halite	kg	1.43E+01	0	0	0	2.06E-03
				Limestone	kg	5.68E+01	0	0	0	-3.12E+01
				soda ash	kg	1.42E-01	0	0	0	0
		Renewable resources		wood	kg	6.51E-01	0	0	0	-2.52E-01
				water	kg	2.23E+04	1.10E+04	6.24E-01	1.59E+05	2.17E+03
	Emission to the environment	To air		CO2	kg	7.95E+02	1.13E+02	2.50E+01	1.63E+03	-3.63E+02
				SOx	kg	4.09E-01	8.60E-02	3.07E-02	1.24E+00	-9.62E-02
				NOx	kg	5.20E-01	6.91E-02	3.84E-01	9.86E-01	-1.50E-01
				N2O	kg	3.87E-02	1.86E-03	4.51E-04	1.78E-02	-6.78E-03
				CH4	kg	3.19E-03	2.62E-03	1.50E-07	3.79E-02	8.60E-04
				CO	kg	1.24E-01	1.67E-02	1.53E-01	2.41E-01	-6.03E-02
				NMVOC	kg	6.23E-03	5.14E-03	2.95E-07	7.43E-02	1.68E-03
				CxHy	kg	2.24E-02	3.74E-04	7.75E-03	3.88E-03	-8.87E-03
				dust	kg	9.58E-02	3.70E-03	3.07E-02	5.32E-02	-5.00E-02
		To water		BOD	kg	-	-	-	-	-
				COD	kg	-	-	-	-	-
				N total	kg	-	-	-	-	-
				P total	kg	-	-	-	-	-
				SS	kg	-	-	-	-	-
		To soil		Unspecified solid waste	kg	4.03E+00	3.69E-05	0	0	9.11E+01
				Slag	kg	1.02E+02	0	0	0	-6.10E+01
				Sludge	kg	2.35E-01	5.50E-01	0	0	0
				Low level radio-active was	kg	8.40E-04	6.84E-04	3.94E-08	9.90E-03	2.23E-04

5. Impact Assessment

5.1 LCIA steps and impact categories used in assessment

The impact assessment was conducted using the Japanese-design "Life Cycle Impact Assessment Method based on Endpoint Modeling" (LIME2) through its three steps consisting of characterization, damage assessment and weighting. The impact categories covered in each step of the assessment are listed in Table 5.1-1.

Table 5.1-1 LCIA steps and environmental impact categories used in assessment

	Characterization	Damage assessment	Weighting
Resource consumption (energy)	○	○	○
Resource consumption (mineral)	○	○	○
Global warming	○	○	○
Urban air pollution	-	○	○
Ozone layer depletion			
Acidification	○	○	○
Eutrophication	○	○	○
Photochemical oxidant creation	○	○	○
Human toxicity			
Ecotoxicity			
Indoor air quality	-		
Noise	-		
Waste	○	○	○
Land use			

5.2 Result of impact assessment

5.2.1 Characterization (high voltage panel)

The characterization results of the environmental impacts of the conventional high voltage panel product (7.2 kV panel) and new product (SLIMEC-V6) in the categories of resource (energy) consumption, resource (mineral) consumption, global warming and waste are laid out in Figure 5.2-1 through Figure 5.2-4. The environmental impacts of the new product have been reduced from the conventional product in all impact categories, owing to the energy conservation and weight reduction achieved for the new product. The reduction in the impacts is especially significant in the categories of mineral consumption and waste as the result of the drastically reduced amount of metal used.

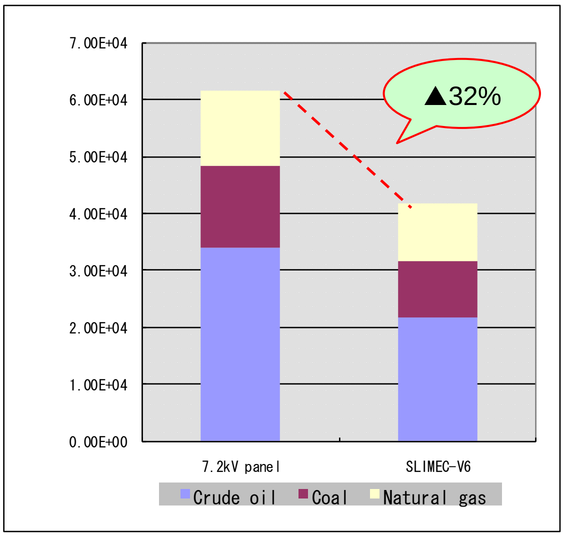

Figure 5.2-1 Characterization result (energy consumption)

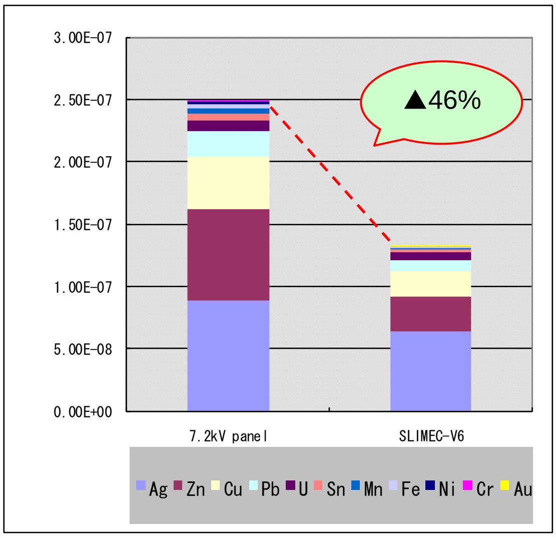

Figure 5.2-2 Characterization result (mineral consumption)

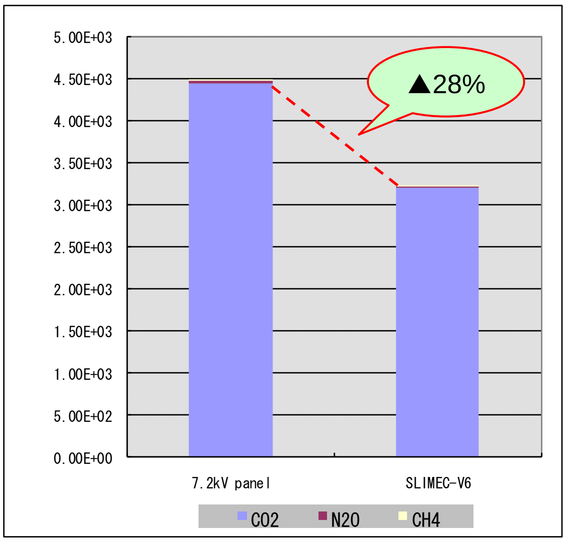

Figure 5.2-3 Characterization result (global warming)

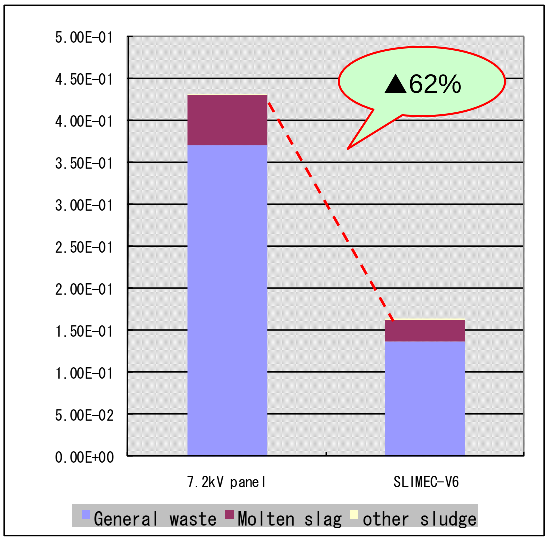

Figure 5.2-4 Characterization result (waste)

5.2.2 Characterization (control center)

The characterization results of the environmental impacts of the conventional control center product (SM1200) and new product (SM3000) in the categories of resource (energy) consumption, resource (mineral) consumption, global warming and waste are laid out in Figure 5.2-5 through Figure 5.2-8. The environmental impacts of the new product have been reduced from the conventional product in the impact categories of energy consumption, global warming and waste owing to the energy conservation and weight reduction achieved for the new product. On the other hand, the impact has increased in the mineral consumption category, which is largely due to the product's silver content. While the total mass of the entire panel of the new product has been decreased as the result of the reduced amount of iron and copper used, the amount of silver used in the new product has increased (Table 5.2-1 and Table 5.2-2).

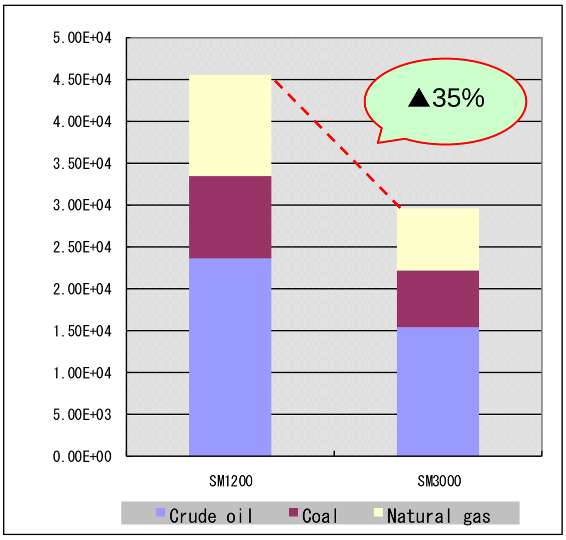

Figure 5.2-5 Characterization result (energy consumption)

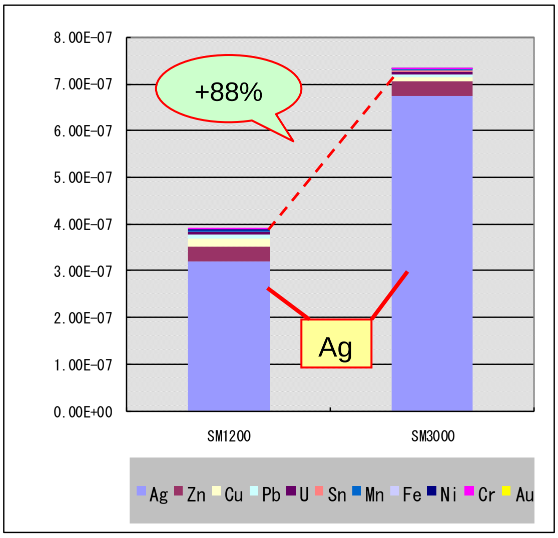

Figure 5.2-6 Characterization result (mineral consumption)

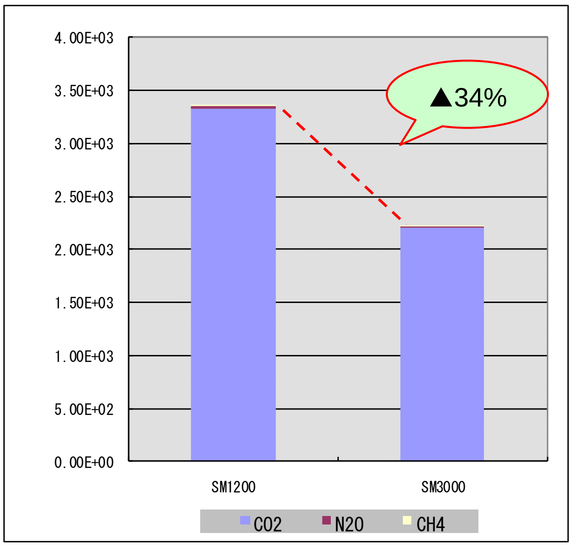

Figure 5.2-7 Characterization result (global warming)

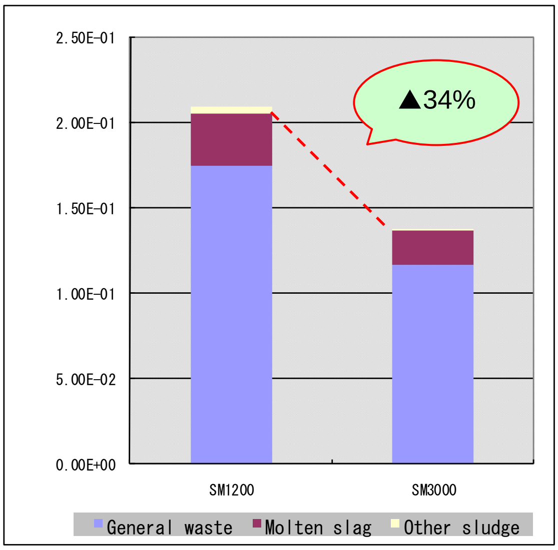

Figure 5.2-8 Characterization result (waste)

Table 5.2-1 Amount of iron, copper and silver used in products

	SM1200	SM3000	Difference
Iron usage (kg)	276.4	235.9	▲40.5
Copper usage (kg)	56.4	30.4	▲26.1
Silver usage (kg)	0.090	0.189	0.1
Total mass (kg)	382.37	296.37	▲86.0

Table 5.2-2 Resource consumption characterization factors for main metal components

	Characterization factor (1/R)
Fe	3.00E-05
Cu	6.20E-03
Al	8.40E-05
Ag	7.50E+00
Au	4.40+01

5.2.3 Damage assessment (high voltage panel)

The results of the damage assessment (breakdown by substance) for four safeguard subjects are laid out in Figure 5.2-9 through Figure 5.2-12. The quantity of damage has been reduced for all safeguard subjects. The reduced waste volume achieved by the reduction of the product weight has contributed considerably to lowering the damage.

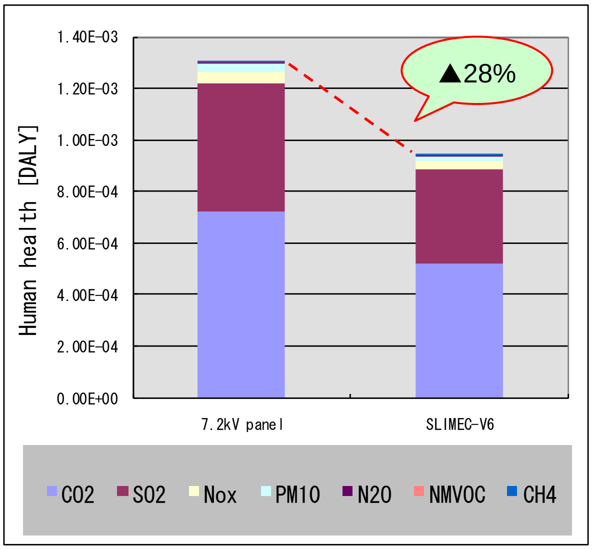

Figure 5.2-9 Result of damage assessment (human health)

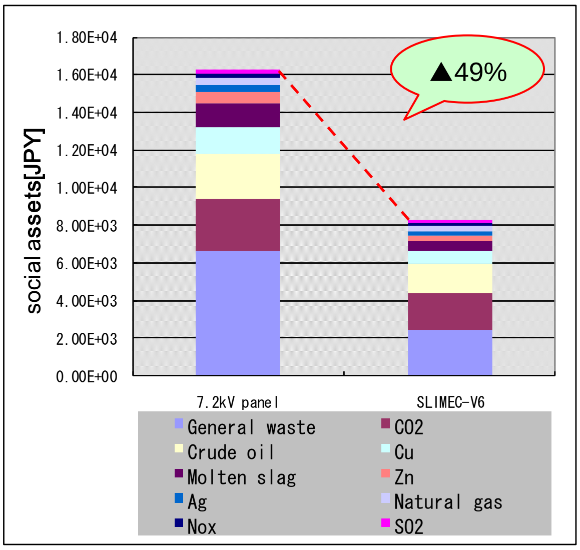

Figure 5.2-10 Result of damage assessment (social assets)

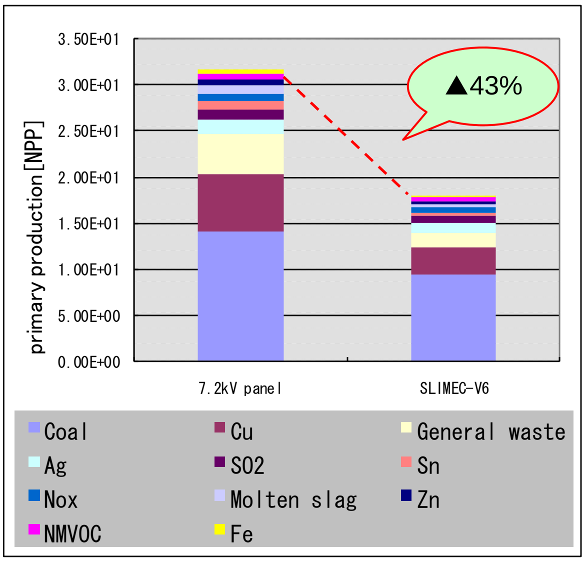

Figure 5.2-11 Result of damage assessment (primary production)

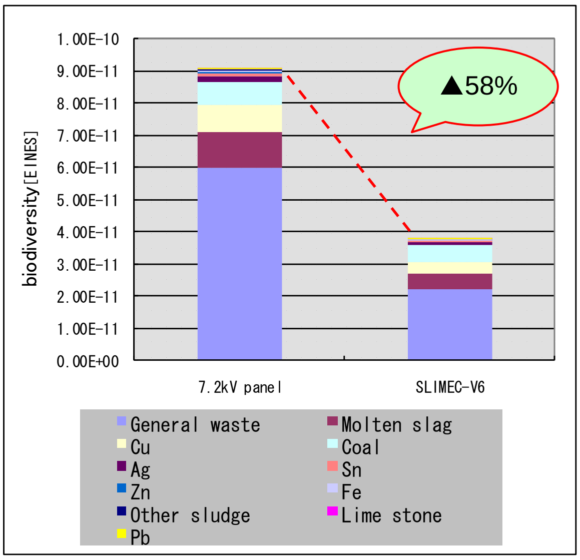

Figure 5.2-12 Result of damage assessment (biodiversity)

5.2.4 Damage assessment (control center)

The results of the damage assessment (breakdown by substance) for four safeguard subjects are laid out in Figure 5.2-13 through Figure 5.2-16. The quantity of damage has been reduced for human health, social welfare and biodiversity. The conservation of energy has contributed considerably to lowering the damage to human health. Damage to primary production has increased slightly due to the impact of silver consumption.

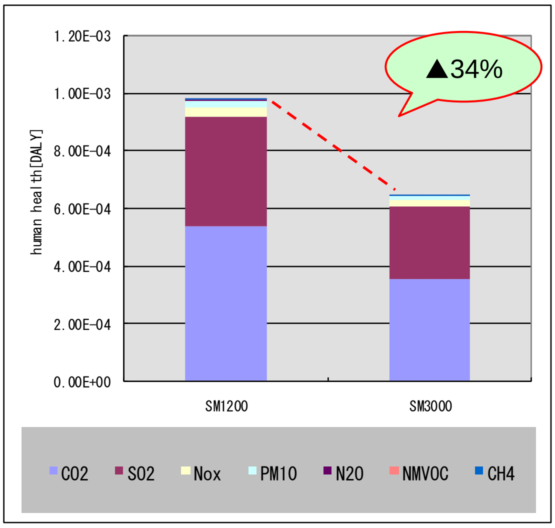

Figure 5.2-13 Result of damage assessment (human health)

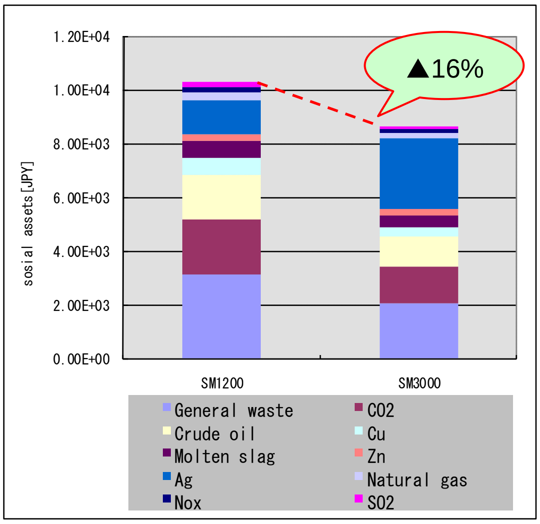

Figure 5.2-14 Result of damage assessment (social assets)

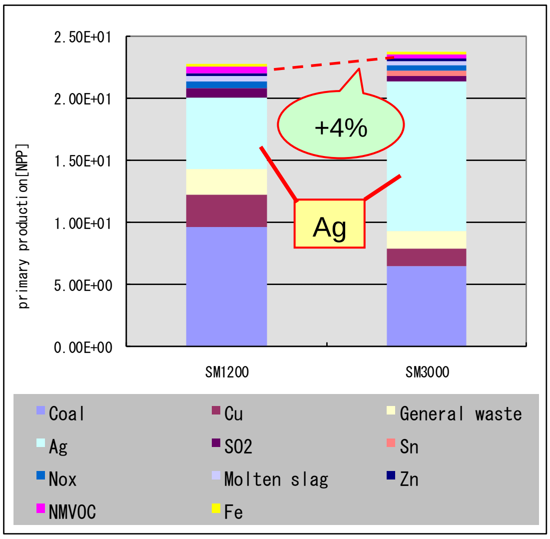

Figure 5.2-15 Result of damage assessment (primary production)

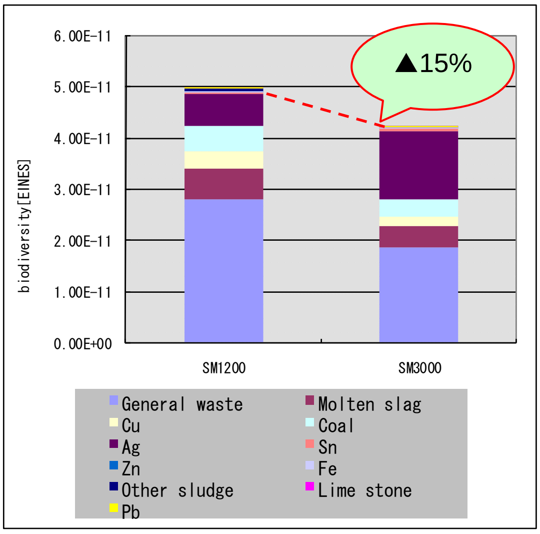

Figure 5.2-16 Result of damage assessment (biodiversity)

5.2.5 Weighting (high voltage panel)

The Weighting results (by substance, by process and by impact category) are shown in Figure 5.2-17 through Figure 5.2-19. The social cost is approximately 410,000 yen for the conventional product and 250,000 yen for the new product, indicating the reduction of about 40%.

The result by substance indicates that the emissions of CO_2, general waste and SO_2 are the major causes of the environmental impacts of the products, and the effect of waste reduction achieved through the reduced weight of the new product has contributed considerably to the assessment result. Despite the prediction we had made prior to the assessment that the largest portion of the products' environmental impact would be associated with the use stage, the Weighting result by process confirmed that almost as much impact occurs in the raw material stage as in the use stage. According to the Weighting result by impact category, the major impacts of the products are non-biological resource consumption, global warming, urban air pollution and waste.

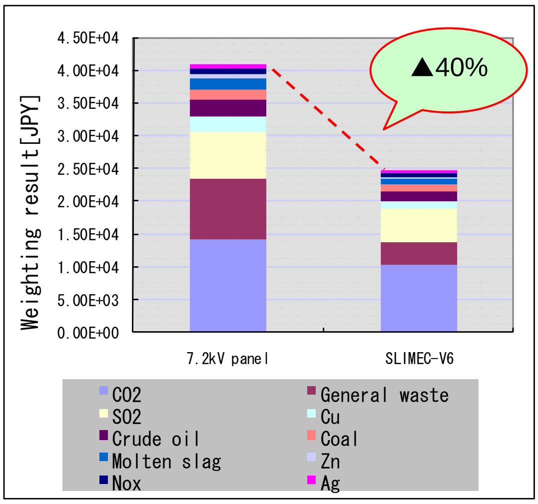

Figure 5.2-17 Weighting result (by substance)

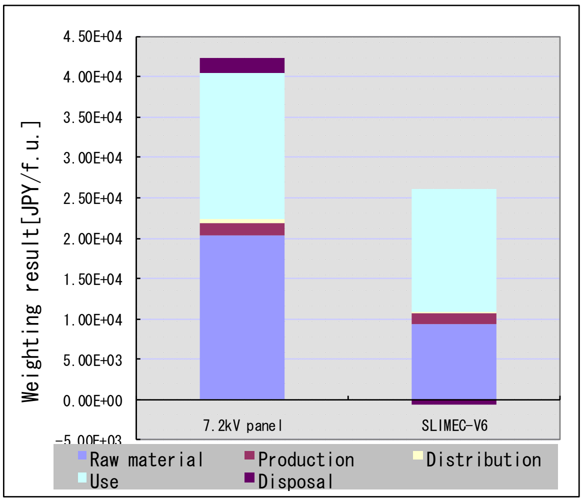

Figure 5.2-18 Weighting result (by process)

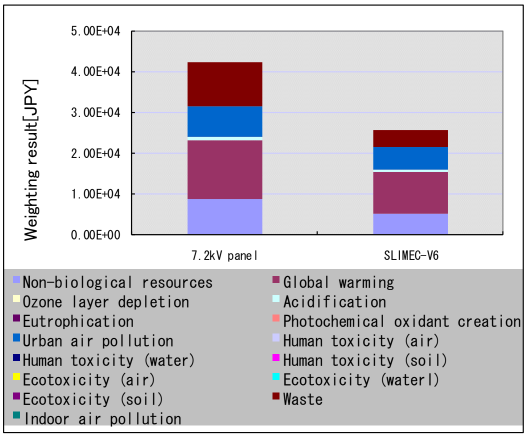

Figure 5.2-19 Weighting result (by impact category)

5.2.6 Weighting (control center)

The Weighting results (by substance, by process and by impact category) are shown in Figure 5.2-20 through Figure 5.2-22. The social cost is approximately 280,000 yen for the conventional product and 220,000 yen for the new product, indicating the reduction of about 20%.

The result by substance indicates that the consumption of silver and emissions of CO_2, general waste and SO_2 are the major causes of the environmental impacts of the products, and the consumption of silver for the new product has significantly affected the assessment result. The effect of environmental load reduction in the use stage achieved as the result of the improved energy efficiency of the new product has contributed considerably to the assessment result as shown in the Weighting result by process. In terms of the proportion of the impacts, however, the result indicates that the portions of the products' environmental impacts occurring in the use stage and raw material stage are almost the same. According to the Weighting result by impact category, the major impacts of the products are non-biological resource consumption, global warming, urban air pollution and waste, which are the same for the high voltage panel products.

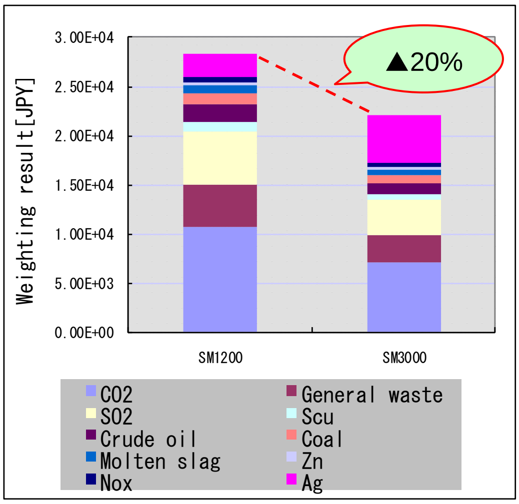

Figure 5.2-20 Weighting result (by substance)

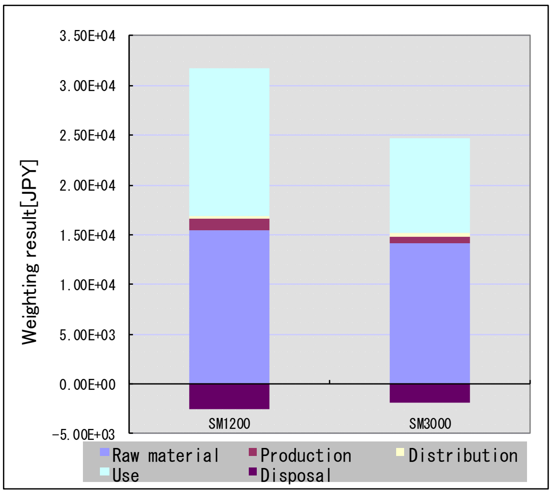

Figure 5.2-21 Weighting result (by process)

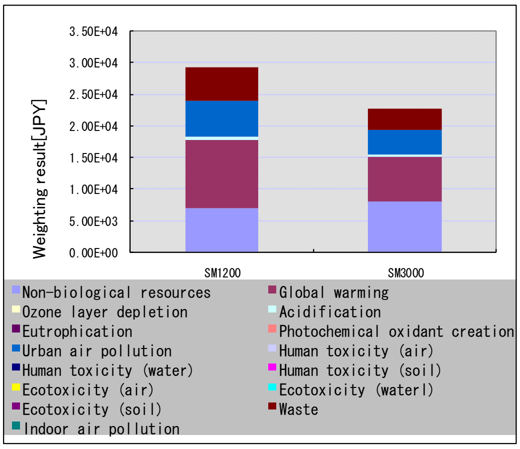

Figure 5.2-22 Weighting result (by impact category)

6. Conclusion

6.1 Summary of study result

In order to determine the effects of energy conservation and weight reduction on improving the environmental impacts of new products compared to conventional products for each of the two models of switchboards (high voltage panel and control center), the assessment was conducted on the environmental impacts of the products over their entire life cycle (raw material, production, transportation, use, and disposal/recycling) using the LIME2 method. The results of the assessment are presented in Table 6.1-1 and Table 6.1-2, which also include the assessment results on the CO_2 emissions of the products.

Table 6.1-1 Assessment result for high voltage panels

High voltage panel	CO_2 emissions (kg)	Social cost (10,000 yen)
7.2 kV panel	4,448	40.9
SLIMEC-V6	3,207	24.7
	-27.9%	-39.6%

Table 6.1-2 Assessment result for control centers

Control center	CO_2 emissions (kg)	Social cost (10,000 yen)
SM1200	3,334	28.3
SM3000	2,200	22.1
	-34.0%	-21.8%

These results verify the effect of improvements made to the new product on reducing the environmental load (social cost) for both switchboard models. The social cost reduction rates have resulted in different values from the CO_2 emissions reduction rates.

Although we had assumed that the largest portion of the products' environmental impacts would be associated with the use stage given that switchboards are generally operated continuously and have long life spans of over 15 years (the use stage is responsible for 70-80% of the CO_2 emissions for both switchboard models according to CO_2 emission assessment results), the Weighting result by process confirmed that almost as much impact occurs in the raw material stage as in the use stage. This indicates that the reduction of product size and weight has the same degree of importance as the improvement of energy efficiency in order to reduce the environmental load of switchboards.

It has also become evident from the Weighting rtesult by substance that the consumption of rare metals such as gold and silver constitutes a large impact. Therefore, limiting the use of rare metals would be effective for reducing the environmental load of switchboards, and collection and recycling following the use of products should also be considered in the future.

6.2 Limitations and future challenges

Because switchboards are build-to-order products with a broad variety of models, the data on the specific models covered in this assessment do not universally apply to all switchboard products. The improvement of the completeness of the assessment scope as well as sensibility analyses based on different calculation conditions, particularly under different use conditions, are priority issues for future assessments.

References

1) Japan Electrical Manufacturers' Association (2000/12): Study report on the present status, trend and future challenges for the recycling of power reception and distribution equipment
2) Paper Recycling Promotion Center (http://www.prpc.or.jp/): Trend in waste paper recovery rate, trend in recovered paper utilization rate
3) Japan Environmental Management Association for Industry: http://202.214.40.151/JEMAI_DYNAMIC/index.cfm
4) Ecoleaf environmental label: http://202.214.40.151/ecoleaf/index.cfm
5) http://jemai-live.ashleyassociates.co.jp/ecoleaf/prodbycmp_companyobj61.cfm

Report on
Environmental Impacts Before and After Installation of a Document Digitization Solution

May 2008

Fujitsu Laboratories Limited

1. General Information

1.1 Assessor

Organization: Environmental Technology Lab. Fujitsu Laboratories Ltd.
Name: Shigeharu Suzuki
Contact: shige@labs.fujitsu.com

1.2 Report preparation date

May 30, 2008

2. Purpose of Study

2.1 Basis of study

Assessment of the environmental impact and understanding of the environmental efficiency of an information-and-communication technology (ICT) solution for digitizing documents (the "document digitizing solution" hereinafter.)

2.2 Application of study result

The study result will be used to understand how the environmental efficiency changes after installation of the solution and also to provide to document digitization solution users quantitative information on the environmental improvement effect of the solution.

3. Scope of Study

3.1 Subject of study and its specifications

A document digitization solution is a solution that digitizes office work instruction manuals or various types of regulatory documents for the purpose of introducing paper-less operation and improving document update efficiency (Figure 3.1-1).
Differences between before and after the document digitization solution are as follows (Figure 3.1-2):

Issues in conventional document creation: traditionally, distribution of printed materials had the following issues: ① it took a long time to distribute or publish printed materials, ② operational and distribution costs were high, and ③ documents could not be revised fast enough to keep up with changes.

How the abovementioned issues were solved with a document digitization solution: use of XML-based technologies allowed creation of a system that: a) required a low operational cost, b) could use existing document assets, and c) could promptly respond to the need for document revision.

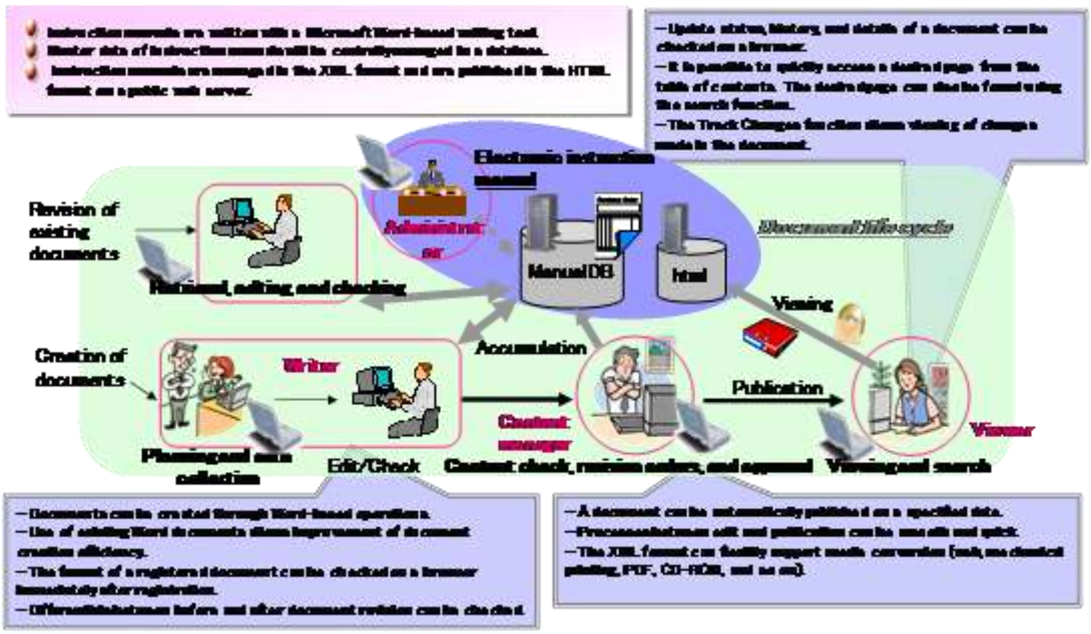

Figure 3.1-1 Overview of a document digitization solution

Issues in conventional document creation

Before the solution installation, conventional tasks involving distribution of printed materials had the following issues:

・It took a long time to distribute or publish printed materials

Because documents were bound and then published, proofreading and printing were necessary. Documents may need to be corrected during proofreading. In this case, interactions with a printing company tended to be complicated, requiring even more time before publication.

・Operational and distribution costs were high

When shipment of bound documents was outsourced to a transportation company, the transportation cost rose as the number of areas or volume of shipment increased. If documents were not printed on-demand, printed material stock and storage space had to be properly managed.

・Documents could not be revised fast enough to keep up with changes

Instruction Manuals or regulatory documents created by a company must be frequently revised as there are product changes, annual reorganizations, and changes in business processes. There were cases where revision of documents could not be completed by the date when revised information must be communicated to document users.

Solution by a document digitization solution

Use of XML-based technologies allowed creation of a system that realized:

a) Low operational cost

By installing a function that allows a document creator to convert a Word document into the XML and then HTML formats, the operational cost can be reduced. Also, by implementing a document control work flow that does not require interactions with a printing company, it is possible that paper-based document-specific costs (artwork creation, binding, and shipment) can be reduced.

b) Effective use of existing document assets

A document digitization solution supports existing document assets. By importing existing Word documents or text documents using a Word-based document creation tool, it is possible to greatly reduce loads of initial digitization tasks.

c) Prompt response to the need for document revision.

A document digitization can quickly respond to the need for document revision. This can be achieved by installing a function that allows correction of a document in units of chapter or section or a function that allows comparison of old and new versions in which the document structure is standardized in the XML format and the features of XML such as tag-based document operation are effectively used.

Figure 3.1-2 Characteristics of a document digitization solution

3.2 Functions and functional unit

The functional unit is the updating of 1,300 types of instruction manuals to be handled in a year when distributing them to 1,500 divisions.

3.3 System boundary

Product use, collection, and disposal stages are included in the system boundary (Figure 3.3-1).

<Assessment condition>

Before installation: Artwork creation, proofreading, and binding were outsourced to a printing company. Printed materials were stored in distribution warehouses and delivered when requested.

After installation: Writers publish their writings on the Internet by themselves without using a printing company. Because documents are available on the Internet, shipment from distribution warehouses has been dramatically reduced.

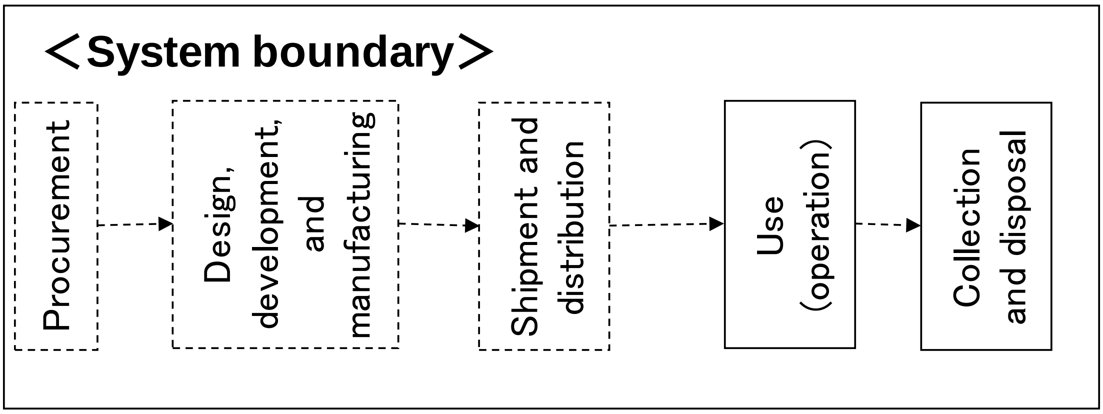

Figure 3.3-1 System boundary of installation of a document digitization solution

3.4 Special note (processes or items exempted from assessment, etc.)

The solution procurement, design, development, manufacturing, shipment, and distribution stages were excluded from the study.

In the assessment, the environmental impact was divided into factors[1) 2)] such as resource consumption, movement of people or objects, efficiency improvement, storage space, and ICT device power consumption.

4. Inventory Analysis

4.1 Foreground data

We interviewed our solution users and obtained measurement data they collected during solution operation.

4.2 Background data

For the product use stage, we referred to the in-house database created based on the 2000 inter-industry relations table, and for paper incineration in the collection and disposal stage, we used EcoLeaf data.

4.3 Inventory analysis item and result table

Tables 4.3-1 and 4.3-2 show the subjects of pre- and post-installation inventory analysis and analysis results.

Table 4.3-1 Result of LCI analysis before installation of the subject document digitization solution

Inventry analyses			Item	unit	Production: Raw material	Production: Product	Distribution	Use	Disposal
Impact by resource consumption	Exhaoustible resources	Energy resources	Coal	kg				7.65E+05	5.80E−01
			Crude oil (for fuel)	kg				6.63E+05	6.99E−01
			LNG	kg				2.06E+05	2.90E−01
			U content of an ore	kg					3.92E−05
		Mineral resources	Crude oil (for material)	kg					0
			Fe content of an ore	kg				1.17E+05	0.00E+00
			Cu content of an ore	kg					0.00E+00
			Al content of an ore	kg					0.00E+00
			Ni content of an ore	kg					0.00E+00
			Cr content of an ore	kg					0.00E+00
			Mn content of an ore	kg					0.00E+00
			Pb content of an ore	kg					0.00E+00
			Sn content of an ore	kg					0.00E+00
			Zn content of an ore	kg					0.00E+00
			Au content of an ore	kg					0.00E+00
			Ag content of an ore	kg					0.00E+00
			Silica sand	kg					0.00E+00
			Halite	kg	–	–	–		0.00E+00
			Limestone	kg					9.45E−01
			soda ash	kg	–	–	–		0.00E+00
	Renewable resources		wood	kg	–	–	–		0.00E+00
			water	kg	–	–	–		5.00E+02
Emission to the environment	To air		CO2	kg				5.53E+06	5.05E+00
			SOx	kg				7.27E+03	5.14E−02
			NOx	kg				1.04E+04	9.67E−02
			N2O	kg					8.11E−05
			CH4	kg					1.05E−04
			CO	kg	–	–	–		1.41E−02
			NMVOC	kg					2.05E−04
			CxHy	kg	–	–	–		3.07E−05
			dust	kg					5.13E−03
	To water		BOD	kg	–	–	–	3.27E+05	0.00E+00
			COD	kg				2.83E+05	0.00E+00
			N total	kg				2.20E+03	0.00E+00
			P total	kg				2.25E+04	0.00E+00
			SS	kg	–	–	–	2.25E+05	
	To soil		Unspecified solid waste	kg					1.70E−03
			Slag	kg					0.00E+00
			Sludge	kg					0.00E+00
			Low level radio−active was	kg	–	–	–	–	2.74E−05

Table 4.3-2 Result of LCI analysis after installation of the subject document digitization solution

					unit	Production		Distribution	Use	Disposal
						Raw material	Product			
Inventry analyses	Impact by resource consumption	Exhaoustible resources	Energy resources	Coal	kg				2.61E+05	2.90E-01
				Crude oil (for fuel)	kg				2.12E+05	3.50E-01
				LNG	kg				7.17E+04	1.45E-01
				U content of an ore	kg					1.96E-05
			Mineral resources	Crude oil (for material)	kg					0
				Fe content of an ore	kg				3.90E+04	0.00E+00
				Cu content of an ore	kg					0.00E+00
				Al content of an ore	kg					0.00E+00
				Ni content of an ore	kg					0.00E+00
				Cr content of an ore	kg					0.00E+00
				Mn content of an ore	kg					0.00E+00
				Pb content of an ore	kg					0.00E+00
				Sn content of an ore	kg					0.00E+00
				Zn content of an ore	kg					0.00E+00
				Au content of an ore	kg					0.00E+00
				Ag content of an ore	kg					0.00E+00
				Silica sand	kg					0.00E+00
				Halite	kg	–	–	–		0.00E+00
				Limestone	kg					4.72E-01
				soda ash	kg	–	–	–		0.00E+00
		Renewable resources		wood	kg	–	–	–		0.00E+00
				water	kg	–	–	–		2.50E+02
	Emission to the environment	To air		CO2	kg				1.85E+06	2.53E+00
				SOx	kg				2.42E+03	2.57E-02
				NOx	kg				3.34E+03	4.84E-02
				N2O	kg					4.05E-05
				CH4	kg					5.25E-05
				CO	kg	–	–	–		7.03E-03
				NMVOC	kg					1.03E-04
				CxHy	kg	–	–	–		1.53E-05
				dust	kg					2.57E-03
		To water		BOD	kg	–	–	–	1.09E+05	0.00E+00
				COD	kg				9.46E+04	0.00E+00
				N total	kg				7.37E+02	0.00E+00
				P total	kg				7.53E+03	0.00E+00
				SS	kg	–	–	–	7.54E+04	
		To soil		Unspecified solid waste	kg					8.52E-04
				Slag	kg					0.00E+00
				Sludge	kg					0.00E+00
				Low level radio-active was	kg	–	–	–	–	1.37E-05

5. Impact Assessment

5.1 LCIA steps and impact categories used in assessment

The impact assessment was conducted using the Japanese-design "Life Cycle Impact Assessment Method based on Endpoint Modeling" (LIME2) through its three steps consisting of characterization, damage assessment and weighting. The impact categories covered in each step of the assessment are listed in Table 5.1-1.

Table 5.1-1 LCIA steps and environmental impact categories used in assessment

	Charactarization	Damage assessment	Weighting
Resource consumption (energy)	○	○	○
Resource consumption (mineral)	○	○	○
Global warming	○	○	○
Urban air pollution	–	○	○
Ozone layer depletion			
Acidification	○	○	○
Eutrophication	○	○	○
Photochemical oxidant creation			
Waste			
Human toxicity			
Ecotoxicity			
Indoor air quality	–		
Land use	※	※	※

※ : No factors in LIME calculation sheet

— : No factors in LIME

5.2 Result of impact assessment

5.2.1 Characterization

Figures from 5.2-1 through 5.2-4 show the results of characterization of energy resource consumption, mineral resource consumption, acidification, and eutrophication before and after installation of the document digitization solution.

For all of the above, the environmental impacts were lower after the installation, and this seems to be attributed to reduction of paper consumption, reduction of people/object movement due to website viewing, and reduction of energy consumption due to improvement of efficiency as a result of installation of the solution.

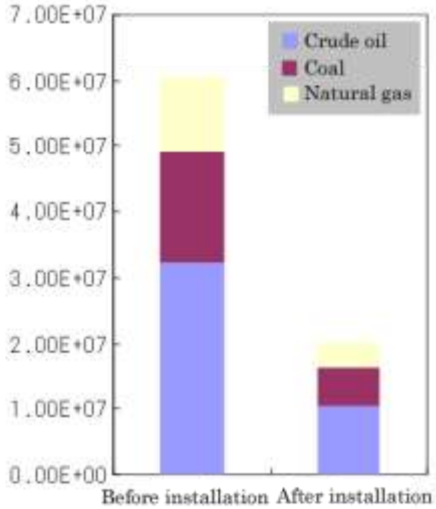

Figure 5.2-1 Characterization result (energy resource consumption)

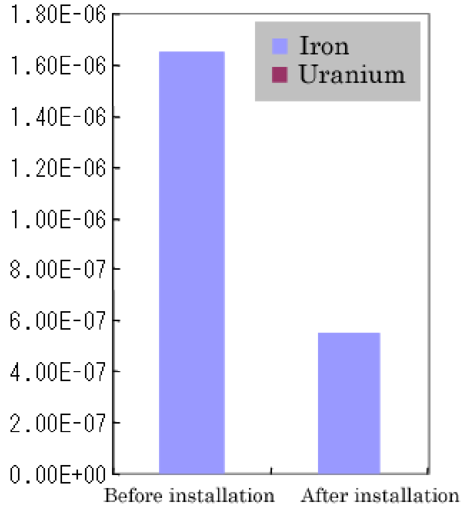

Figure 5.2-2 Characterization result (mineral resource consumption)

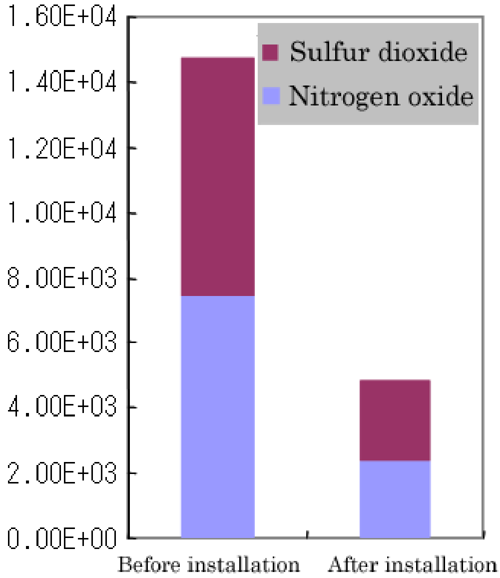

Figure 5.2-3 Characterization result (acidification)

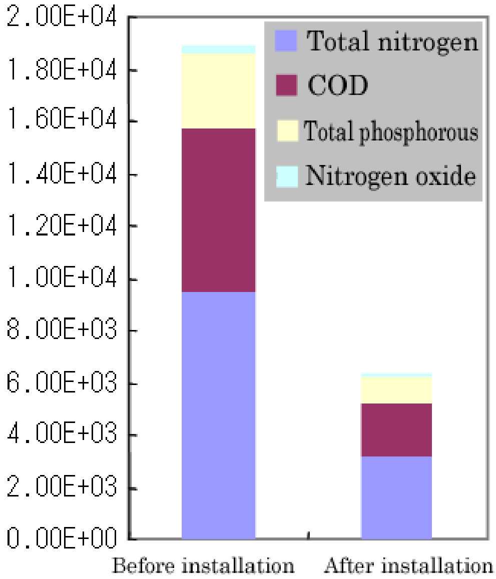

Figure 5.2-4 Characterization result (eutrophication)

5.2.2 Damage assessment

Figures 5.2-5 through 5.2-8 show the results of damage assessment (by substance) for four areas of protection.

The four areas of protection are human health, social assets, primary production, and ecodiversity, and for all of them, damage was dramatically reduced after installation of the solution. In human health, installation of the solution resulted in dramatic reduction of damage caused by CO_2 and SOx, and in social assets, damage of crude oil, total phosphorous, and total nitrogen was halved. This seems to be attributed to reduction of paper consumption, reduction of people/object movement due to website viewing, and reduction of energy consumption due to improvement of efficiency. In primary production and ecodiversity, there was reduction in coal consumption after installation of the solution perhaps due to reduction of paper consumption and improvement of efficiency.

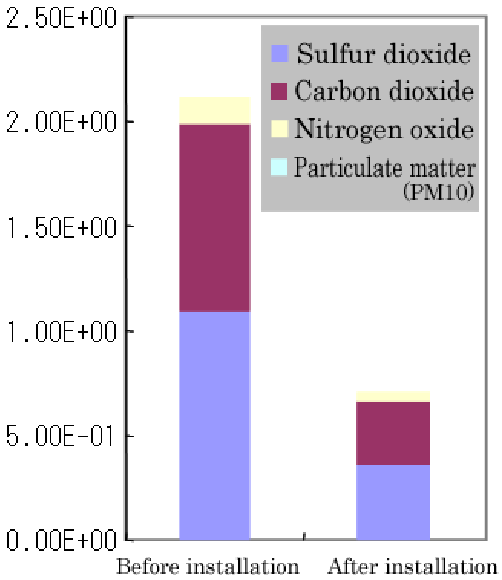

Figure 5.2-5 Damage assessment result (human health)

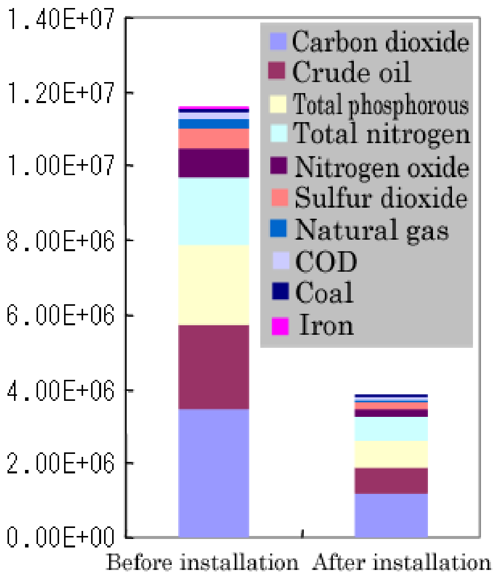

Figure 5.2-6 Damage assessment result (social assets)

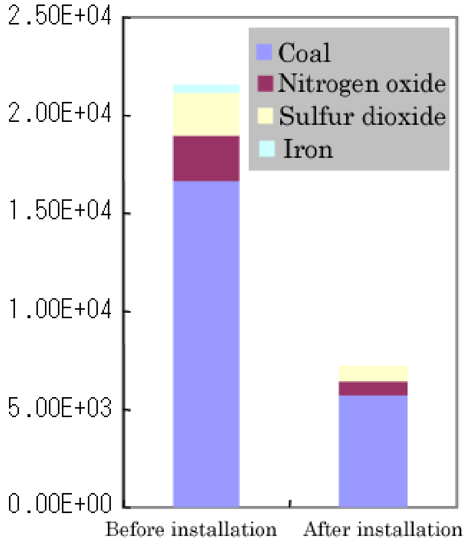

Figure 5.2-7 Damage assessment result (primary production)

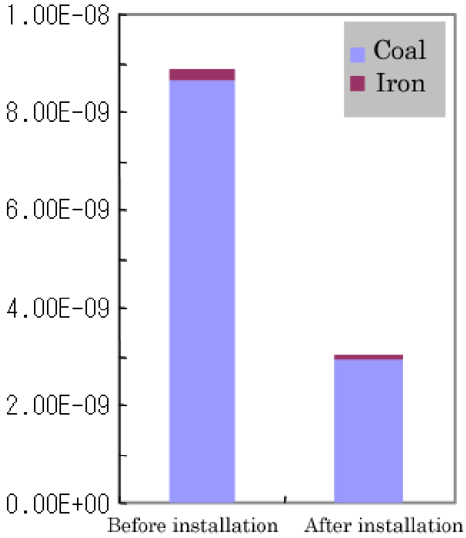

Figure 5.2-8 Damage assessment result (biodiversity)

5.2.3 Weighting

Figure 5.2-9 shows the weighting result (by substance) for before and after installation of the document digitization solution. Because the environmental impact of CO_2 and SOx emissions accounted for approximately 70% of the entire impact both before and after the installation, reduction thereof through reduction of paper consumption and energy consumption by improving efficiency as a result of solution installation contributed to reduction of the entire environmental impact.

Figure 5.2-10 shows the breakdown by area of influence. Both before and after installation, the environmental impact was high in the areas of global warming and urban air pollution. The dramatic reduction of the environmental impact in these areas can be attributed to the global warming or pollution suppression effect supported by the reduction of paper consumption and energy consumption.

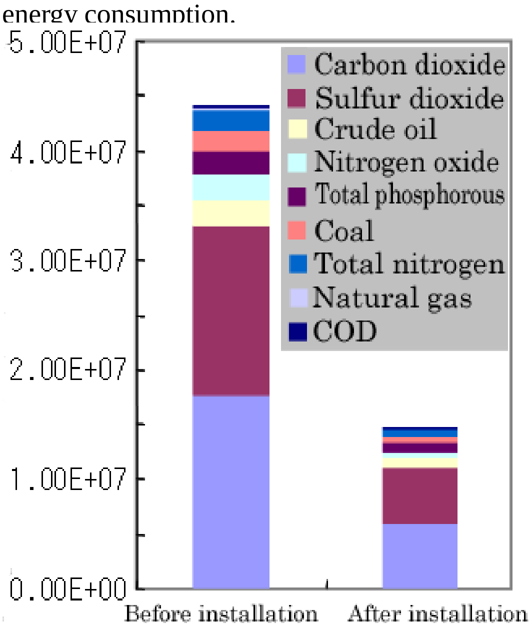

Figure 5.2-9 weighting result (by substance)

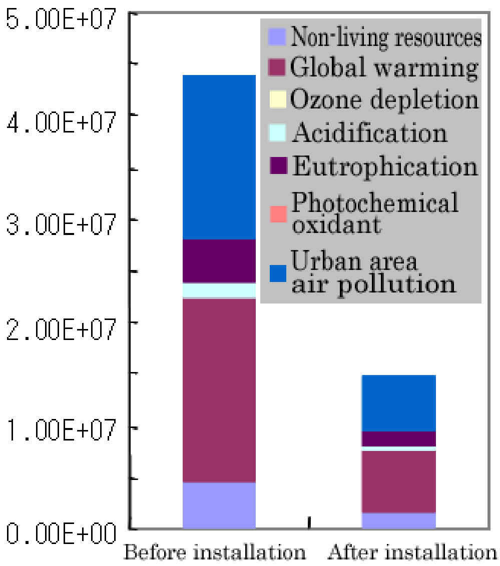

Figure 5.2-10 weighting result (by area of influence)

6. Conclusion

6.1 Summary of study result

The environmental effect of updating 1,300 types of instruction manuals, which is the amount being handled in a year, and distributing them to 1,500 divisions was assessed for the document digitization solution users. The study showed that the environmental impact dramatically decreased after installation of the solution. This seems to be attributed to reduction of paper consumption, reduction of people/object movement due to website viewing, and reduction of energy consumption due to improvement of efficiency.

Characterization results showed that reduction of paper consumption, reduction of people/object movement due to website viewing, reduction of energy consumption due to improved efficiency (crude oil and coal), and CO_2 and SOx emissions were the major determinants of the level of environmental impact.

The damage assessment showed that, both before and after the installation, human health was affected by the reductions of CO_2 and SOx emissions that influenced global warming and urban air pollution, and public assets such as the consumption of non-living resources, global warming, and eutrophication are reduced with a reduction in CO_2 and crude oil consumption. By reducing the consumption of coal which is a product of primary production and biodiversity, its influence is made obvious that it is the main cause of the reduction in the consumption of non-living resources.

The weighting results showed that, both before and after the installation, reduction of CO_2 and SOx emission was the key to reduction of global warming and urban air pollution, meaning that reduction of paper consumption and energy consumption would have a global warming or pollution suppression effect.

6.2 Limitations and future challenges

This assessment was conducted to understand how the environmental efficiency changed after installation of the solution and also to provide to document digitization solution users quantitative information on the environmental improvement effect of the solution. For this reason, the assessment was conducted for the stages from the product use to the collection and disposal stages.

Generally speaking, the product use stage has the largest environmental impact within the entire life cycle of a solution (procurement, design and development, manufacturing and shipment, distribution, use, and collection and disposal), and the assessment in this study seems to mostly agree with this tendency.

Strictly speaking, however, it is necessary to examine how to define and prorate man-hours required for software design, development, and manufacturing, as well as collection, disposal, and recycling. Also, while paper incineration and power consumption caused by the use of ICT devices such as PCs were included as the subject of assessment, there was no study on chemical substances contained in materials because the assessment did not include device materials or manufacturing processes as the subjects of the assessment. These elements should have a great influence on assessment results when it focuses on device materials or manufacturing processes. For this reason, this assessment may not have included all the items that would have been required as study subjects. It is thus necessary to carefully interpret the study results depending on the assessment purpose.

References

1) Yasunari Matsuno, et al (ed.): Assessing IT Society from the Environment Point of View, Japan Environmental Management Association for Industry, 2007.
2) Shigeharu Suzuki, et al: LIME-based Environmental Load Assessment of an ICT Solution, Abstract of the 16th Annual Meeting of the Japan Institute of Energy, pp. 382-383

Report on "Environmental Impact Study of LCD Projector"

May 2008

Hitachi, Ltd.

1 General Information

1.1 Assessor

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1.2 Report preparation date

May 19, 2008

2 Purpose of Study

2.1 Basis of study

Assess the environmental impact of a liquid crystal projector (LCD projector) throughout its life cycle with the use of LCA, and analyze the future approaches to be taken in the environmentally conscious designing.

2.2 Application of study result

Analyze the environmental impact of household electrical appliances other than global warming, using an LCD projector as a case example.

3 Scope of Study

3.1 Subject of study and its specifications

The appearance of a high-definition capable LCD projector PJ-TX200J [1], which is used as the subject of this study, and the overview of its specifications are as shown below.

Figure 3.1-1 LCD projector

Table 3.1-2　LCD projector specification overview

Model	PJ-TX200J
Projection system	Transmissive 3LCD shutter projection system
Panel resolution	921,600 pixels (1,280 V × 720 H)
Maximal brightness	1200 lm
Contrast ratio	7000:1
Power supply	100V AC (50/60 Hz)
Power consumption	220 W
Dimensions	340 (W) x 113 (H) × 299 (D) mm
Weight	Product: 4.7 kg, Package and other: 2.2 kg

The main environmentally-conscious feature of this LCD projector is that lead-free solder is used for the assembly of its printed circuit board. Other features include the use of non-halogen resin in its exterior parts, and the mechanical parts that are manufactured completely polyvinyl chloride-free. The use of foam polystyrene as a packaging material has also been discontinued, replaced by pulp-mold made from used paper. This indicates that consideration for the environment is incorporated not only into the product itself but also into its packaging materials.

3.2 Functions and functional unit

The functional unit is specified as the entire life cycle of 1 (one) LCD projector, under the condition that the projector is used for 3.5 hours/day, during 100 days/year, for a total of 5 years, for the purpose of viewing digital high-definition images.

3.3 System boundary

The system boundary encompasses the processes including the raw material, assembly (production), transportation (distribution), use, and disposal stages (Figure 3.3-1).

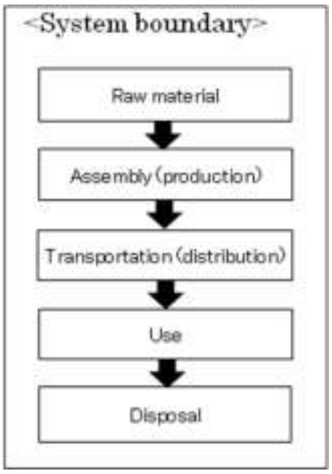

Figure 3.3-1　System boundary of LCD projector

3.4 Special notes (processes or items exempted from assessment, etc.)

The inventory was calculated using as the assessment criteria the Product-Specific Criteria for Data Projector (PSC-ID: AG-03) [2)] established by the Ecoleaf environmental labeling program of the Japan Environmental Management Association for Industry (JEMAI). The outline of the assessment criteria is described below.

- Transportation (distribution) stage:
  Transportation means is land transportation by truck; transportation distance is 500 km.
- Use stage:
  Use of this product by a customer for 3.5 hours/day, 100 days/year, for 5 years.
- Disposal stage:
  The product is disposed of as general waste after use.

Data on part of the assembly (production) processes that are outsourced or components manufactured externally, such as purchased parts, are not covered in this assessment.

4 Inventory Analysis

4.1 Foreground data

The assessment was conducted using the actual measurement data taken at the company plants.

4.2 Background data

Data provided in the Ecoleaf program were used for the inventory analysis.

4.3 Inventory analysis item and result table

Table 4.3-1 presents the list of items covered in the inventory (LCI: Life Cycle Inventory) analysis of the LCD projector and the result of the analysis. This analysis result contains some data extracted from within published information of the aforementioned Ecoleaf program [3)] that were necessary for this analysis.

Table 4.3-1　Result of LCI analysis of the LCD projector (unit: kg)

[Unit: kg/kWh]

In/Out items \ Life Cycle Stage					Unit	Production		Distribution	Use	Disposal
						Raw material	Product			
Energy Consumption					MJ	1.09E+03	2.07E+02	1.45E+01	3.63E+03	7.20E+00
					Mcal	2.60E+02	4.95E+01	3.47E+00	8.66E+02	1.72E+00
Inventory analyses	Resource consumption from the environment	Exhaustible resources	Energy and resources	Coal	kg	7.74E+00	1.30E+00	3.40E-05	2.06E+01	5.00E-02
				Crude oil (for fuel)	kg	1.18E+01	1.48E+00	3.17E-01	2.33E+01	6.44E-02
				LNG	kg	2.26E+00	6.50E-01	4.90E-03	1.03E+01	2.54E-02
				U content of an ore	kg	2.47E-04	8.79E-05	2.30E-09	1.40E-03	3.38E-06
			Mineral material	Crude oil (for material)	kg	2.26E+00	0	0	0	0
				Fe content of an ore	kg	8.52E-01	0	0	0	0
				Cu content of an ore	kg	1.97E-01	0	0	0	0
				Al content of an ore	kg	4.01E-01	0	0	0	0
				Ni content of an ore	kg	2.75E-02	0	0	0	0
				Cr content of an ore	kg	3.74E-02	0	0	0	0
				Mn content of an ore	kg	1.34E-02	0	0	0	0
				Pb content of an ore	kg	1.29E-02	0	0	0	0
				Sn content of an ore	kg	0	0	0	0	0
				Zn content of an ore	kg	1.27E-01	0	0	0	0
				Au content of an ore	kg	0	0	0	0	0
				Ag content of an ore	kg	0	0	0	0	0
				Silica Sand	kg	3.00E+00	0	0	0	0
				Halite	kg	2.79E+00	0	0	0	2.77E-03
				Limestone	kg	4.45E-01	0	0	0	6.71E-02
				Natural soda ash	kg	6.30E-02	0	0	0	0
		Renewable resources		wood	kg	5.64E+00	0	0	0	0
				water	kg	7.11E+03	9.84E+02	2.51E-02	1.56E+04	4.22E+01
	Emission/Discharge to the environment	To atmosphere		CO2	kg	6.33E+01	1.01E+01	1.02E+00	1.60E+02	7.17E+00
				SOx	kg	7.55E-02	7.70E-03	1.26E-03	1.22E-01	3.71E-03
				NOx	kg	9.19E-02	6.16E-03	1.59E-02	9.70E-02	6.92E-03
				N2O	kg	5.60E-03	1.11E-04	1.85E-05	1.75E-03	1.00E-05
				CH4	kg	6.47E-04	2.35E-04	6.15E-09	3.73E-03	9.06E+06
				CO	kg	1.48E-02	1.49E-03	6.27E-03	2.37E-02	1.01E-03
				NMVOC	kg	1.27E-03	4.60E-04	1.20E-08	7.32E-03	1.77E-05
				CxHy	kg	2.41E-03	2.41E-05	3.17E-04	3.82E-04	4.50E-06
				dust	kg	1.02E-02	3.30E-04	1.26E-03	5.24E-03	3.67E-04
		To water system		BOD	kg	—	—	—	—	—
				COD	kg	—	—	—	—	—
				N total	kg	—	—	—	—	—
				P total	kg	—	—	—	—	—
				SS	kg	—	—	—	—	—
		To soil system		Unspecified solid waste	kg	5.22E-01	0	0	0	3.47E+00
				Slag	kg	2.10E+00	0	0	0	0
				Sludge	kg	8.05E-01	0	0	0	0
				Low level radioactive waste	kg	1.74E-04	6.13E-05	1.61E-09	9.74E-04	2.36E-06

5　Impact Assessment

5.1　LCIA steps and impact categories used in assessment

The second version of the Japanese-design "Life Cycle Impact Assessment Method based on Endpoint Modeling" (LIME2) was used for this impact assessment, employing the method's three steps consisting of characterization, damage assessment and weighting. The impact categories covered in each step of the assessment are shown in Table 5.1-1.

Table 5.1-1 LCIA steps and environmental impact categories used in assessment

Environmental impact category \ LCIA steps	Characterization	Damage assessment	Weighting
Resource consumption (energy)	○	○	○
Resource consumption (ore)	○	○	○
Global warming	○	○	○
Urban air pollution	—	○	○
Ozone layer depletion	○	○	○
Acidification	○	○	○
Eutrophication	○	○	○
Photochemical oxidant	○	○	○
Waste	○	○	○
Human toxicity	○	○	○
Ecotoxicity	○	○	○
Indoor air quality	—	○	○
Noise	—	○	○
Land use	※	※	※

*: Not covered in the LIME calculation sheet

-: No coefficients by LIME

5.2 Result of impact assessment

5.2.1 Characterization

The characterization result of the environmental impact of the LCD projector is laid out in Figure 5.2-1 through 5.2-7. While Hitachi's environmentally conscious designing has been carried out mainly from the perspective of preventing global warming and depletion of resources, the use of LIME also enables other environmental categories such as eutrophication and photochemical oxidant creation to be studied. A noticeable aspect shown in this result is that nitrogen oxides have an impact on many of the categories overall. In Figure 5.2-2, larger environmental impacts in the category of mineral consumption are indicated in the order of zinc, copper and nickel. Meanwhile, by referring to the inventory volumes, it can be observed that the impact of nickel consumption is the greatest. The following section will provide the analysis of the degree of damage attributable to each impact category, which will then be used to determine areas that require concentrated effort.

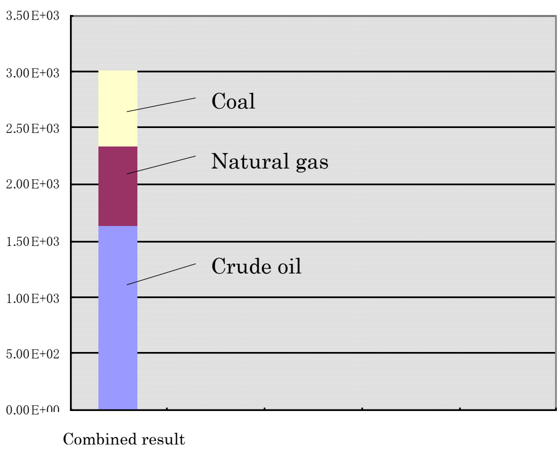

Figure 5.2-1 Characterization result (energy consumption)

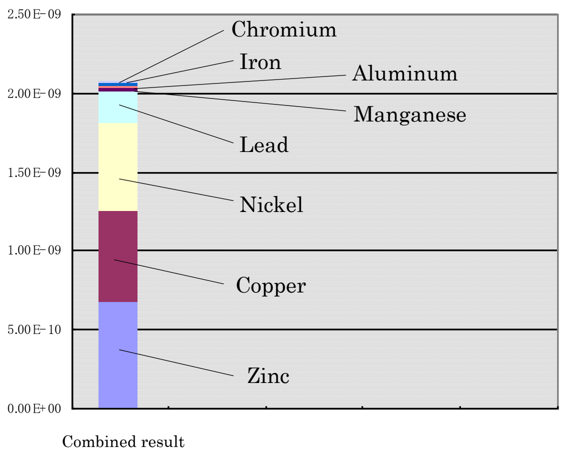

Figure 5.2-2 Characterization result (mineral consumption)

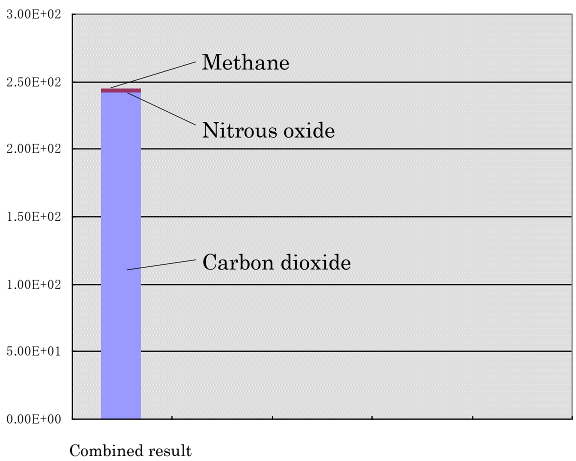

Figure 5.2-3 Characterization result (global warming)

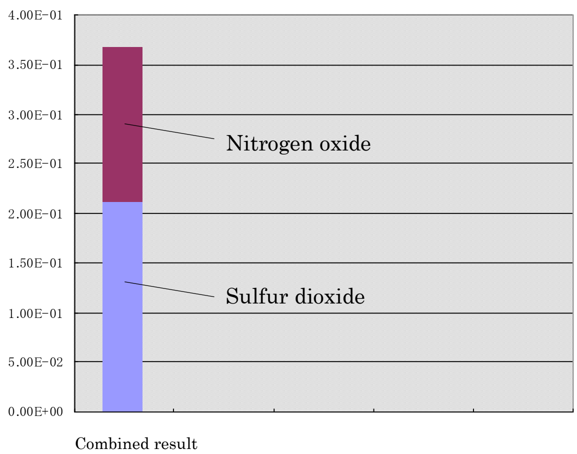

Figure 5.2-4 Characterization result (acidification)

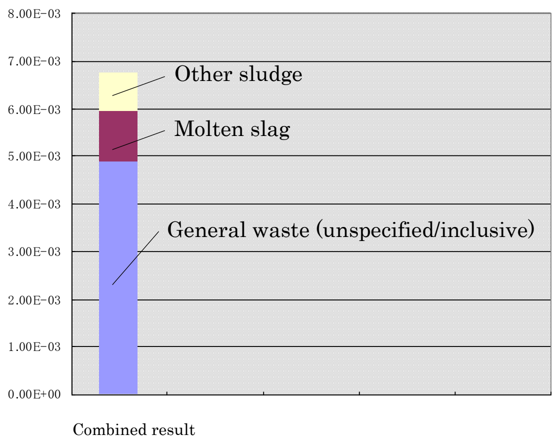

Figure 5.2-5 Characterization result (waste)

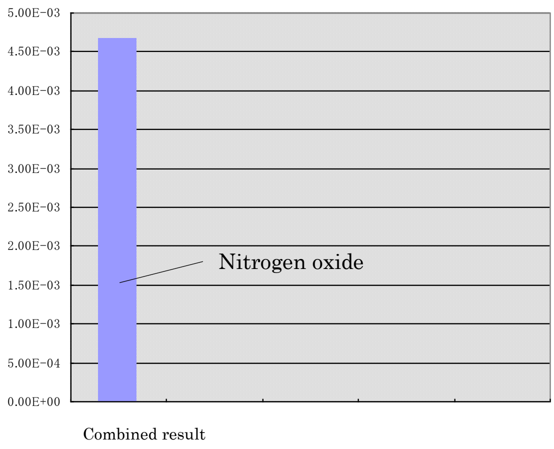

Figure 5.2-6 Characterization result (eutrophication)

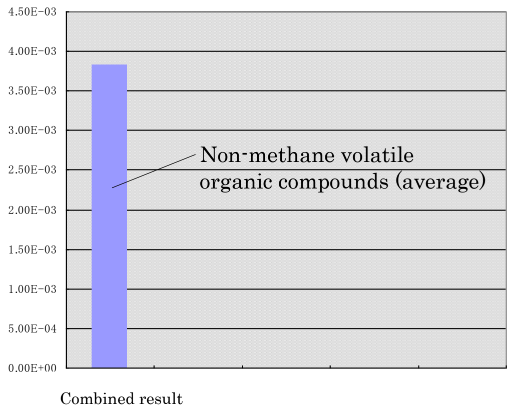

Figure 5.2-7 Characterization result (Photochemical oxidant creation)

5.2.2 Damage assessment

(1) Breakdown by substance

The result of damage assessment for four safeguard subjects is laid out in Figure 5.2-5 through 5.2-8 (breakdown by substance). The main cause of both the damage to human health indicated in Figure 5.2-5 and damage to social welfare in Figure 5.2-6 is carbon dioxide (hereinafter referred to as CO_2). Damage to primary production shown in Figure 5.2-7 is contributed largely by coal, and damage to biodiversity in Figure 5.2-8 is primarily as the result of general waste. The result also confirms that sulfur dioxide (hereinafter referred to as SO_2), nitrogen compound and general waste each have an impact on three safeguard subjects.

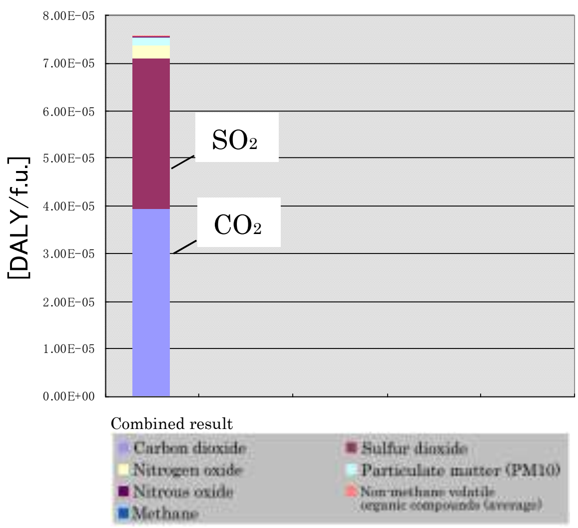

Figure 5.2-5 Damage to human health by substance

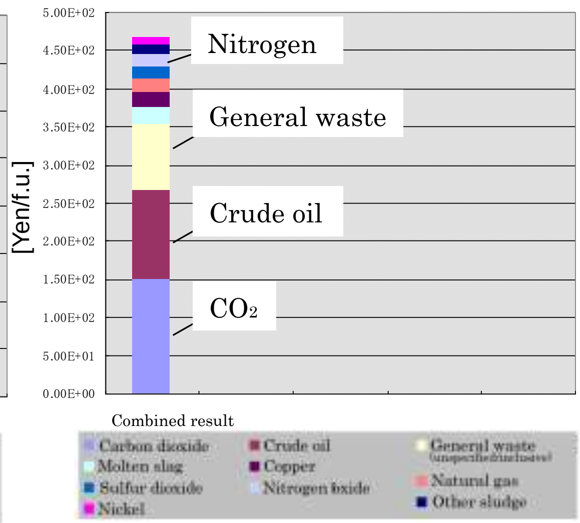

Figure 5.2-6 Damage to social welfare by substance

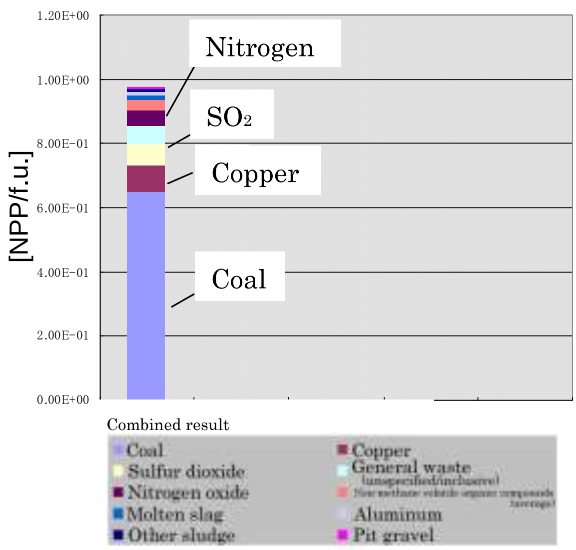

Figure 5.2-7 Damage to primary production by substance

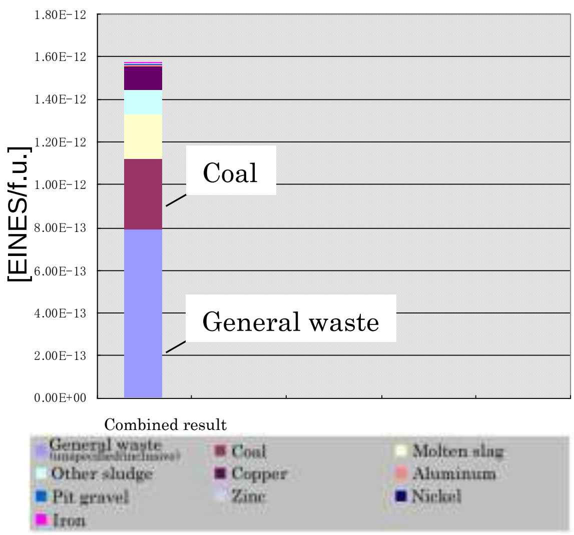

Figure 5.2-8 Damage to biodiversity by substance

(2) Breakdown by process

The breakdown of the result by process is laid out in Figure 5.2-9 through 5.2-12. The raw material stage consistently accounts for a large portion of the total impact for each of all safeguard subjects. The use stage has the greatest impact on human health, social welfare and primary production as shown in Figure 5.2-9 to 5.2-11, and the disposal stage is the dominant contributor to the damage to biodiversity as illustrated in Figure 5.2-12.

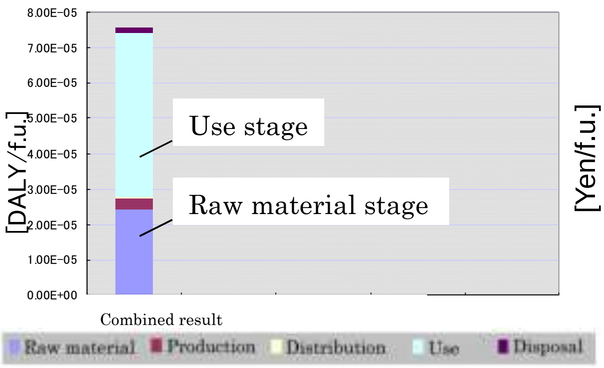

Figure 5.2-9 Damage to human health by process

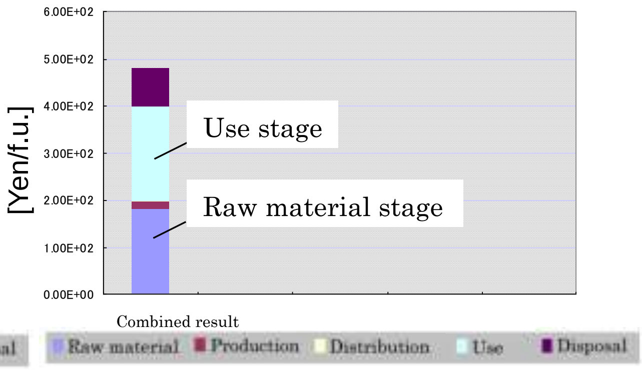

Figure 5.2-10 Damage to social welfare by process

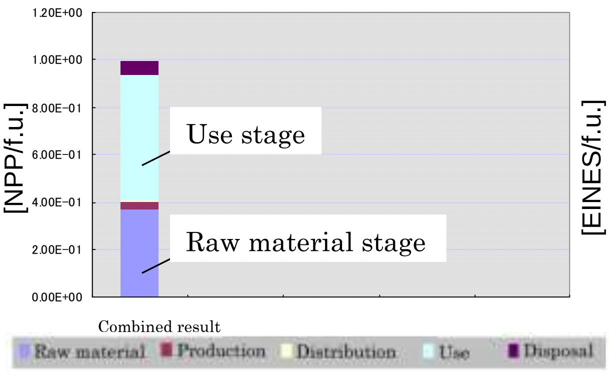

Figure 5.2-11 Damage to primary production by process

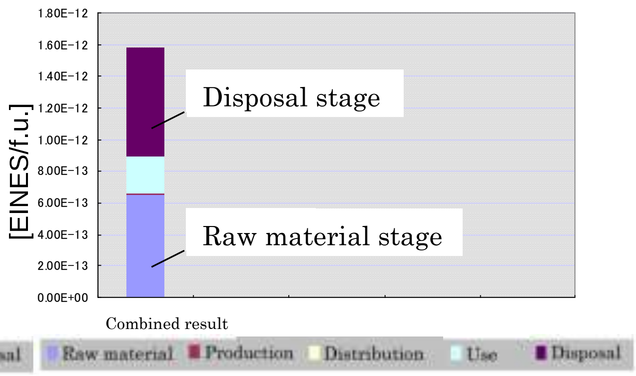

Figure 5.2-12 Damage to biodiversity by process

(3) Breakdown by impact category

The breakdown of the result by impact category is laid out in Figure 5.2-13 through 5.2-16. The impacts of eutrophication and photochemical oxidant creation observed in the characterization process in Section 5.2.1 are not found in this result except for primary production. It can therefore be assumed that these two categories have relatively small impacts at present. Safeguard subjects that are affected by environmental impacts other than global warming includes human health shown in Figure 5.2-13, which is also affected by urban air pollution, and primary production in Figure 5.2-15 on which non-biological resources have a significant impact. The result also indicates that the impacts of non-biological resources and waste are present on social welfare in Figure 5.2-14 and biodiversity in Figure 5.2-16.

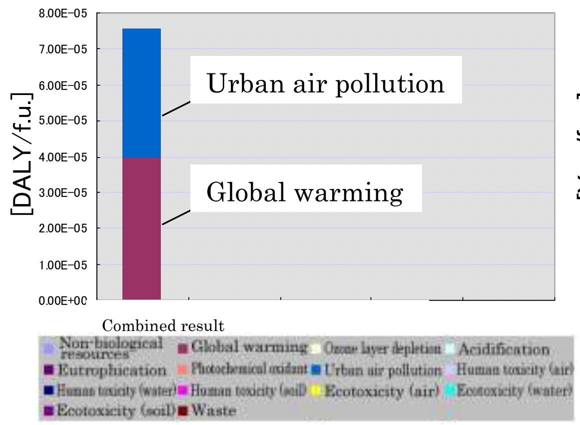

Figure 5.2-13 Damage to human health by impact category

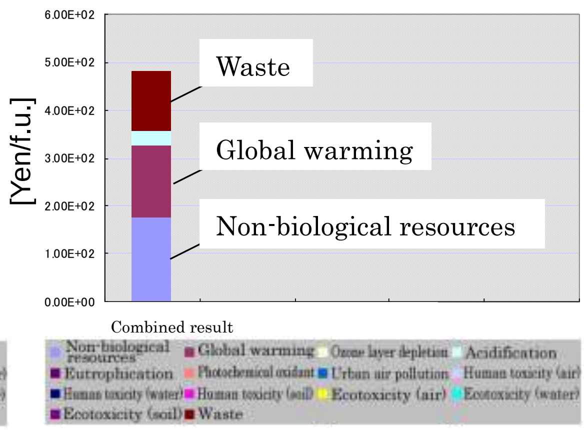

Figure 5.2-14 Damage to social welfare by impact category

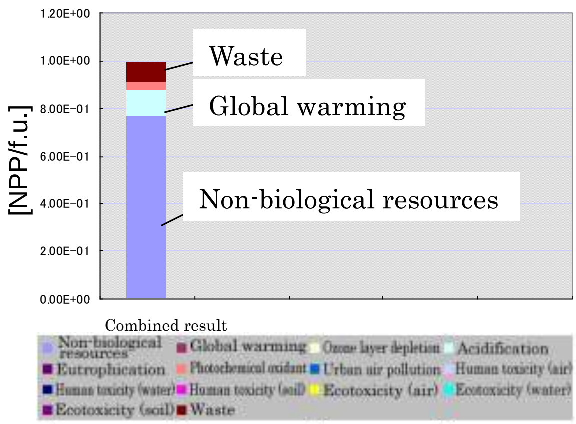

Figure 5.2-15 Damage to primary production by impact category

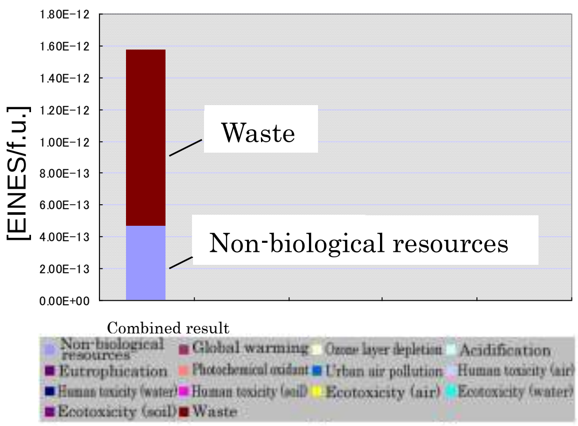

Figure 5.2-16 Damage to biodiversity by impact category

5.2.3 Weighting

The weighting result by substance is shown in Figure 5.2-17. In addition to CO_2, SO_2 and general waste that are all found to have impacts on most of the safeguard subjects as shown in Section 5.2.2 Damage assessment (1) Breakdown by substance, this weighting result indicates that crude oil constitutes a sizable impact while the impact of nitrogen oxide is relatively small.

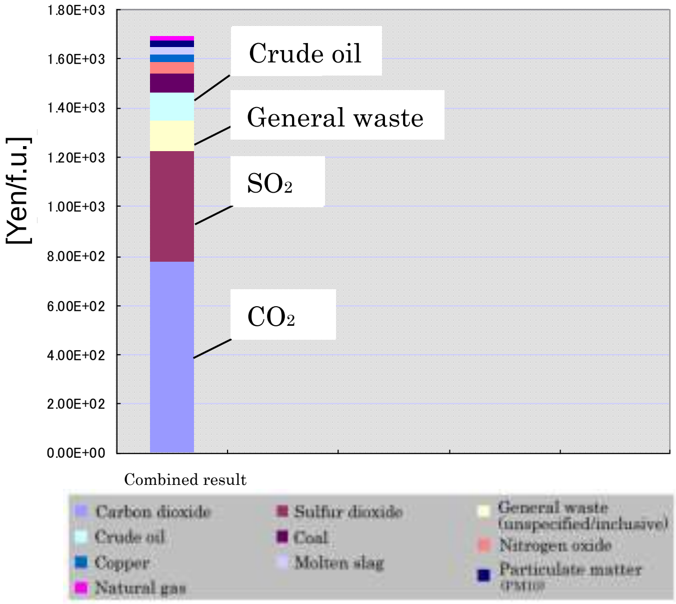

Figure 5.2-17 Weighting result by substance

Figure 5.2-18 represents the weighting result by process. The use and raw material stages, which are confirmed to have large environmental impacts in Section 5.2.2 Damage assessment (2) Breakdown by process, are also shown responsible for the majority of the total impact in this result.

Figure 5.2-19 shows the breakdown by impact category. In this weighting result, urban air pollution, which is found to have an impact only on human health in 5.2.2 Damage assessment (3) Breakdown by impact category, accounts for a larger impact than non-biological resources that shows a sizable impact on most of the safeguard subjects in the same damage assessment.

The result also suggests that environmental impacts of urban air pollution, non-biological resources and waste should also be taken into consideration in addition to global warming.

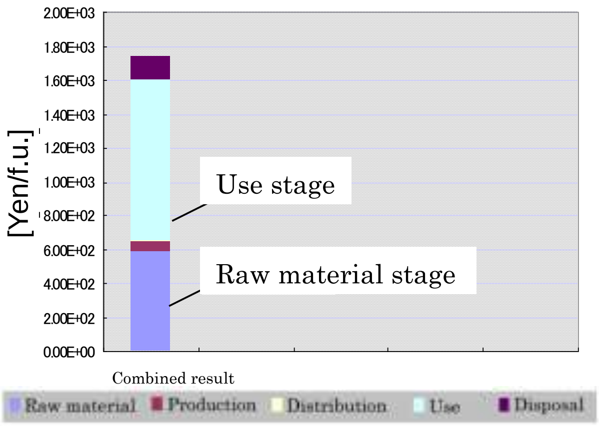

Figure 5.2-18 weighting result by process

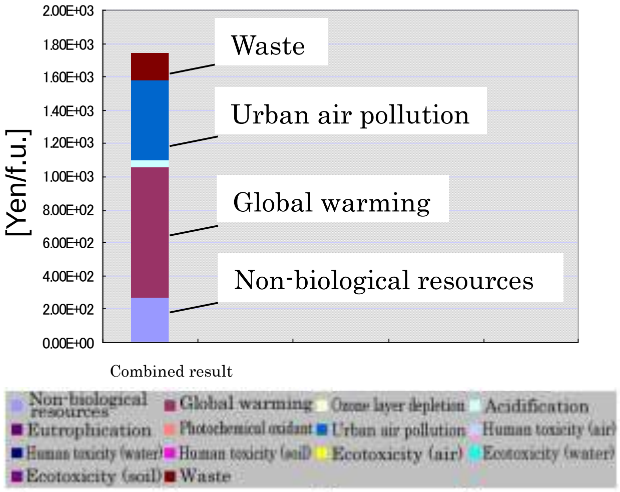

Figure 5.2-19 weighting result by impact category

6 Conclusion

6.1 Summary of study result

The assessment of the environmental impact of an LCD projector was conducted covering its entire life cycle from the raw material stage to the assembly (production), use (3.5 hours/day, 100 days/year, for 5 years), transportation (land transportation by truck; distance 500 km) and disposal (treated as general waste after use) stages.

According to the result, the environmental impacts associated with the LCD projector consist largely of those generated during the use and raw material stages. The assessment result by impact category has identified environmental impacts of urban air pollution, non-biological resources and waste in addition to global warming, and determined that the major causes of these impacts are the emissions of CO_2 and SO_2, general waste and the consumption of crude oil. By referring to the inventory, CO_2 and SO_2 emissions and crude oil consumption are assumed to be attributable to energy consumption. In light of the fact that there are no items found in this part of the assessment that are unique to an LCD projector, it can be assumed that the above result is common for household appliances of which the main environmental impact is electricity consumption.

Based on the above study result, the analysis for future approaches in environmentally conscious designing is summarized as follows. Considering that energy consumption is the main factor of the environmental impact of the LCD projector, promoting the further development of energy-saving technologies for the product is crucial in order to reduce its burdens to the environment. The environmental impact of the raw material stage is also significant and it is therefore important that improvements are made such as by selecting the types of raw materials that produce lower environmental burdens, and reducing the amount of raw materials used in the product by adopting a lightweight design. In addition to the reduction of raw material use, the promotion of recycling is also deemed important for the purpose of reducing waste generation.

6.2 Limitations and future challenges

This assessment has contributed toward identifying several other environmental impacts than global warming. However, the result is based on the conditions specified by the PSC, and the environmental impacts confirmed in the assessment may vary under different assessment conditions. For example, this assessment was conducted on the assumption that the product is treated as general waste in the disposal stage. The environmental impacts should also be studied considering different conditions, such as when the product is recycled instead of disposed of entirely as waste.

References

1) WOOO World LCD Projector, Hitachi, Ltd.
http://av.hitachi.co.jp/homeproj/index.html
2) Product-Specific Criteria for Data Projector (PSC ID: AG-03), Japan Environmental Management Association for Industry
http://www.jemai.or.jp/JEMAI_DYNAMIC/data/current/groupobj-451-pdf.pdf
3) Ecoleaf environmental label registration No. AG-06-024, Japan Environmental Management Association for Industry
http://www.jemai.or.jp/JEMAI_DYNAMIC/data/current/prodobj-928-pdf.pdf

Report on "Environmental Impact Assessment of Household Air Conditioner"

June 2008

1. General Information

1.1 Assessor

Organization: System Engineering Laboratory, Corporate Research & Development Center, Toshiba Corporation
Name: Yoshiyuki Hondo
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1.2 Report preparation date

June 14, 2008

2. Purpose of Study

2.1 Basis of study

Assess the subject product provided with energy-saving features (released in 2006) and the benchmark product (released in 2000) using LIME2 (Japanese-design Life Cycle Impact Assessment Method based on Endpoint Modeling), and confirm the reduced environmental impacts of the subject product.

2.2 Application of study result

Toshiba has developed its own environmental efficiency indicator named "Factor T" [1) 2)], which is calculated incorporating an environmental impact assessment using LIME1. Taking into account the result of this study, the updating of the assessment method to LIME2 will be considered.

3. Scope of Study

3.1 Subject of study and its specifications

The study looks at two household air conditioner models that are manufactured, used and disposed of within Japan. The benchmark product model is a household air conditioner RAS-406YDR, and the subject product model is a household air conditioner "Daiseikai SDR Series" RAS-402SDR.

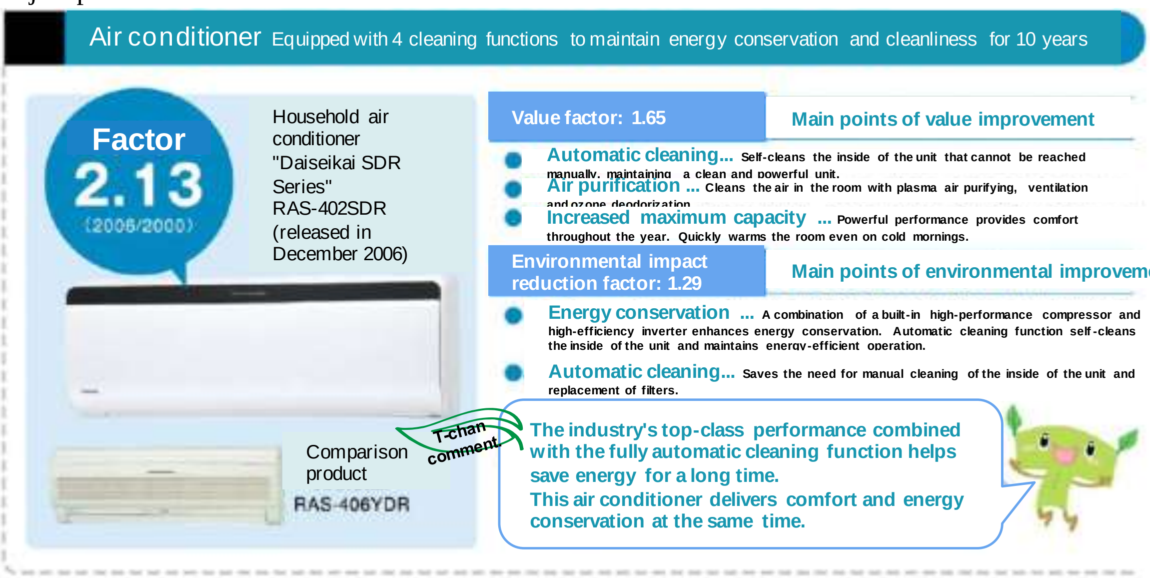


Figure 3.1-1 Subject of study

3.2 Functions and functional unit

As the functional unit, the assessment uses the assumption that one household air conditioner is used in a household for the duration of 10 years. The use conditions in the use stage are set according to the calculation conditions for annual performance factor (APF) (the Japan Refrigeration and Air Conditioning Industry Association standard (JRA 4046: calculation conditions for period power consumption of room air conditioner)) (Table 3.2-1).

Table 3.2-1 Use conditions applied to this assessment

Item	Conditions
Outside air temperature	Apply Tokyo model
Indoor temperature setting	27°C for air conditioning, 20°C for heating
Period	Air conditioning for 3.6 months (June 2 - September 21)
	Heating for 5.5 months (October 28 - April 14)
Time of use	18 hours from 6:00 to 24:00
Building type	Average wooden house

3.3 System boundary

The assessment covers the raw material, assembly (production), transportation (distribution), use, disposal, and recycling stages (Figure 3. 2-1).

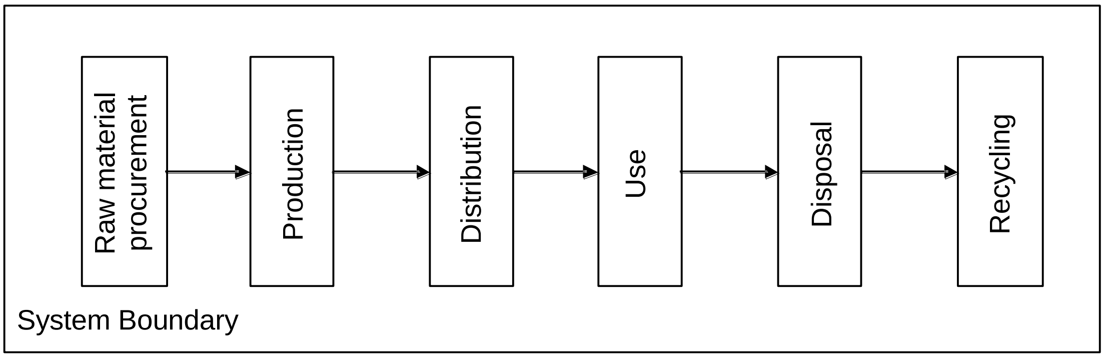


Figure 3.2-1 System boundary for this assessment

3.4 Special notes (processes or items exempted from assessment, etc.)

This study uses data referenced from existing literature [3] in the assessment for the disposal and recycling stages. The assessment is conducted based on the assumption that the entire amount of CFC refrigerant is collected.

4. Inventory Analysis

4.1 Foreground data

The assessments for the raw material (procurement) and use stages were conducted using design data. For the production stage, input items (energy etc.) were allocated according to the shipping value.

4.2 Background data

As the background data, this assessment used the environmental impact intensities [4] based on the 2000 edition of the inter-industry relations table provided with the Easy-LCA [3] assessment tool. For waste, the weight of waste was calculated according to the disposal rate of each material, and included in the industrial waste (unspecified/inclusive) category of the LIME2 classification. The disposal model used in Easy-LCA was also applied to this assessment. LIME2 involves two types of coefficients for wood: a coefficient for "wood (natural)," which indicates wood harvested from managed forests, and a coefficient for "wood (unknown)," which is for woods from forests of which the management status is unknown. The wood consumption volume was calculated using applicable environmental impact intensity, and was divided according to the ratios of natural forests and artificial forests for pulpwood published on the website of the Japan Paper Association [5].

4.3 Inventory analysis item and result table

Table 4.3-1 and 4.3-2 represent the list of items covered in the inventory analyses of the two models of household air conditioners and the results of the analyses.

Table 4.3-1 Result of LCI analysis of household air conditioner (benchmark product)

(unit: kg/f.u.)

			Raw material procurement	Production	Distribution	Use	Disposal/ recycling
Impact of resource consumption	Exhaustible resources	Crude oil for fuel	0.39	0.25	0.00	186.73	−0.10
		Coal	26.31	2.51	0.00	1816.78	−13.89
		Natural gas	4.47	2.53	0.00	1037.12	−0.90
		Crude oil for material	11.62	1.01	0.72	188.08	−1.05
		Iron	22.55	0.03	0.00	13.36	−14.22
		Copper	1.00	0.00	0.00	0.19	−0.33
		Aluminum	4.35	0.00	0.00	0.51	−1.63
		Lead	0.03	0.00	0.00	0.02	0.00
		Zinc	0.25	0.00	0.00	0.15	−0.13
		Manganese	0.12	0.00	0.00	0.08	−0.07
		Nickel	0.01	0.00	0.00	0.01	−0.01
		Chromium	0.10	0.00	0.00	0.07	−0.06
		Gravel	0.59	0.08	0.00	36.51	−0.14
		Crushed stone	1.56	0.05	0.00	25.03	−0.62
		Limestone	13.07	0.07	0.00	30.17	−7.41
	Renewable resources	Wood (natural)	0.13	0.00	0.00	1.79	−0.03
		Wood (unknown)	0.06	0.00	0.00	0.84	−0.01
Impact of emission /discharge to the environment	To outdoor air	CO2	121.06	12.65	1.64	8970.36	−39.27
		Sox	0.12	0.01	0.00	3.61	−0.04
		Nox	0.17	0.01	0.01	5.51	0.22
		HFC	0.00	0.00	0.00	0.00	0.00
		HFC23	0.00	0.00	0.00	0.00	0.00
		PFC	0.00	0.00	0.00	0.00	0.00
		SF6	0.00	0.00	0.00	0.00	0.00
		Dust	0.02	0.00	0.00	0.33	−0.01
	To water system	COD	0.02	0.00	0.00	0.07	0.00
		T−N	0.03	0.01	0.00	5.01	−0.01
		T−P	0.00	0.00	0.00	0.09	0.00
	To soil system	Waste	0.00	0.00	0.00	0.00	1.31

Table 4.3-2 Result of LCI analysis of household air conditioner (subject product)

(unit: kg/f.u.)

			Raw material procurement	Production	Distribution	Use	Disposal/ recycling
Impact of resource consumption	Exhaustible resources	Crude oil for fuel	0.42	0.25	0.00	144.20	−0.10
		Coal	27.84	2.51	0.00	1403.02	−13.89
		Natural gas	4.71	2.53	0.00	800.92	−0.90
		Crude oil for material	13.76	1.01	0.76	145.24	−1.05
		Iron	23.67	0.03	0.00	10.32	−14.22
		Copper	1.11	0.00	0.00	0.15	−0.33
		Aluminum	4.66	0.00	0.00	0.39	−1.63
		Lead	0.03	0.00	0.00	0.01	0.00
		Zinc	0.26	0.00	0.00	0.11	−0.13
		Manganese	0.13	0.00	0.00	0.06	−0.07
		Nickel	0.01	0.00	0.00	0.01	−0.01
		Chromium	0.10	0.00	0.00	0.05	−0.06
		Gravel	0.63	0.08	0.00	28.19	−0.14
		Crushed stone	1.63	0.05	0.00	19.33	−0.62
		Limestone	14.35	0.07	0.00	23.30	−7.41
	Renewable resources	Wood (natural)	0.14	0.00	0.00	1.38	−0.03
		Wood (unknown)	0.07	0.00	0.00	0.65	−0.01
Impact of emission /discharge to the environment	To outdoor air	CO2	129.00	12.65	1.74	6927.40	−39.27
		Sox	0.13	0.01	0.00	2.79	−0.04
		Nox	0.18	0.01	0.01	4.25	0.22
		HFC	0.00	0.00	0.00	0.00	0.00
		HFC23	0.00	0.00	0.00	0.00	0.00
		PFC	0.00	0.00	0.00	0.00	0.00
		SF6	0.00	0.00	0.00	0.00	0.00
		Dust	0.02	0.00	0.00	0.25	−0.01
	To water system	COD	0.02	0.00	0.00	0.05	0.00
		T−N	0.04	0.01	0.00	3.87	−0.01
		T−P	0.00	0.00	0.00	0.07	0.00
	To soil system	Waste	0.00	0.00	0.00	0.00	1.47

5. Impact Assessment

5.1 LCIA steps and impact categories used in assessment

The impact assessment was conducted using the Japanese-design "Life Cycle Impact Assessment Method based on Endpoint Modeling" (LIME2) through its three steps consisting of characterization, damage assessment and weighting. The impact categories covered in each step of the assessment are listed in Table 5.1-1.

Table 5.1-1 LCIA steps and environmental impact categories used in assessment

	Characterization	Damage assessment	Weighting
Resource consumption (energy)	○	○	○
Resource consumption (mineral)	○	○	○
Global warming	○	○	○
Urban air pollution		○	○
Ozone layer depletion			
Acidification	○	○	○
Eutrophication	○	○	○
Photochemical oxidant creation			
Human toxicity			
Ecotoxicity			
Indoor air quality			
Noise			
Waste	○	○	○
Land use			

5.2 Result of impact assessment

5.2.1 Characterization

The characterization results of the environmental impacts of the household air conditioners in the categories of resource (energy) consumption and resource (mineral) consumption are laid out in Figures 5.2-1 and 5.2-2. The energy consumption is largely attributable to the consumption of electricity, and the result shows that the energy consumption of the subject model has been reduced by 22% from that of the benchmark model as the result of the energy-saving design. While the resource (mineral) consumption has been reduced slightly, the breakdown indicates that the ratio of copper has increased. This is due to changes made to the composition of parts.

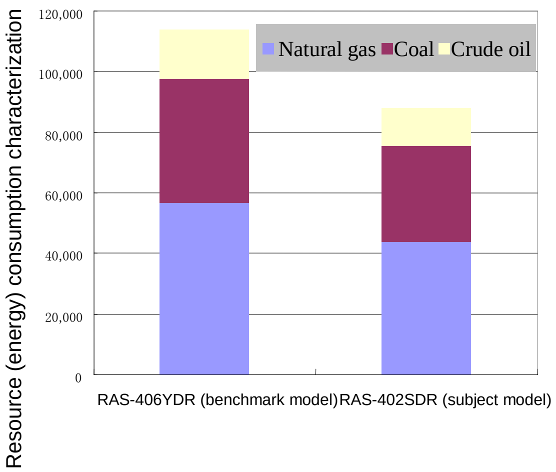


Figure 5.2-1 Characterization result (energy consumption)

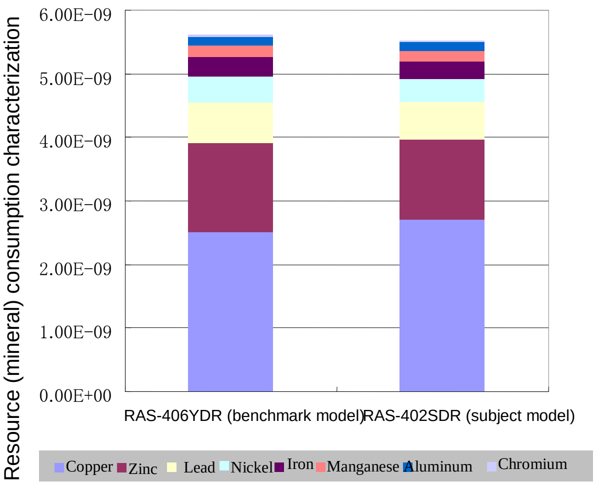
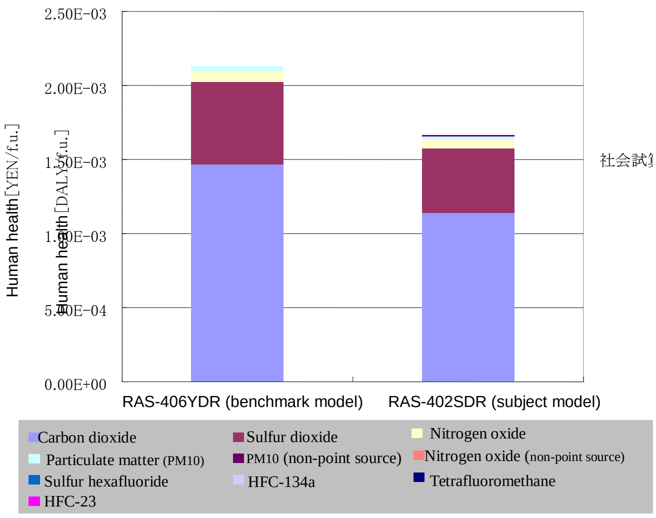


Figure 5.2-2 Characterization result (mineral consumption)

5.2.2 Damage assessment

The results of the damage assessment (breakdown by substance) for four safeguard subjects are laid out in Figures 5.2-3 through 5.2-6. All the results indicate that the subject product has the smaller impact than the benchmark product. Carbon dioxide emissions account for a major part of the impacts on human health and social welfare. Coal consumption and wood consumption have large impacts on primary production and biodiversity, respectively.



Sulfur hexafluoride

Figure 5.2-3 Result of damage assessment (human health)

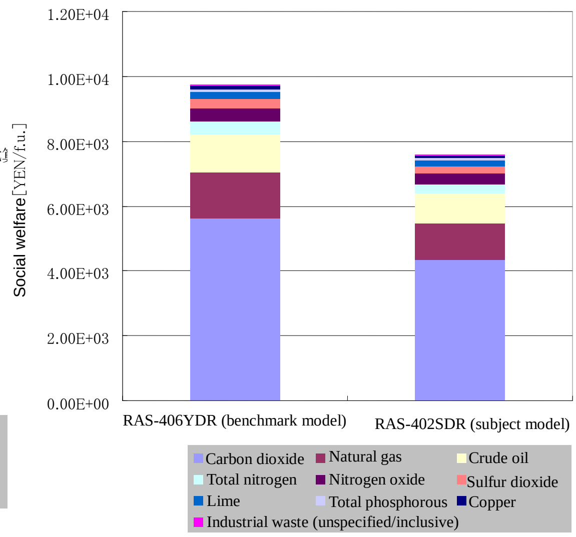


Figure 5.2-4 Result of damage assessment (social welfare)

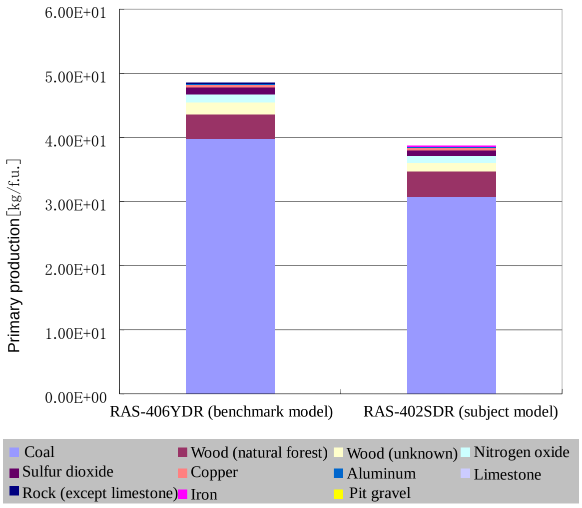


Figure 5.2-5 Result of damage assessment (primary production)

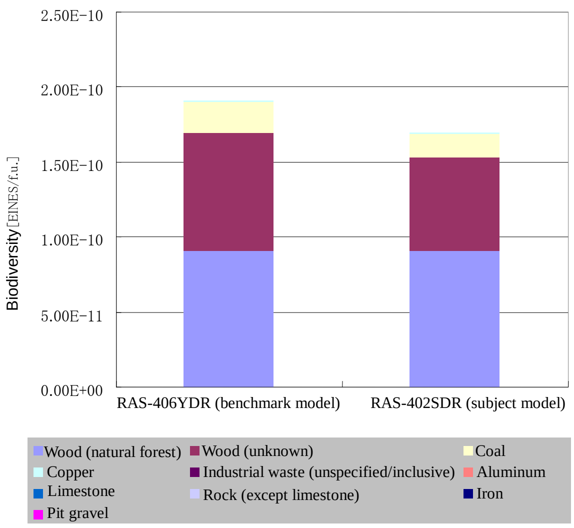


Figure 5.2-6 Resultof damage assessment (biodiversity)

5.2.3 Weighting

The weighting result (by process) for the benchmark and subject models is shown in Figure 5.2-9. While the environmental impact of the subject model at the raw material procurement stage has increased by 7.7% over the benchmark model because of the increase in the volume of copper used, the total impacts over the product life cycle, measured in terms of the monetary value of associated environmental damage, were calculated as 48,870 yen for the benchmark model and 38,199 yen for the subject model. This indicates that the environmental impact of the subject model has been reduced by approximately 22% compared with the benchmark model. A large majority of the overall environmental impacts of household air conditioners is associated with their electricity consumption during the use stage, and impacts that occur in other stages constitute only a small portion. The result shows that the environmental impact of the subject model has been successfully reduced in the use stage, which is due to its energy-saving design.

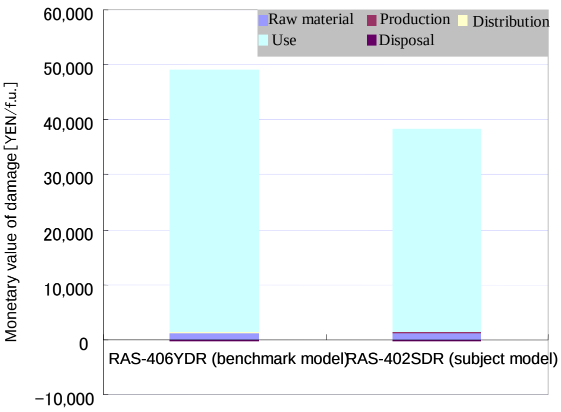


Figure 5.2-9 weighting result (by process)

Figure 5.2-10 and 5.2-11 respectively represent the breakdown of the result by substance and by impact category. The breakdown by substance indicates that major contributors to the total environmental impact are carbon dioxide and sulfur dioxide emissions and coal consumption, and the breakdown by impact category illustrates that dominant environmental impacts are global warming, urban air pollution and non-biological resource consumption.

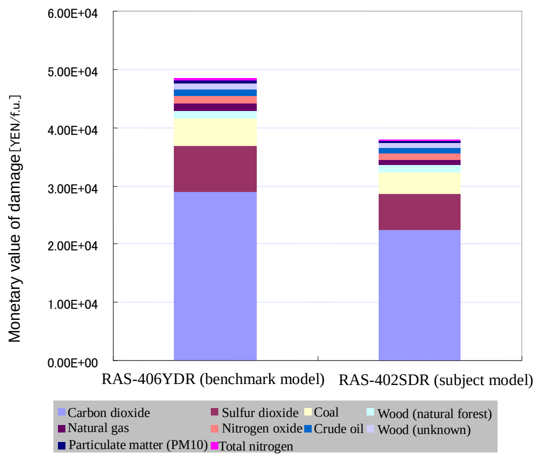


Figure 5.2-10 weighting result (by substance)

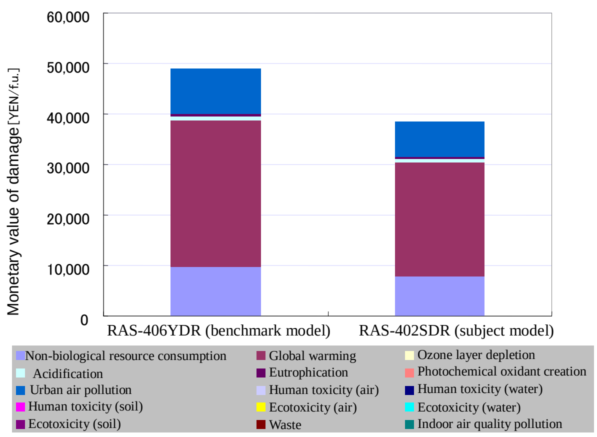


Figure 5.2-11 weighting result (by impact category)

6. Conclusion

6.1 Summary of study result

The assessment of the environmental impacts of household air conditioners was conducted on two models (benchmark model released in 2000 and subject model released in 2006) covering their entire life cycle. The weighting result using LIME2 confirmed that the environmental impact of the subject model has been reduced by 22% over the benchmark model. The major portion of the reduction has been achieved through the reduction in electricity consumption during the use stage, which demonstrates the effect of the energy-saving design. Although the consumption of copper has been slightly increased due to changes made to the composition of parts, its impact is very small in light of the reduction achieved in the overall environmental impact.

6.2 Limitations and future challenges

As mentioned previously, the assessments concerning the disposal and recycling stages were conducted using values referenced from existing literature based on statistics on the disposal of general waste, and also on the assumption that the entire amount of CFC refrigerant is collected. However, in order to obtain results reflecting the actual conditions more accurately, further detailed assessments of the present disposal and recycling processes will need to be carried out. This should be addressed as one of the future priorities.

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Report on
Environmental Impact Analysis of Indoor Air Quality Improvement through the Use of a High-Function Building Material

July 2008

Environmental Office
TOSTEM CORPORATION

1. General Information

1.1 Assessor

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1.2 Report preparation date

July 31, 2008

2. Purpose of Study

2.1 Basis of study

Sick building syndrome has been considered an important house-related issue, and a wide variety of solutions have been implemented such as reduction of formaldehyde exuding from building materials and improvement of ventilation system performance in well-sealed houses. Also, one of the newest possible solutions is allowing wall materials or their decorations such as wallpapers to have an ability to adsorb and decompose indoor air quality contaminants. According to the study by the Center for Housing Renovation and Dispute Settlement Support, the number of consultations about sick building syndrome has been decreasing after it peaked in FY2008. However, considering the fact that the Japan Testing Center for Construction Materials has established a voluntary industrial standard called the Standard of Emission Rates of Volatile Organic Compounds from Building Products, it seems that the sick building syndrome issue is now widely known and better understood instead of attracting less attention than before.

In this study, LCA was conducted to assess the life cycle environmental impact of the interior material called MOISS which has the ability to adsorb and decompose indoor air quality contaminants. Then, after an understanding of its environmental characteristics was obtained, its formaldehyde adsorption and decomposition capability was assessed while taking into account CO_2 emission caused by decomposition of the contaminants. The current and potential effectiveness of recycling of MOISS, mainly made of natural materials, was then assessed.

2.2 Application of study result

The study result will be used to understand the environmental efficiency of MOISS, identify important processes for reducing the environmental impact, and provide information to contribute to design improvement. Also, the potential of product appeal or business activity indices using LIME2 environmental impact assessment results will be tested.

3. Scope of Study

3.1 Subject of study and its specifications

The interior material called MOISS, which is manufactured, used, and disposed of in Japan, was the study subject. As the control subject, a commonly used type of wall (cloth-covered gypsum board) was used. Both MOISS and the gypsum board had a thickness of 9.5 mm.

MOISS is characterized by: humidity adjustment and deodorant functions like soil walls or trees; adsorption and decomposition of toxic substances due to the use of vermiculite as the main ingredient; no adhesive finish as it does not need to be covered by paper; and recyclability due to the use of natural material as the main ingredient.

3.2 Functions and functional unit

The functional unit is the entire life cycle of a wall to furnish one side of a room. For MOISS, it is 6 boards each having an area of 910 mm × 1820 mm, a total of approximately 10.0 m^2 (weight: 9.4 kg × 6 pieces). For a common wall, too, it is 6 boards with a total area of approximately 10.0 m^2 (weight: 10.8 kg × 6 pieces). Formaldehyde exposure for 8 years of wall use is used in the assessment as the indoor air quality contaminating parameter.

3.3 System boundary

The raw material procurement, manufacturing, distribution, use, and disposal stages were included within the system boundary (Figures 3.3-1 and Figure 3.3-2). In this study, the environmental impact assessment for product-specific processes, excluding the product use stage, was the 'ver. 1' assessment, and the environmental impact assessment including the product use stage (formaldehyde-related environmental impact assessment) was the 'ver. 2' assessment.

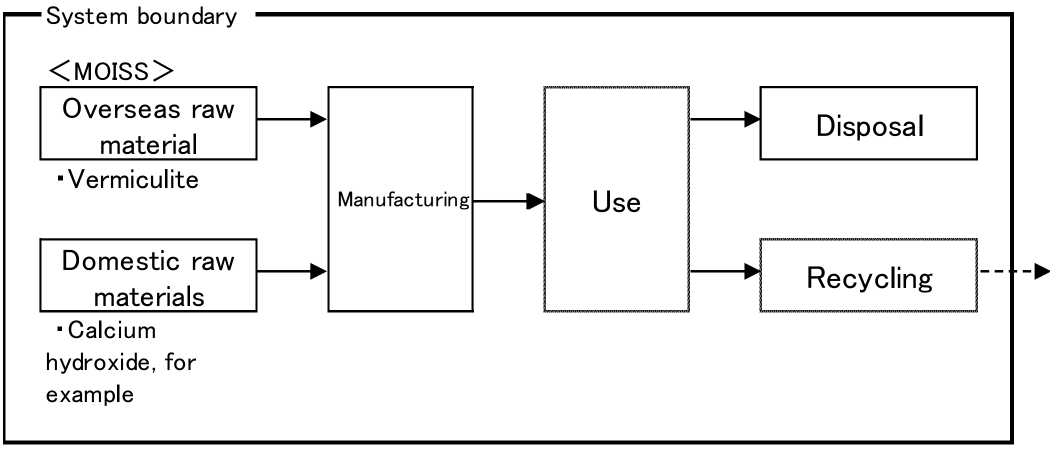


Figure 3.3-1 System boundary of MOISS

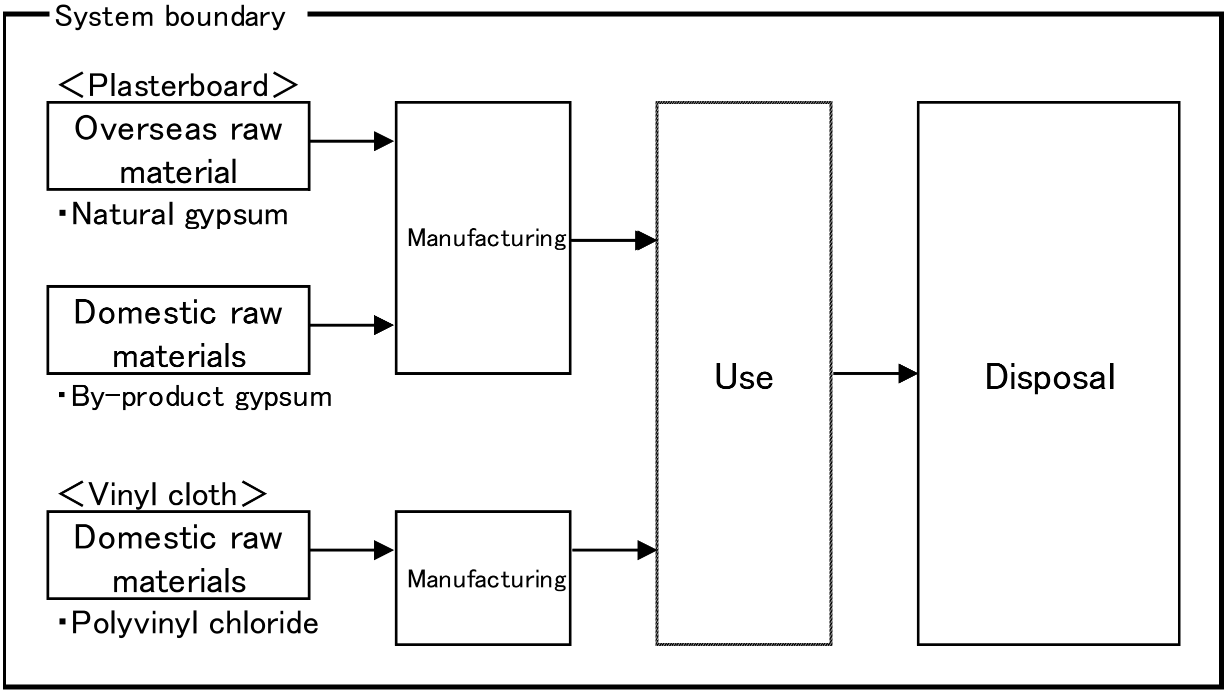


Figure 3.3-2 System boundary of a common wall

3.4 Special notes (processes or items exempted from assessment, etc.)

The by-product gypsum refinement process (flue-gas desulfurization) was not included in the by-product gypsum environmental impact parameter as it was a by-product process. Also, construction, maintenance, and disposal of factories and machines for product manufacturing as well as construction and demolition of residences were not within the scope of the assessment.

Note that the formaldehyde adsorption and decomposition capability of MOISS was calculated based on its performance test result.[1)] Although an interior material recycling model is now under development, in order to incorporate the current status, both MOISS and the common wall were both treated as industrial waste (debris). MOISS is considered as industrial waste of a stabilized type and a gypsum board is considered as industrial waste of a controlled type, but this type difference was not taken into consideration in this study.

4. Inventory Analysis

4.1 Foreground data

Data on the amount of raw materials, resources, and energy used in MOISS manufacturing was collected in FY2004 with the cooperation of the manufacturer MITSUBISHI MATERIALS KENZAI CORPORATION. Data on the amount of gypsum boards and vinyl wallpaper was cited from the 3rd revision of the FY2007 JLCA-LCA database created by the Japan Environmental Management Association for Industry [2)]. The environmental impact of the product use stage was calculated based on the result of the study by Kaneko, et al [3)] and references for that study [4)]. Also, results of interviews with the manufacturers and the result of the study by the Investigation Committee for Promotion of Waste Gypsum Board Recycling [5)] were referred to in order to obtain information on the current status of the disposal stage.

4.2 Background data

Based on the information obtained through interviews with the MOISS distributor, MITSUBISHI MATERIALS KENZAI CORPORATION, it was assumed in the study that raw materials of MOISS were procured domestically as well as internationally; vermiculite was imported from South Africa, and other raw materials were procured in Japan. As for procurement of raw materials of gypsum boards, it was assumed in this study that natural gypsum was imported from Thailand and Australia, and by-product gypsum and other raw materials were domestically procured based on the statistical data provided by the Gypsum Board Association of Japan [6] and also the result of the study by the Investigation Committee for Promotion of Waste Gypsum Board Recycling [5]. Other data required in the study was from the database of JEMAI-LCA Pro of the Japan Environmental Management Association for Industry [7].

4.3 Inventory analysis item and result table

Tables 4.3-1 and 4.3-2 show the subjects and results of inventory analysis for MOISS and the common wall, respectively.

Table 4.3-1 MOISS LCI analysis result [Unit: kg/f.u.])

			Material	Manufacturing	Distribution	Use	Disposal
Environmental load of consumption	Depleted resources	Coal	3.76E-01	1.56E+00	7.25E-05		
		Crude oil (fuel)	1.53E+00	5.51E+00	4.49E-03		
		Natural gas	2.53E-01	1.07E+00	8.59E-05		
		Uranium	3.87E-05	1.66E-04	2.33E-09		
		Sand	1.81E+01				
		Limestone	2.84E+01				
		Feldspar	1.35E+01				
	Recyclable resources	Wood					
		Water	-	-	-	-	-
Environmental load of emission	Outdoor air	CO_2	1.85E+01	3.50E+01	6.61E+00	(2.80E-02)	
		SOx	3.83E-04	6.87E-03	2.39E-03		
		NOx	2.30E-03	1.45E-02	3.77E-04		
		N_2O	1.67E-04	6.40E-04	1.90E-05		
		CH_4	1.70E-04	5.68E-04	7.27E-05		
		NMVOC	7.84E-05	3.37E-04			
		PM10	1.99E-04	3.89E-04	1.14E-04		
		PM10 (source)	1.43E-05	8.99E-05	7.86E-04		
		NOx (source)	1.96E-04	1.23E-03	2.46E-02		
		SO_2	3.45E-04	3.84E-04	8.28E-06		
	Indoor air	HCHO				(2.58E-03)	
	Soil	Industrial waste					56.64

Table 4.3-2 Common wall LCI analysis result [Unit: kg/f.u.])

			Material	Manufacturing	Distribution	Use	Disposal
Environmental load of consumption	Depleted resources	Coal	7.57E-01	5.37E-01	5.48E-05		
		Crude oil (fuel)	8.55E-01	7.75E+00	3.12E-03		
		Natural gas	5.23E-01	4.69E-01	6.01E-05		
		Uranium	5.68E-05	5.70E-05	1.76E-09		
		Crude oil (raw material)	2.27E+00				
		Limestone	2.00E+01				
	Recyclable resources	Wood					
		Water	-	-	-	-	-
Environmental load of emission	Outdoor air	CO_2	7.18E+00	2.73E+01	4.14E+00		
		SOx	1.36E-03	9.80E-03	1.62E-03		
		NOx	3.44E-03	1.46E-02	2.85E-04		
		N_2O	3.51E-04	5.33E-04	1.44E-05		
		CH_4	3.75E-04	7.37E-04	5.49E-05		
		NMVOC	1.15E-04	1.15E-04			
		PM10	7.02E-04	5.50E-03	8.61E-05		
		PM10 (source)	1.08E-04	2.11E-05	4.79E-04		
		NOx (source)	1.47E-03	2.88E-04	1.50E-02		
		SO_2	3.52E-03	1.88E-02	6.24E-06		
	Indoor air	HCHO				(2.18E-02)	
	Soil	Industrial waste					65.1

5. Impact Assessment

5.1 LCIA steps and impact categories used in assessment

The impact assessment was conducted using the Japanese-design "Life Cycle Impact Assessment Method based on Endpoint Modeling" (LIME2) through its three steps consisting of characterization, damage assessment and weighting. The impact categories covered in each step of the assessment are listed in Table 5.1-1.

Table 5.1-1 LCIA steps and environmental impact categories used in assessment

	Characterization	Damage assessment	Weighting
Resource consumption (energy)	○	○	○
Resource consumption (mineral)	○	○	○
Global warming	○	○	○
Urban air pollution	-	○	○
Ozone layer depletion	-	○	○
Acidification	○	○	○
Eutrophication	-	○	○
Photochemical oxidant creation	-	○	○
Human toxicity	-	○	○
Ecotoxicity	-	○	○
Indoor air quality	○	○	○
Noise	-		
Waste	○	○	○
Land use			

5.2 Result of impact assessment

5.2.1 Characterization

As the result of characterization of MOISS and the common wall, Figure 5.2-1 and 5.2-2 show their resource (energy) consumption and global warming effects. The graphs marked as 'ver. 1' show the result of the assessment that did not include the product use stage (indoor air pollution). The graphs marked as 'ver. 2' show the result of the assessment that did include the product use stage (this applies to the damage assessment and weighting results). In terms of resource (energy) consumption, MOISS had a slightly lower environmental impact than the common wall. However CO_2 emission of MOISS had a higher environmental impact than the common wall on global warming. Therefore, different types of energy had different levels of environmental impact. When other areas of influence were included, MOISS had less energy consumption, acidification, and waste than the common wall while the common wall had less mineral resource consumption and global warming effects than MOISS.

In this result, it is noteworthy that MOISS ver. 1 and ver. 2 had approximately the same level of CO_2 impact on global warming and that the impact of CO_2 emission caused by formaldehyde decomposition was marginal in the overall result.

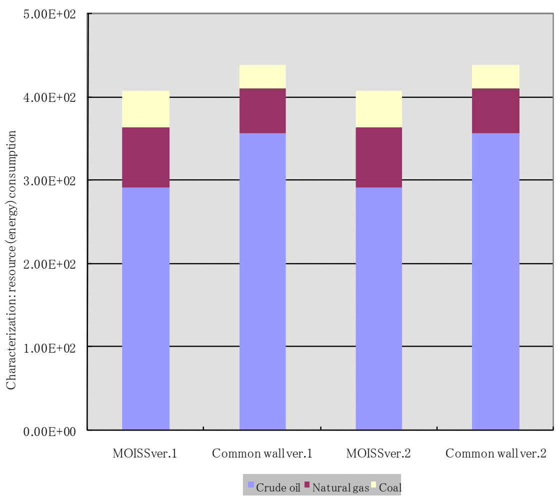


Figure 5.2-1 Characterization (energy consumption)

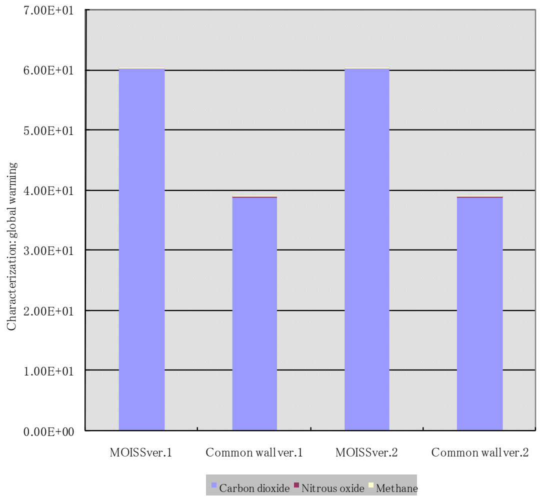
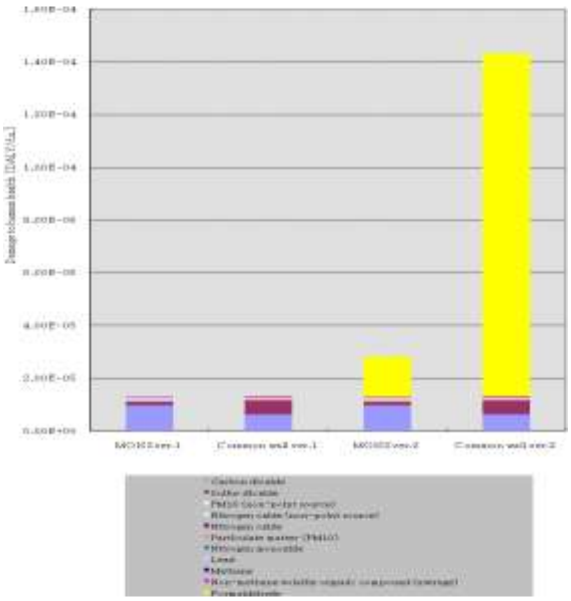


Figure 5.2-2 Characterization (global warming)

5.2.2 Damage assessment

Figures 5.2-3 through 5.2-6 show the assessment result of damage (by substance) to 4 areas of protection. MOISS had slightly lower environmental impacts on social assets and biodiversity than the common wall while the common wall had a slightly lower environmental impact on primary production. The graphs also show that the environmental impact of waste (debris) was the largest of all substances in the areas of social assets, primary production, and biodiversity.

In the area of human health, the ver. 2 result shows that formaldehyde had a large impact, meaning that high formaldehyde adsorption and decomposition capability would greatly contribute to human health. It should also be noted that CO_2 and SOx emission also had relatively large impacts.



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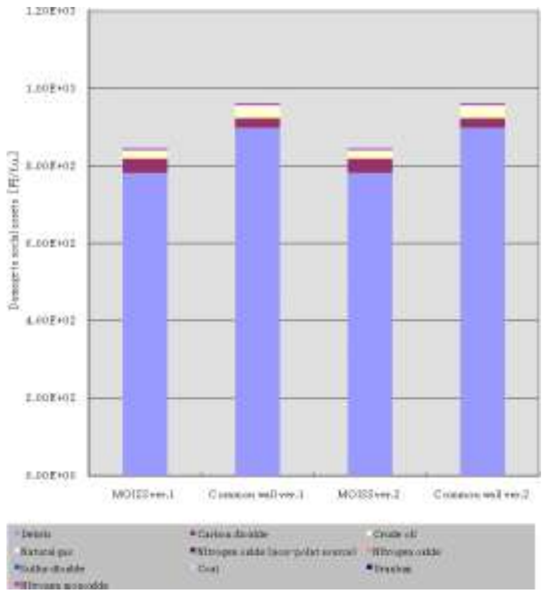

Figure 5.2-4 Damage assessment result (social assets)

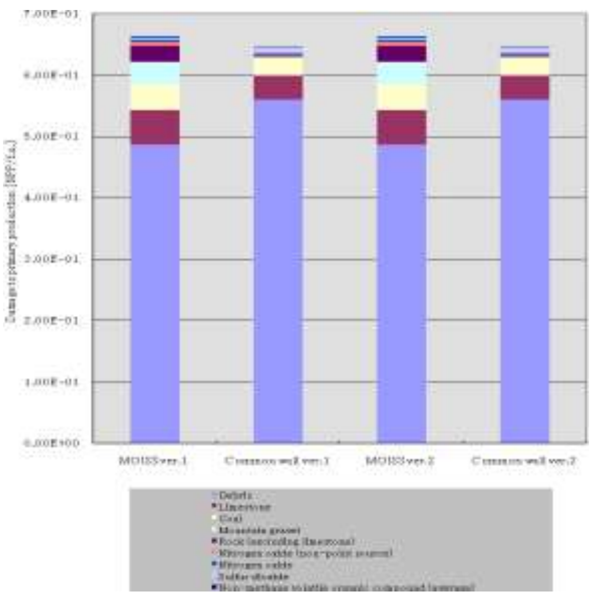

Figure 5.2-5 Damage assessment result (primary production)

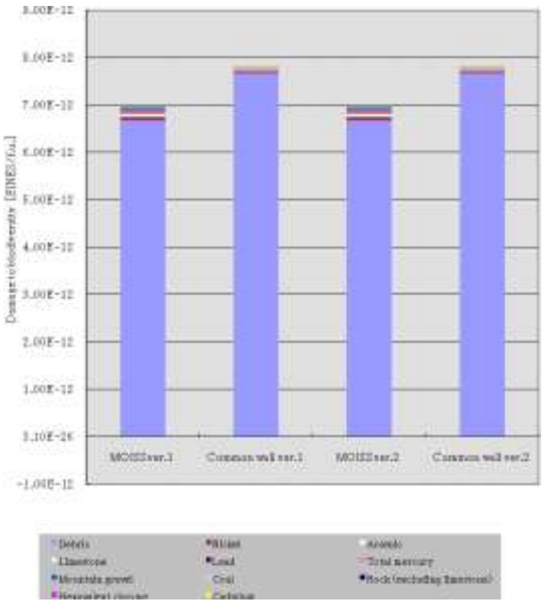

Figure 5.2-6 Damage assessment result (biodiversity)

Figure 5.2-7 shows damage to primary production by process wherein the structure is different between MOISS and the common wall. Because desulfurization gypsum is a by-product gypsum generated during power generation and is used as the main ingredient of the common wall, its loads were not included in the assessment; therefore, the graph shows that the common wall caused smaller damage than MOISS in the material stage. Vermiculite, the main ingredient of MOISS, is also a by-product of excavation of other minerals or vermiculite of higher quality; however, based on the conclusion that it would be appropriate if the material loads were included, the material loads based on weights were included in the assessment. Note, however, examination of inclusion of parameters other than weights, such as prices that show quality difference, should also be examined in the future.

Finally, the disposal stage of both MOISS and the common wall accounted for most of the damage to primary production, and the damage of the disposal stage of MOISS ver. 1 in particular accounted for 73% of the entire damage caused by MOISS ver. 1.

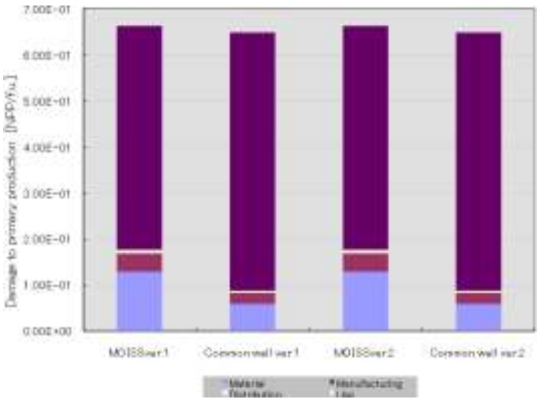

Figure 5.2-7 Damage to primary production by process

5.2.3 Weighting

Figure 5.2-8 shows the weighting study result (by substance) for MOISS and the common wall. For both types of wall, debris (industrial waste), CO_2 emission, SOx emission, and crude oil consumption of ver. 1 had large environmental impacts. When the product use stage was included in the assessment (ver. 2) to add the environmental impact of formaldehyde, the social cost, or environmental impact, was 1,500 yen/f.u. for MOISS and 3,200 yen/f.u. for the common wall.

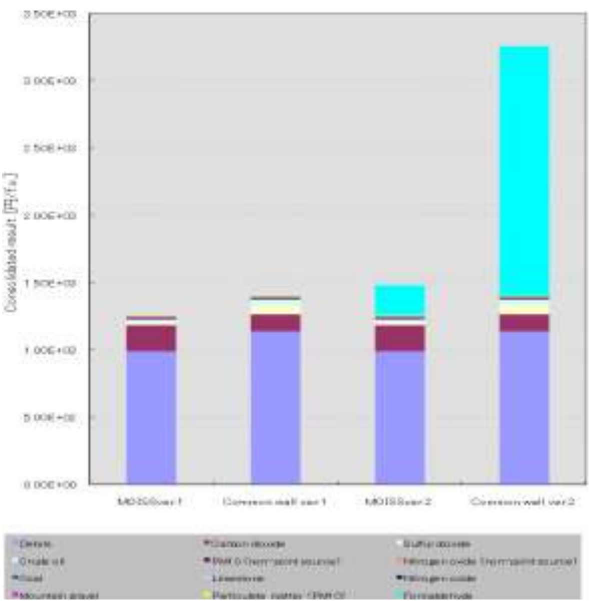

Figure 5.2-8 Weighting result (by substance)

Figure 5.2-9 shows the environmental impact by process, and Figure 5.2-10 shows the environmental impact by the area of influence. When examined by process, both MOISS and the common wall had large environmental impacts in their manufacturing, (use), and disposal stages, accounting for most of the entire impact. When examined by the area of influence, the environmental impact of indoor air quality pollution of the process including the use stage (common wall ver. 2) was equal to all the other parameters combined for that process. In addition, the environmental impacts of waste, global warming, and urban area air pollution were prominent.

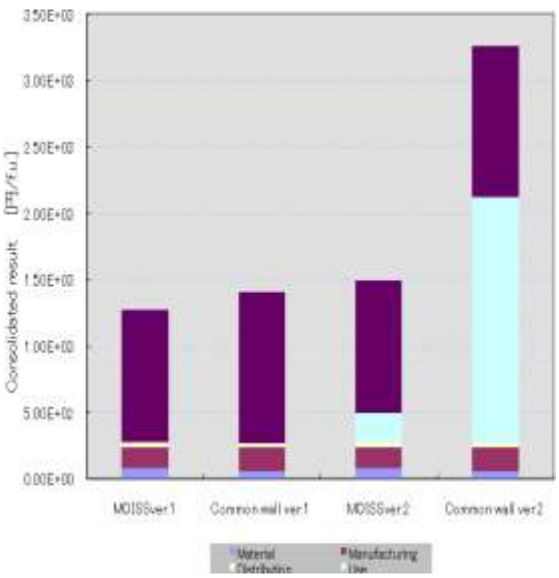

Figure 5.2-9 weighting result (by process)

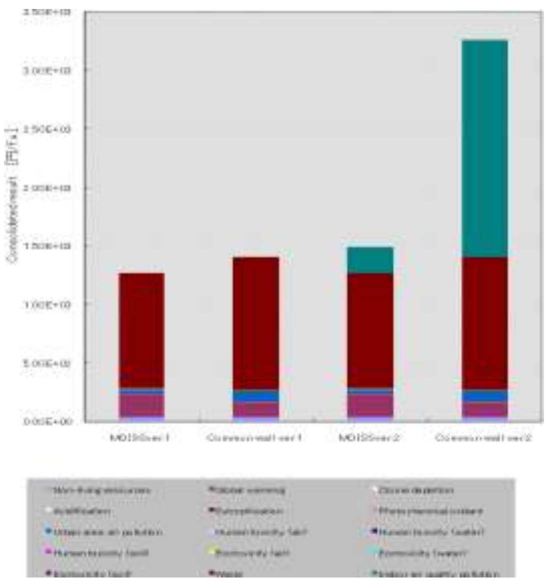

Figure 5.2-10 weighting result (by area of influence)

5.2.4 Process structure of MOISS

Figure 5.2-11 shows the weighting result by process for MOISS (ver. 1). Its environmental impact was the largest in its disposal stage, accounting for 78%. As for other stages, the material, manufacturing, and distribution stages accounted for 6%, 12%, and 4%, respectively. Although it was originally expected that transportation of vermiculite would cause a large environmental impact because it is imported from South Africa (transportation distance: approximately 15,000 km); however, it turned out that its impact was small due to the use of bulk carriers.

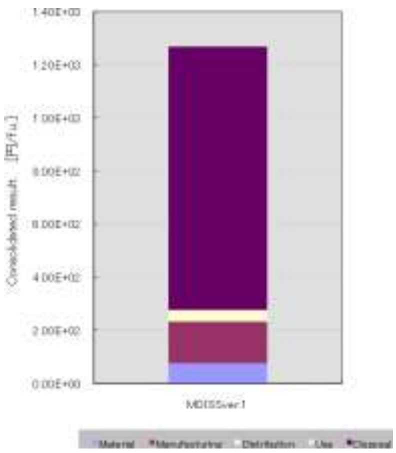

Figure 5.2-11 weighting result (by process)

5.2.5 Recycling effect

Figure 5.2-12 shows the estimate of MOISS recycling effects. Here, in ver. 1 the product use stage was excluded from the calculation and the product was assumed to be processed as industrial waste (debris). To compare with this, in ver. 3 it was assumed that 25% of the waste product from a dismantled residence was used as cover soil and the rest was processed as industrial waste, and in ver. 4 it was assumed that 25% of the waste product from a dismantled residence as collected, ground, and recycled into materials at its production base and the rest was transported to an industrial waste processing facility. Note that, the value 25% is a value tentatively set referring to the ratio of recycled material contained in other building materials.

Using cover soil did not result in any significant effect because the waste product would still be disposed of at a disposal field; however, grinding and material recycling indicated effects. Because no rare minerals are consumed when manufacturing the product, the effect of material recycling was more significant in the disposal stage than in the material stage.

A model is now being developed to recycle waste materials including gypsum boards collected from the site of residence demolition.[8] Also, since no adhesive is used in manufacturing of MOISS and its main ingredients are all natural materials, it is highly likely that it will be easy to implement a material recycling system once the collection system is established.

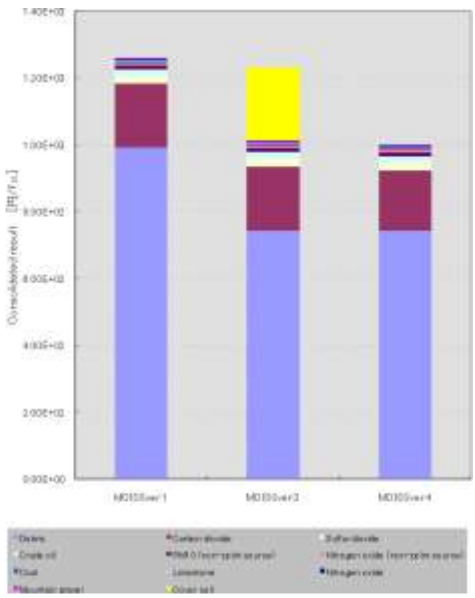

Figure 5.2-12 weighting result (by substance)

6. Conclusion

6.1 Summary of study result

In this study, the environmental impact was assessed for the entire life cycle (material, manufacturing, distribution, use (8 years of use; assessment of the environment impact of formaldehyde), disposal, and recycling stages) of MOISS and a commonly used wall (cloth-covered gypsum board). When the use stage was excluded from the assessment, the environmental impact as social costs was 1,200 to 1,300 yen. When the use stage was included in the assessment, however, the environmental impact was approximately 1,500 yen for MOISS and approximately 3,200 yen for the common wall.

For both study subjects, the disposal stage accounted for most of the environmental impact. The study also showed that the manufacturing stage had a larger environmental impact than the material or distribution stages. Aside from the disposal stage, CO_2 emission, SOx emission, and crude oil consumption had relatively large environmental impacts. When the product use stage was included in the assessment, the indoor air quality pollution had a large environmental impact, meaning that adsorption and decomposition of formaldehyde would greatly contribute to reduction of the environmental impact even though there would be CO_2 emission during decomposition.

Finally, the study indicated that material recycling of MOISS would be effective in reduction of the environmental impact.

6.2 Limitations and future challenges

The scope of the product assessment covered important processes (material, manufacturing, distribution, use, and disposal); therefore, the study results should have high validity. Meanwhile, the amount of formaldehyde adsorption and decomposition, which was the assessment subject of the use stage, was obtained based on the corresponding previous performance test results. Even though the value was based on previous studies, it may still be different from exposure in a real residence. Furthermore, MOISS has not only the formaldehyde adsorption and decomposition capability but also VOC adsorption as well as humidity control capabilities. Assessment of the effectiveness of these capabilities should also be studied in the future.

When LIME was upgraded to LIME2, the function to assess the environmental impact of indoor air quality pollution was added to widen the scope of assessment. The assessment quality also became higher in LIME2. Therefore, it is our plan to use the LIME2 assessment results to promote product features or create a business activity plan.

Acknowledgements

We would like to express our gratitude to: Mr. Itsubo and Mr. Motoshita of the National Institute of Advanced Industrial Science and Technology for advice and guidance; the Japan Environmental Management Association for Industry for managing the office used for this project; Mr. Ogura of Mitsubishi Materials Corporation and Mr. Shoda of Mitsubishi Shoji Construction Materials Corporation for advice on inventory data collection; participating companies for providing us with valuable comments during the project; and cooperating TOSTEM employees.

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Report on Sustainable Forest Management and Environmental Impact Assessment in Relation to Base Paper for Paper Cups

July 2010

Paper Cup Working Group, Printers Association of Japan

1 General

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Organization: Paper Cup Working Group, Printers Association of Japan
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1.2 Date of Report Creation

July 14, 2010

2 Study Objective

2.1 Background of the Study

The main ingredient of a paper cup for beverages is paper. Paper is made from trees, and the impact of deforestation on primary production and biodiversity has been a strong concern. The beverage paper cup LCA carried out by the Paper Cup Working Group (WG) indicated that the weighting values changed greatly depending on: if wood was obtained from forests that were managed so that primary production and biodiversity could be protected; or if it was obtained from forests that were not under such management.[1)]

In that LCA, environmental impacts were compared between the two abovementioned forest patterns on an all-or-nothing basis without taking into account their actual forest management status. Therefore, figures indicating the current forest management status were not studied in that assessment.

In this study, based on the knowledge of the countries of origin of wood chips, country-specific environmental load coefficients were used to conduct LCA reflecting as much reality as possible, and the result of the LCA thus conducted was compared with the assessment of a scenario in which base paper for paper cups was all procured from properly managed forests. By doing so, the objective of the study was to gain a quantitative understanding of the importance of forest management.

2.2 Application of the Study Result

The study result will be used for acquisition of a quantitative understanding of the importance of proper management of forests where base paper for paper cups is obtained, and the result will also be referred to in future material procurement.

[1)] Since it was difficult to collect data on production of base paper for paper beverage cups, data on a 200-ml brick-shape paper container was used as a close example.

3 Scope of the Study

3.1 Subject and its Specifications

The subject of the study was a beverage paper cup produced, used, and disposed of inside Japan (product weight: 5.56 g).

3.2 Function and Functional Unit

For a beverage paper cup whose maximum capacity is 275 ml (usually used with approximately 200 ml of beverage), the functional unit in this study was a combination of its entire life cycle and material recycling after use (recycled pulp production).

3.3 System boundary

The system included the material, container manufacturing, shipment, incineration, recycled pulp production, and substituted values (electricity was substituted for waste power generation during incineration, and virgin pulp production was substituted for recycled pulp production) (Figure 3.2-1).

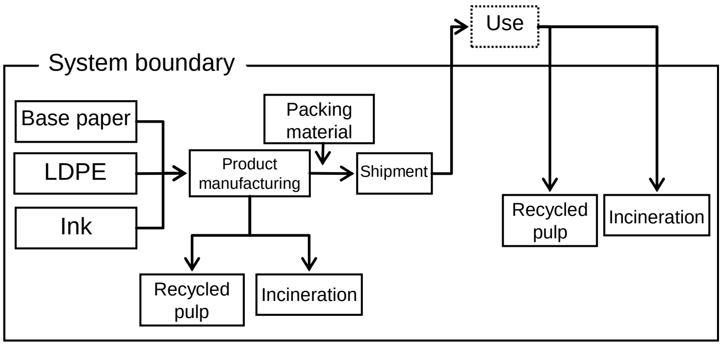

Figure 3.2-1 Product system and system boundary of a paper cup for beverages

3.4 Note (Processes or Items Excluded from the System Boundary)

Paper cups for beverages are used in a wide variety of places such as in vending machines, at fast food restaurants, and in general households. It was therefore difficult to create product use scenarios and to collect environmental load data in these scenarios. As far as the study objective was concerned, inclusion or exclusion of the product use stage would not influence the study result; therefore, we did not include the product use stage in the system boundary.

4 Inventory Analysis

4.1 Priority Data

Data on material transportation, product manufacturing, and product shipment was collected from 5 leading paper cup manufacturers (Shioku Pack, Dai Nippon Printing, Tokan Kogyo, Toppan Printing, and Dixie Japan; they account for more than 90% of the Japanese paper cup market share). Data to be used in the assessment was then prepared by obtaining the weighted average using the manufactured product weight.

4.2 Background Data

Data on paper production was created by combining data of a 200-ml brick-shape paper container [1] [2] provided by the former Institute for Policy Sciences (current Research Center for Policy Studies) and data (on high-grade white paperboard) available in the database of the Life Cycle Assessment Society of Japan (JLCA). [2]

For LDPE resin production data, its indirect energy consumption involved in production was supplemented by JEMAI-LCA Pro data based on the JLCA data.

JEMAI-LCA Pro data was used to obtain data on environmental loads associated with energy consumption and transportation and also with recycled pulp production (pulp production as a result of collection and recycling of waste sheets and used paper cups disposed of by factories).

Analysis of environmental impacts on primary production and biodiversity requires wood procurement data (where it is obtained and if trees are planted or naturally grown). For this, the CSR Report Detailed Version [3] issued by the Nippon Paper Group was used. Note that, since it was difficult to obtain procurement data focusing only on base paper for paper beverage cups, procurement data for paper in general was used.

4.3 Subjects of Inventory Analysis and a List of Analysis Results

Table 4.3-1 shows the result of inventory analysis of a paper beverage cup. Here, inter-scenario comparisons with regard to primary production and biodiversity means comparisons among the results of calculation using different wood-related coefficients, and the inventory was the same across all the scenarios.

The Disposal process shown in Table 4.3-1 includes the substituted values. There are two types of substitution. The first type results from collection and recycling (into recycled pulp) [3] of some waste sheets and used paper cups disposed of by factories. This recycling is replaced by virgin pulp production. The other type results from waste power generation during incineration of uncollected used paper cups. This is replaced by purchased electricity.

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[2] Although the data provided by the former Institute for Policy Sciences allowed calculation of energy consumption in paper production, it did not clearly indicate what kind of energy source was used. For this reason, the high-grade white paperboard data of JLCA was used to create a breakdown of Bunker C and purchased electricity.

[3] At places like baseball stadiums, some used paper cups are collected and recycled into toilet paper. Currently, the paper cup collection rate (against the production volume) is approximately 4%[4] and, for this reason, the collection rate was set at 4% for the substituted value calculation purpose.

Table 4.3-1 Paper beverage cup LCI

I/O	Type	Substance	Material	Manufac-turing	Distribution	Disposal	Σ
INPUT	MATERIAL	Uranium	1.39E-08	3.47E-08	2.08E-09	-9.10E-09	4.16E-08
	ENERGY	Coal	2.16E-04	3.94E-04	2.37E-05	-2.39E-04	3.95E-04
		Crude oil	1.65E-03	3.34E-04	5.40E-04	-1.62E-04	2.36E-03
		Natural gas	2.25E-04	2.26E-04	1.10E-05	-4.72E-05	4.15E-04
	MATERIAL	Aluminum	7.26E-09	7.94E-09	0	6.64E-10	1.59E-08
		Copper	1.11E-07	1.64E-09	0	1.38E-10	1.13E-07
		Lead	4.08E-09	6.06E-11	0	5.07E-12	4.15E-09
		Zinc	2.26E-08	3.36E-10	0	2.81E-11	2.30E-08
		Limestone	1.20E-08	1.15E-08	0	9.52E-10	2.45E-08
		Wood	1.44E-02	0	0	0	1.44E-02
OUTPUT	Air	Carbon dioxide	4.40E-03	2.76E-03	1.78E-03	-1.31E-04	8.81E-03
		Methane	1.54E-07	5.19E-08	1.17E-06	-5.30E-08	1.32E-06
		Nitrogen monoxide	6.29E-08	1.09E-07	3.79E-08	-2.91E-08	1.81E-07
		Nitrogen oxide	1.68E-05	1.11E-06	1.75E-05	-7.66E-07	3.46E-05
		Nitrogen monoxide (non-point source)	2.14E-07	2.68E-07	4.34E-06	-1.38E-07	4.68E-06
		Sulfur dioxide	3.80E-06	4.84E-07	1.42E-05	-9.56E-07	1.75E-05
		Hydrogen chloride	1.92E-10	0	0	0	1.92E-10
		Arsenic	1.32E-11	3.29E-11	1.98E-12	-8.64E-12	3.94E-11
		Cadmium	1.09E-12	2.72E-12	1.63E-13	-7.14E-13	3.26E-12
		Total mercury	1.59E-11	3.97E-11	2.39E-12	-1.04E-11	4.76E-11
		Non-methane volatile organic compound (average)	2.90E-08	7.24E-08	4.35E-09	-1.90E-08	8.68E-08
		Nickel	2.69E-11	6.73E-11	4.04E-12	-1.77E-11	8.05E-11
		PM10 (non-point source)	1.19E-08	1.96E-08	1.30E-07	-1.01E-08	1.51E-07
		Lead	6.31E-11	1.58E-10	9.47E-12	-4.14E-11	1.89E-10
	Water	Arsenic	7.21E-14	7.88E-14	0	6.60E-15	1.58E-13
		Cadmium	1.08E-14	1.18E-14	0	9.90E-16	2.36E-14
		Total mercury	7.21E-15	7.88E-15	0	6.60E-16	1.58E-14
		COD	3.06E-06	0	0	0	3.06E-06
		Total phosphorus	2.56E-09	0	0	0	2.56E-09
		Total nitrogen	7.80E-08	0	0	0	7.80E-08
	Industrial	Dust	5.44E-07	3.78E-08	2.64E-07	-2.15E-07	6.31E-07
		Debris	1.65E-10	2.46E-12	0	2.06E-13	1.68E-10
		Slag	2.14E-07	3.18E-09	0	2.66E-10	2.17E-07
		Sludge	1.00E-05	0	0	0	1.00E-05
		Waste acid	3.19E-08	0	0	0	3.19E-08
		Waste oil	8.77E-07	0	0	0	8.77E-07
		Industrial waste (estimated fixed value if amount is unknown)	7.23E-05	6.13E-05	2.10E-07	-2.80E-08	1.34E-04
	General	Incineration ash	0	0	0	2.21E-07	2.21E-07

5 Impact Assessment

5.1 Subject Assessment Steps and Areas of Impact

In the impact assessment, LIME2 (Life cycle Impact assessment Method based on Endpoint modeling 2) was used to assess the following three steps: characterization, damage assessment, and weighting. Table 5.1-1 shows the areas of impact subject to the assessment in each step.

Table 5.1-1 Subject areas of environmental impact and assessment steps

	Characterization	Damage assessment	Weighting
Resource consumption (energy)	○	○	○
Resource consumption (mineral)	○	○	○
Global warming	○	○	○
Urban air pollution	○	○	○
Ozone depletion			
Acidification	○	○	○
Eutrophication	○	○	○
Photochemical oxidant	○	○	○
Human toxicity	○	○	○
Ecotoxicity	○	○	○
Indoor air quality	-		
Noise	-		
Waste	○	○	○
Land use			

5.2 Impact Assessment Result

5.2.1 Characterization

Figure 5.2-1 shows the result of characterization of a paper beverage cup. Crude oil accounted for most of the resource (energy) consumption as it was used not only as an energy resource but also as polyethylene to be applied on a paper cup. Uranium accounted for most of the resource (mineral) consumption. Here, uranium was used as an energy source (power generation).

CO_2 accounted for most of the global warming. Nitrogen oxide accounted for a large part of acidification and eutrophication, and mercury and arsenic accounted for high percentages in human toxicity and ecotoxicity. It is believed that the high percentage of mercury is attributed to use of industrial water, and arsenic is attributed to use of electricity.

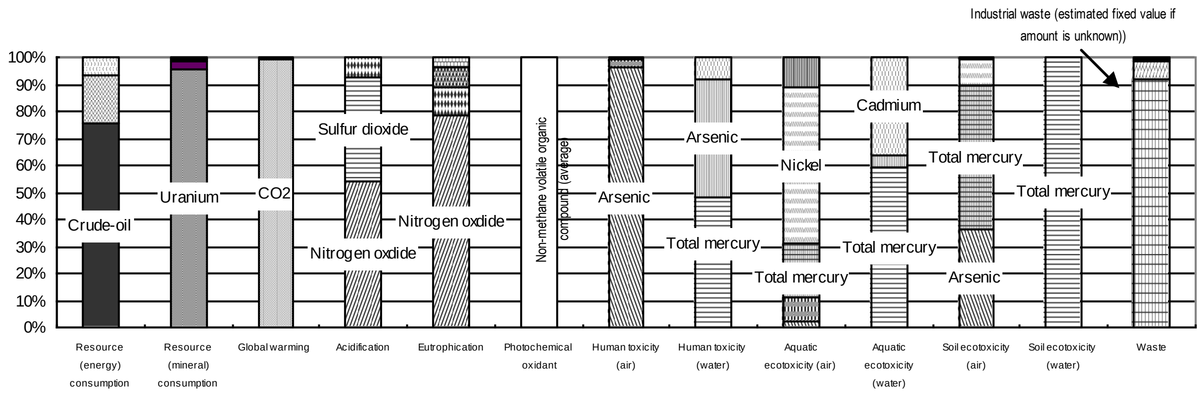


Figure 5.2-1 Characterization result

5.2.2 Damage Assessment

Inter-scenario comparison was conducted to assess damage. The five scenarios described below were different from each other in terms of how wood, the raw material of a paper cup, would affect primary production and biodiversity. In Scenarios A through D, it was assumed that there would be some kind of influence on primary production and biodiversity. In Scenario E, it was assumed there would be no impact on primary production or biodiversity. In all scenarios, it was assumed that wood obtained from planted forests had no impact on primary production or biodiversity (Table 5.2-1).

In Scenario A, the cutting down of trees in natural forests affects both primary production and biodiversity.

In Scenario B, reforestation after cutting down trees in natural forests leads to elimination of the impact on primary production, but nothing is done to eliminate the impact on biodiversity.

In Scenario C, reforestation after cutting down trees in certified forests leads to elimination of the impact on primary production and biodiversity, but both are affected when trees in uncertified forests are cut down.

In Scenario D, certified forests are treated in the same way as Scenario C, but for uncertified forests, reforestation is carried out after cutting down the trees. In this case, although there is no impact on primary production, biodiversity is affected.

In Scenario E, all trees are subject to sustainable forest management, and there is no impact on primary production or biodiversity.

In these scenarios, the ratio between wood from planted forests and wood from natural forests, and also the ratio between certified forests and natural forests were both based on the breakdown of places of origin and also the breakdown of natural and planted forests provided in the CSR report issued by the Nippon Paper Group.[4)] Note that the data described above is not an accurate description of base paper for paper cups; it is believed to describe paper in general.

Table 5.2-1 Scenarios

	Wood from planted forests		Wood from natural forests	
	Certified	Uncertified	Certified	Uncertified
Scenario A	PP: No BD: No	PP: No BD: No	PP: Yes BD: Yes	PP: Yes BD: Yes
Scenario B	PP: No BD: No	PP: No BD: No	PP: No BD: Yes	PP: No BD: Yes
Scenario C	PP: No BD: No	PP: No BD: No	PP: No BD: No	PP: Yes BD: Yes
Scenario D	PP: No BD: No	PP: No BD: No	PP: No BD: No	PP: No BD: Yes
Scenario E	PP: No BD: No	PP: No BD: No	PP: No BD: No	PP: No BD: No

Note 1: PP refers to primary production, and BD refers to biodiversity.
Note 2: Shaded cells show items that have impacts on the environment.

1) Category comparison

Figure 5.2-2 shows the result of damage assessment (primary production). While the calculated environmental load was 8.65E-03 in Scenario A (all natural trees affect primary production), it was 4.78E-03 in Scenario C (uncertified natural trees affect primary production), and it was 2.53E-05 in other scenarios. The environmental load was slightly lower in Scenario C because it was assumed that certified natural trees would not affect primary production. The environmental load was even lower in Scenarios B, D, and E where it was assumed that acquisition of wood would not affect primary production.

According to the breakdown, most of the environmental load in Scenarios A and C was attributed to resources, but in other scenarios, acidification accounted for more than half of the environmental load.

[4)] If information specifically about base paper for paper cups had been available, that information would have been used as Scenario A; however, no such information was available. Therefore, data on paper in general provided by one company was used in Scenario A.

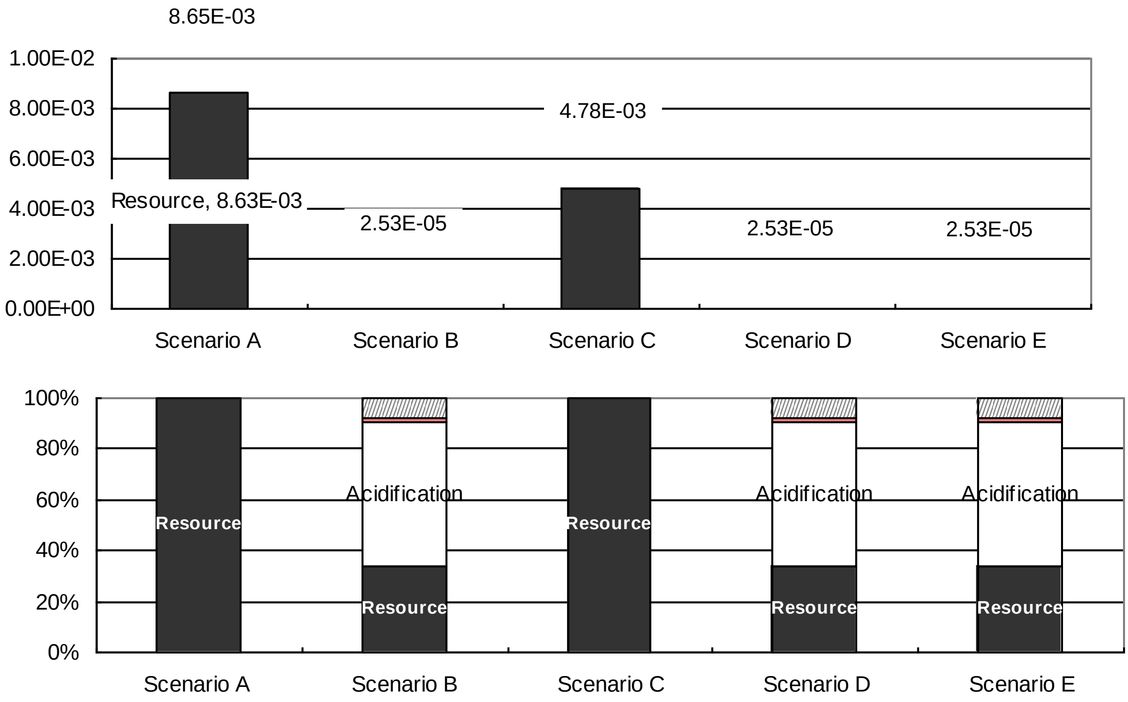


Figure 5.2-2 Damage assessment result (primary production)

Figure 5.2-3 shows the result of damage assessment (biodiversity). In Scenarios A and B (all natural trees affect biodiversity), the calculated environmental load was 2.14E-13 (100% attributed to wood). In Scenarios C and D (uncertified natural trees affect biodiversity), the environmental load was 8.29E-14 (of which, 8.28E-14 was attributed to wood). In Scenario E (all wood is under sustainable forest management), the environmental load was 7.54E-17.

According to the breakdown, in Scenario E, ecotoxicity (air) accounted for approximately 57%, waste for approximately 37%, and resources for approximately 6% of the environmental load. In other scenarios, resources were responsible for almost the entire environmental load.

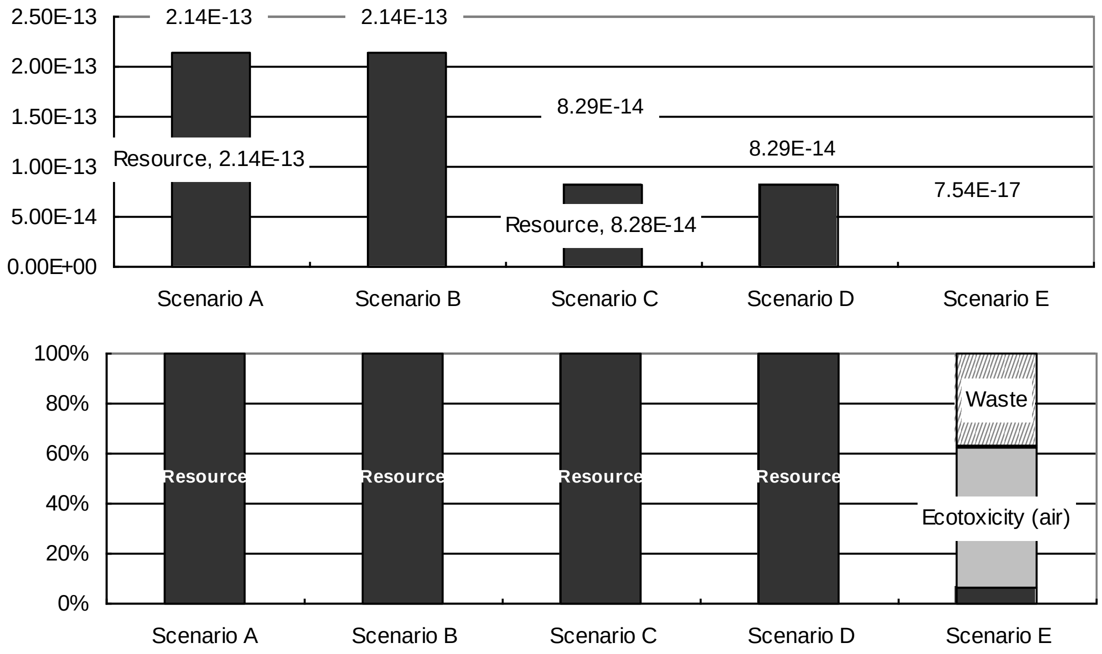


Figure 5.2-3　Damage assessment result (biodiversity)

Figures 5.2-4 and 5.2-5 show the result of damage assessment reorganized in terms of substances.

For primary production, wood accounted for most of the environmental load in Scenarios A and C.　In Scenarios B, D, and E, coal and nitrogen oxide accounted for approximately 30% and sulfur dioxide accounted for approximately 20% of the environmental load.

In biodiversity, wood accounted for most of the environmental load in scenarios other than Scenario E.　In Scenario E, industrial waste accounted for approximately 35%, nickel accounted for approximately 22%, and arsenic accounted for approximately 15%.

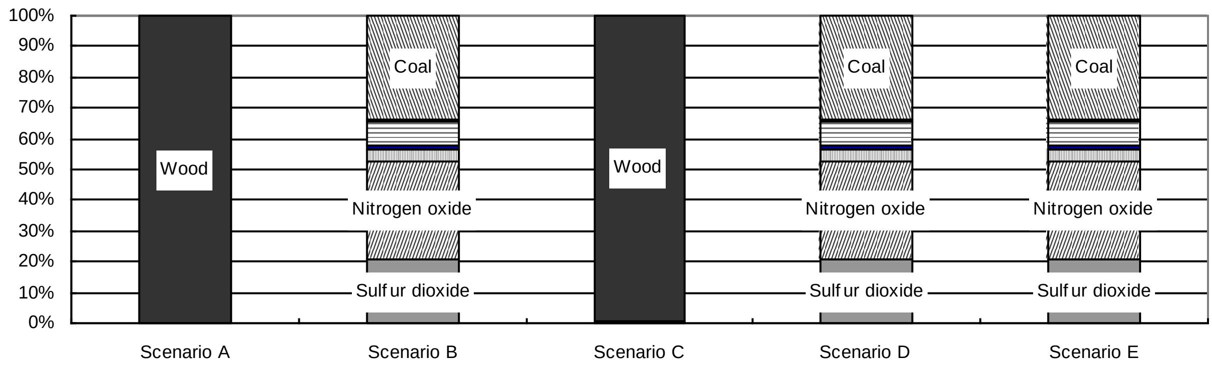


Figure 5.2-4　Damage assessment (primary production; by substance)

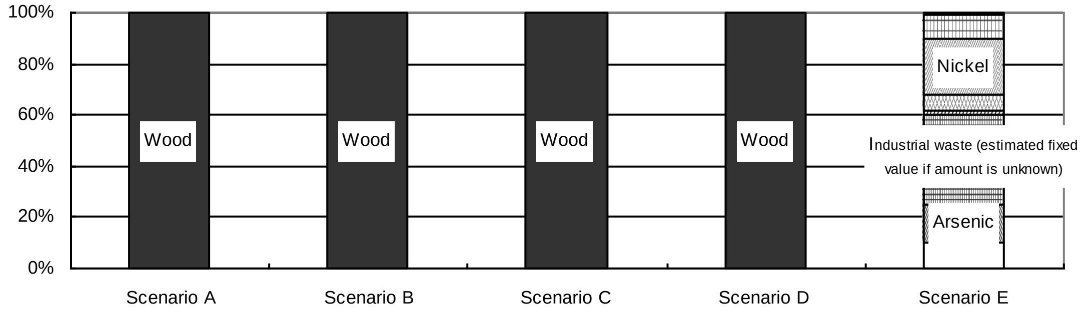


Figure 5.2-5　Damage assessment (biodiversity; by substance)

5.2.3　Weighting

Figure 5.2-6 shows the weighting result for each scenario described in the Damage Assessment section. Calculated social costs were as follows: 3.51 yen for Scenario A, 3.12 yen for Scenario B, 1.48 yen for Scenario C, 1.26 yen for Scenario D, and 0.09 yen for Scenario E.　For Scenario A, 3.42 yen out of 3.51 yen was attributed to wood.　Wood also accounted for a large part of social costs for Scenarios B, C, and D.　In Scenario E, however, the social cost was significantly low because it was assumed that wood would not have any impact on the social cost.

In terms of substance, wood accounted for almost the entire environmental load in Scenarios A through D, while SO_2 and CO_2 accounted for 42% and 32% respectively in Scenario E.　The high percentage of SO_2 was believed to be attributed to Bunker C used in sea transportation (by tankers) when raw materials were imported (Figure 5.2-7).

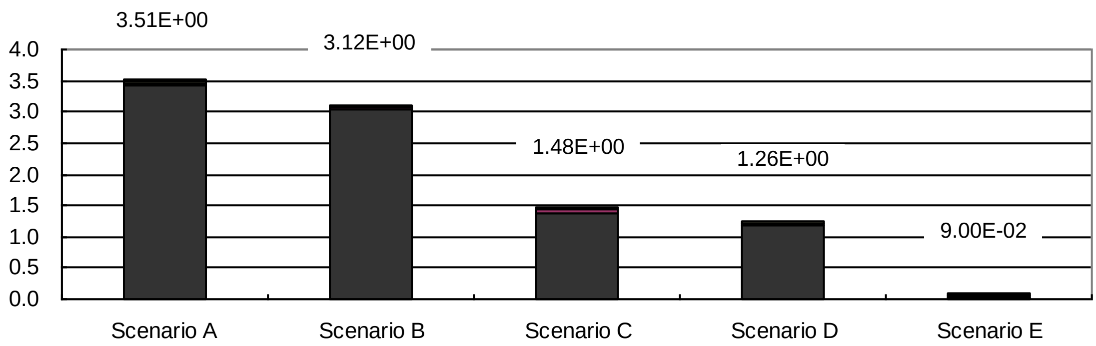


Figure 5.2 -6 weighting result (by scenario)

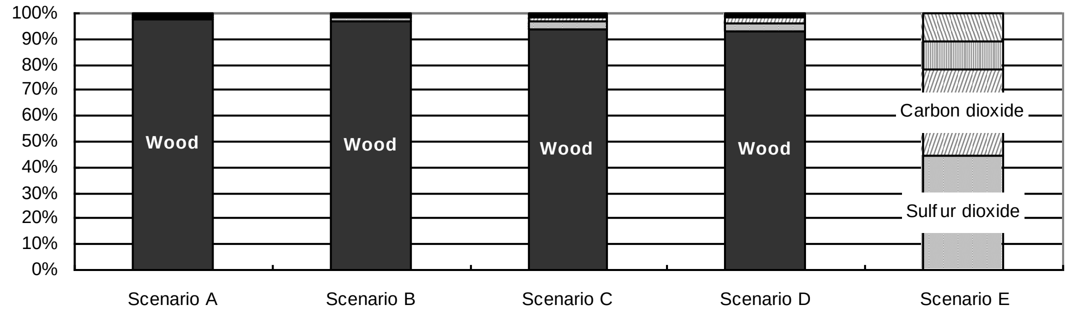


Figure 5.2-7 weighting result (breakdown by substance in each scenario)

Figure 5.2-8 shows the weighting result in terms of process in each scenario. The material process was responsible for most of the environmental load in Scenarios A through D while the logistics, material, and manufacturing processes accounted for 49%, 38%, and 17%, respectively, of the environmental load in Scenario E.

In terms of the category of environmental impact, resources accounted for most of the environmental load in Scenarios A through D. In Scenario E, however, urban air pollution and global warming accounted for 48% and 32%, respectively, of the environmental impact in Scenario E. Urban air pollution was caused by NOx and SO_2, and global warming was caused by CO_2 emissions.

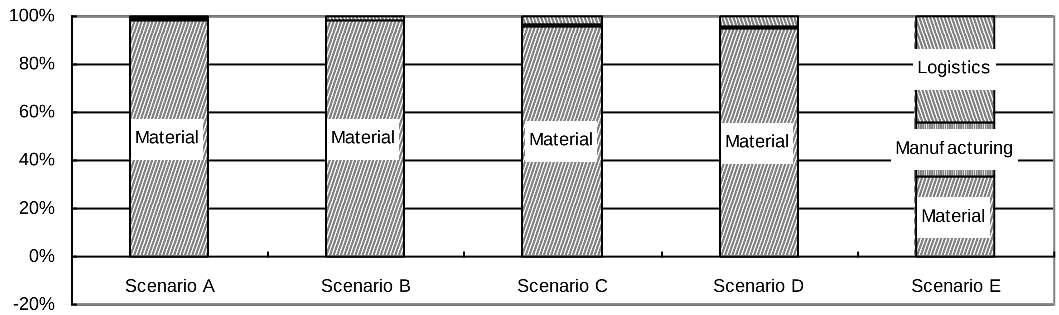


Figure 5.2-8 Weighting result (breakdown by process)

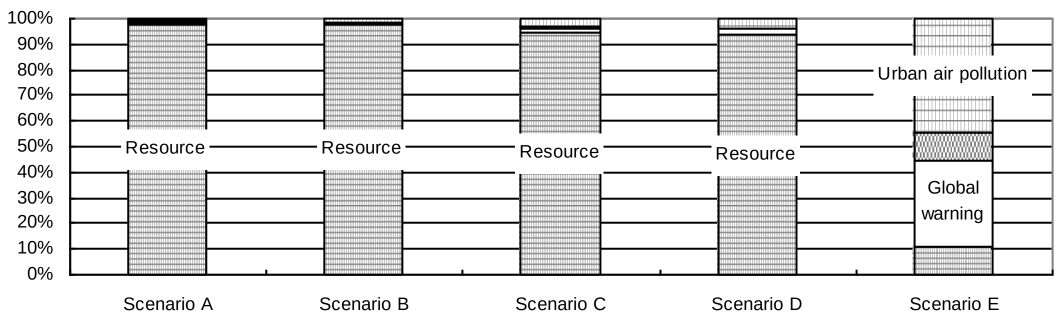


Figure 5.2-9 weighting result (breakdown by category)

6 Conclusion

6.1 Summary of the Study Result

The environmental impact assessment of the entire life cycle, including substituted values for recycling, was conducted with a paper cup for beverages. In this study, we looked at how LCA results would be influenced by where the wood used for the base paper in paper cups was sourced, namely from planted forests or natural forests. Such sensitivity analysis was carried out because the main raw material of a paper cup was wood and previous studies had shown that the paper production process had a relatively high environmental load.

When base paper for paper cups was procured in the same way as paper in general, the weighting result for the entire life cycle (including substituted values obtained when 4% of used paper cups was collected and recycled) showed that the social cost was 3.51 yen. Of which, 3.42 yen was attributed to wood.

In wood procurement, forestation and forest certification programs have been implemented in order to realize sustainable wood procurement. It should be noted, however, not all base paper for paper cups was procured from properly managed forests.

If all wood was procured from forests under sustainable management (with no adverse effects on primary production and biodiversity), as shown in the weighting result, the social cost was 0.09 yen. The social cost was 3.51 when base paper for paper cups was procured in the same way as paper in general. There was therefore a large difference in social costs, suggesting the importance of forest management.

6.2 Limitations of the Study and Future Tasks

In this study, data on procurement of paper in general was used since data specifically on procurement of base paper for paper cups was not available. The data for paper in general, however, was not complete, and thus there were some assumptions in this study:

- Paper was in fact procured from multiple paper manufacturers, but procurement data could be obtained from only one manufacturer. Therefore, it was assumed in this study that paper was procured from only this company (or, it was assumed that the procurement conditions were the same at all manufacturers).

- Data on places of origin (countries or regions) was available. Cumulatively, for all procured wood, there was data on the ratio of trees from planted forests and natural forests. However, the ratio of trees from planted forests and natural forests in each country was not known. For this reason, it was assumed in this study that the ratio of trees from planted forests and natural forests was the same in all applicable countries and regions.

- It was assumed that a relatively large amount of wood leftover from logging was used to produce paper cups. However, data on just how much was not available; therefore, the rate of leftover wood used for paper cup production was assumed to be the same as for the rate of leftover wood used for general paper production.

It is therefore necessary in the future to carry out more fact-based LCA using data on procurement status specifically on base paper for paper cups. Then, using the result of the study thus conducted, it will be necessary to produce paper cups that would impose lower environmental loads by maximizing procurement and use of wood from forests under sustainable management.

Also, base paper used in production of paper cups is made of virgin pulp and does not contain any recycled paper. Used paper cups can become high quality recycled paper materials. Currently, only some used paper cups are collected and recycled. In the future, it will be necessary to improve the collection and recycling rates and also to explore more effective ways to use used paper cups.

Reference

1) Paper Cup Working Group,Printers Association of Japan: Environmental Impact Assessment of a Paper Cup by the Printers Association of Japan. http://www.jstage.jst.go.jp/article/ilcaj/2008/0/19/_pdf/-char/ja/ (see 2010-5-17)

2) The Institute for Policy Sciences: Survey Report on Container Package Life Cycle Assessment, pp.37-39, pp.52-52, and pp.104-107 (2005).

3) Nippon Paper Group 2009 CSR Report Detailed Version. http://www.np-g/com/csr/report_2009pdf_02html (see 20110-5-17)

4) Paper Cup Recycling Promotion Conference: FY2007 Material Flow after the Paper Cup Production Phase. http://www.alpha-research.co.jp/common/pdf/material_flow_19.pdf (see 2010-3-23)

■ Reference material: Procurement Data Preparation and Environmental Load

In this study, wood procurement data was prepared using the following procedure for environmental load calculation.

① For paper cup materials, check the ratio between broad leaf trees and needle leaf trees.

Material producer countries and tree species (FY2008)

Broad leaf trees

Country	In 1,000 bone dry tons	Ratio	Tree species
Australia	1,837.0	50.1%	Eucalyptus
Chile	678.8	18.5%	Eucalyptus
South Africa	652.1	17.8%	Eucalyptus, Acacia
Brazil	287.2	7.8%	Acacia
Uruguay	143.3	3.9%	Eucalyptus
America	50.8	1.4%	Oak mix
Thailand	18.9	0.5%	Eucalyptus
Total	3,668.1	100.0%	

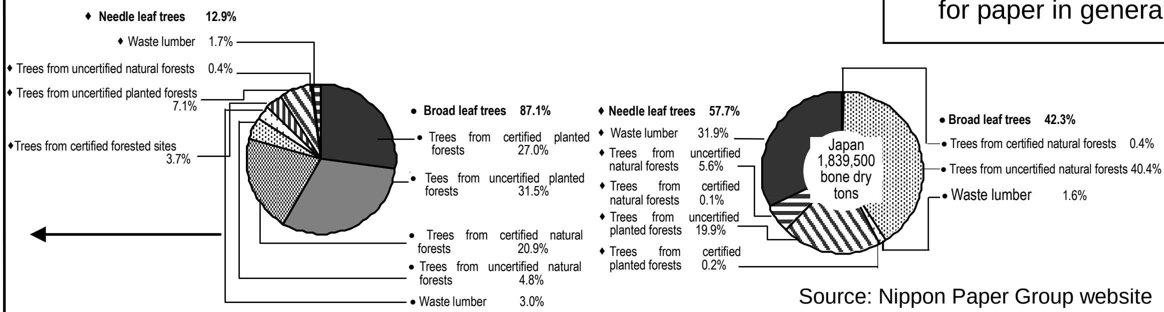
Broad leaf trees

Country	In 1,000 bone dry tons	Ratio	Tree species
Australia	418.0	77.2%	Pinus radiata
America	69.0	12.7%	Douglas fir
New Zealand	19.7	3.6%	Pinus radiata
Chile	18.3	3.4%	Pinus radiata
Russia	16.6	3.1%	Abies sanchalinensis
Total	541.6	100.0%	

Source: Nippon Paper Group w ebsite

② Identify paper producer countries (then, the broad leaf tree-needle leaf tree ratio must be adjusted for base paper for paper cups).

Breakdown of procured materials (FY2008)



Source: Nippon Paper Group website

③ Identify raw materials for paper in general.

④ Reorganize the material data based on the ratios excluding waste lumber (same ratio in each country).

		Trees from planted forests	Trees from natural forests	Total
Australia	%	%	%	100%
Chile	%	%	%	100%
South Africa	%	%	%	100%
(Waste lumber)	%	%	%	100%
Total	100%			

⑤ Add waste lumber through economic dispatch (see the next page for the dispatch method).

⑥ Use country- and category-specific coefficients to calculate environmental loads.

Primary production

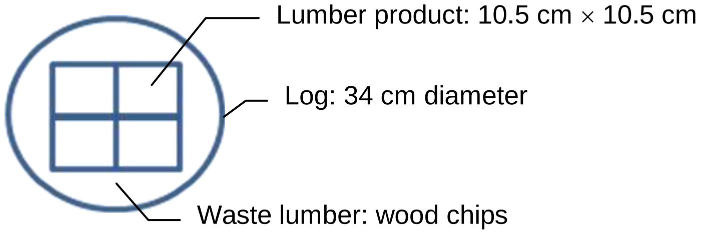
Biodiversity

[Economic dispatch of waste lumber]

* Approximately 11.7% of wood chips used in production of base paper for paper cups is waste lumber and is subject to economic dispatch as described below (environmental load was calculated for the remaining 88.3% without economic dispatch).

* Economic dispatch was based on: the price of a square of abies sanchalinensis lumber with a cross section of 7.5 × 7.5 cm or larger for lumber products; and the price of needle leaf tree wood chips for waste lumber. Prices of these lumber products and wood chips were based on the Statistics of the Ministry of Agriculture, Forestry and Fisheries on Wood Prices (March 2010) (approximate figures).

* The wood chip price was not only for chips made from waste lumber; it was also for chips made from logs.



* Weight ratio between lumber products and wood chips
  - The bottom area of a log (34 cm diameter) is 907.46 m^2 (100%)
  - The bottom area of 4 pieces of a 10.5 × 10.5 cm square log is 441.00 m^2 (48.6%)
  - The bottom area of the log that becomes waste lumber is 466.46 m^2 (51.4%)

* Weight of lumber and waste lumber that can be obtained from 1 ton of logs (the bottom area ratio is directly translated into the weight ratio)
  - Lumber: 0.486 tons
  - Waste lumber: 0.514 tons

* Economic value of lumber (lumber products) and wood chips (waste lumber) that can be obtained from 1 ton of logs (unit price × weight)
  - Lumber: 116,047 yen/t × 0.486 tons = 56,395 yen (89.6%)
  - Wood chips: 12,700 yen/t × 0.51 tons = 6,528 yen (10.4%)
  - Total (per ton of logs): 62,923 yen (100.0%)

* Log weight required for acquisition of 1 ton of wood chips
  - Lumber 0.95 tons (0.486 divided by 0.514)
  - Wood chips: 1.00 tons
  - Total: 1.95 tons

* Therefore, the environmental load of 1 ton of wood chip equals 10.4% of logs weighing 1.95 tons. (Wood chip weight × 1.95 × 10.4% × coefficient = environmental load of wood chips made from waste lumber)

● Procurement of wood chips for paper production for paper cups (Scenario A)

Place of origin			Inventory per 1 kg of lumber	Primary production Coefficient	Primary production Impact	Biodiversity Coefficient	Biodiversity Impact
Broad leaf	Australia	Certified planted forest	1.05E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
trees	3.27E-01	Uncertified planted forest	1.22E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Certified natural forest	8.11E-02	2.30E+00	1.86E-01	1.97E-11	1.60E-12
8.16E-01		Uncertified natural forest	1.86E-02	2.30E+00	4.28E-02	1.97E-11	3.67E-13
	Chile	Certified planted forest	3.87E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	1.21E-01	Uncertified planted forest	4.52E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Certified natural forest	3.00E-02	1.16E+00	3.47E-02	2.86E-11	8.58E-13
		Uncertified natural forest	6.88E-03	1.16E+00	7.97E-03	2.86E-11	1.97E-13
	South Africa	Certified planted forest	3.72E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	1.16E-01	Uncertified planted forest	4.34E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Certified natural forest	2.88E-02	8.60E-01	2.48E-02	1.37E-10	3.95E-12
		Uncertified natural forest	6.61E-03	8.60E-01	5.69E-03	1.37E-10	9.06E-13
	Brazil	Certified planted forest	1.64E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	5.11E-02	Uncertified planted forest	1.91E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Certified natural forest	1.27E-02	8.60E-01	1.09E-02	1.37E-10	1.74E-12
		Uncertified natural forest	2.91E-03	8.60E-01	2.50E-03	1.37E-10	3.99E-13
	Uruguay	Certified planted forest	8.18E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	2.55E-02	Uncertified planted forest	9.54E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Certified natural forest	6.33E-03	8.60E-01	5.44E-03	1.37E-10	8.67E-13
		Uncertified natural forest	1.45E-03	8.60E-01	1.25E-03	1.37E-10	1.99E-13
	America	Certified planted forest	2.90E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	9.04E-03	Uncertified planted forest	3.38E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Certified natural forest	2.24E-03	1.51E+00	3.39E-03	1.47E-11	3.29E-14
		Uncertified natural forest	5.15E-04	1.51E+00	7.79E-04	1.47E-11	7.56E-15
	Japan	Certified planted forest	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	1.38E-01	Uncertified planted forest	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Certified natural forest	1.35E-03	1.71E+00	2.31E-03	1.93E-11	2.61E-14
		Uncertified natural forest	1.37E-01	1.71E+00	2.33E-01	1.93E-11	2.64E-12
	Lumber	Russian planted forest	9.51E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	2.85E-02	Russian natural forest	5.63E-03	1.37E+00	8.03E-04	7.41E-12	4.33E-15
		North American planted forest	4.58E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		North American natural forest	2.71E-03	1.51E+00	4.25E-04	1.47E-11	4.12E-15
		South-sea planted forest	6.34E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		South-sea natural forest	3.75E-03	2.59E+00	1.01E-03	1.98E-10	7.71E-14
		Other planted forest	1.44E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Other natural forest	8.55E-03	8.60E-01	7.62E-04	1.37E-10	1.22E-13
Needle leaf	Australia	Certified planted forest	1.41E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
trees	4.27E-02	Uncertified planted forest	2.70E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Certified natural forest	0.00E+00	2.30E+00	0.00E+00	1.97E-11	0.00E+00
1.84E-01		Uncertified natural forest	1.52E-03	2.30E+00	3.50E-03	1.97E-11	3.00E-14
	America	Certified planted forest	2.33E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	7.04E-03	Uncertified planted forest	4.46E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Certified natural forest	0.00E+00	1.51E+00	0.00E+00	1.47E-11	0.00E+00
		Uncertified natural forest	2.52E-04	1.51E+00	3.80E-04	1.47E-11	3.69E-15
	Chile	Certified planted forest	6.17E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	1.87E-03	Uncertified planted forest	1.18E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Certified natural forest	0.00E+00	1.16E+00	0.00E+00	2.86E-11	0.00E+00
		Uncertified natural forest	6.67E-05	1.16E+00	7.72E-05	2.86E-11	1.91E-15
	Japan	Certified planted forest	4.33E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	5.58E-02	Uncertified planted forest	4.31E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Certified natural forest	2.16E-04	1.71E+00	3.70E-04	1.93E-11	4.18E-15
		Uncertified natural forest	1.21E-02	1.71E+00	2.07E-02	1.93E-11	2.34E-13
	Lumber	Russian planted forest	2.56E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	7.69E-02	Russian natural forest	1.52E-02	1.37E+00	2.16E-03	7.41E-12	1.17E-14
		North American planted forest	1.23E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		North American natural forest	7.30E-03	1.51E+00	1.15E-03	1.47E-11	1.11E-14
		South-sea planted forest	1.71E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		South-sea natural forest	1.01E-02	2.59E+00	2.72E-03	1.98E-10	2.08E-13
		Other planted forest	3.89E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Other natural forest	2.30E-02	8.60E-01	2.05E-03	1.37E-10	3.27E-13
Total	1.00E+00		1.10E+00		5.99E-01		1.48E-11

1.95E+00 tons of lumber are required to produce 1 ton of wood chips.

Economic value of wood chips with respect to lumber: 10.4%

Report on Environmental Impact Assessment of Ethanol Production Using Rice Straw as a Raw Material

March 2010

National Institute of Advanced Industrial Science and Technology

1 General

1.1 Persons in charge of the assessment

Names: Masaharu Motoshita and Cuifen Yang
Organization: Research Institute of Science for Safety and Sustainability, National Institute of Advanced Industrial Science and Technology
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1.2 Date of Report Creation

April 29, 2010

2 Study Objective

2.1 Background of the Study

We conducted this study to assess the environmental impacts of ethanol made of rice straw as a raw material, to identify influential processes in ethanol production, and to discuss differences in the level of environmental impacts attributed to the utilization of its byproducts.

2.2 Application of the Result

The result is expected to promote the reduction of environmental impacts caused by the operation of plants.

3 Scope of the Study

3.1 Product system

The product system is the ethanol production process using from rice straw. The rice straw is naturally dried on a farm field after being harvested, compressed, packaged, and transported to the plant by trucks. Transported material rice straw is hydrolyzed with concentrated sulfuric acid and subsequently fermented to produce ethanol. Two scenarios for the use of a byproduct (lignin) were assumed to be assessed. Lignin produced in the hydrolyzing process is utilized as a fuel of boilers for production of electricity and steam in one scenario (scenario 1: with a lignin-fueled boiler), and is filled in a land as waste in the other scenario (scenario 2: without a lignin-fueled boiler).

3.2 Function and Functional Unit

The functional unit is to produce 1GJ of ethanol from unutilized or low utilized rice straw (ethanol yield: 0.236 L/kg).

3.3 System boundary

All processes from rice straw collection to transportation of produced ethanol including the processes of crushing, hydrolyzing, and fermenting raw material were assessed. Rice straw production was not included in the assessment (Figures 3.2-1 and 3.2-2).

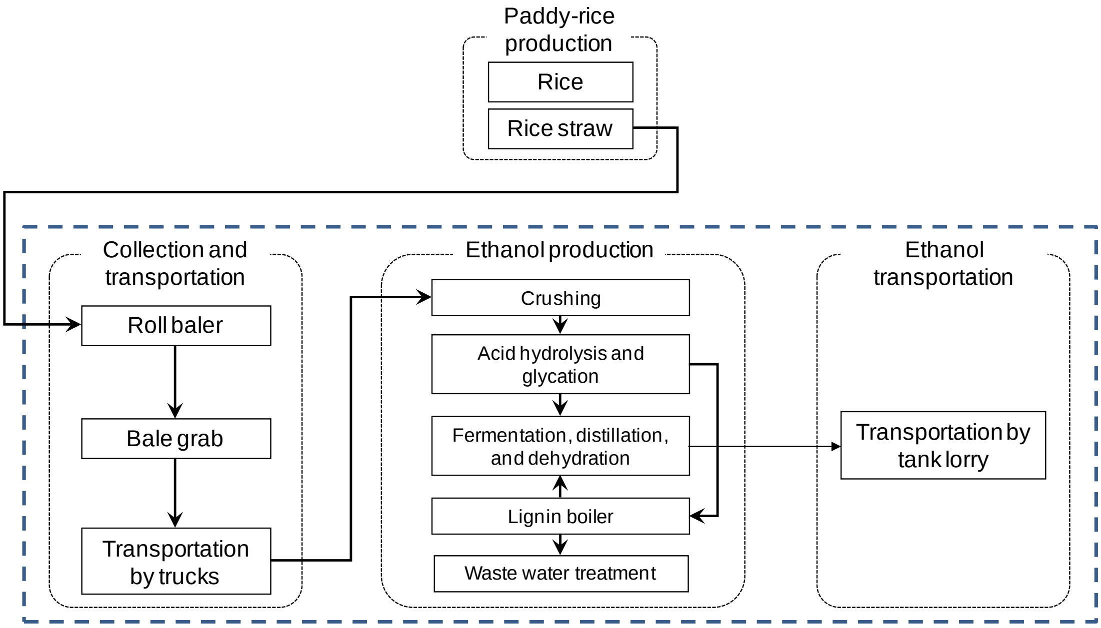

Figure 3.2-1 System boundary for the assessment of ethanol production from rice straw (scenario 1: with a lignin-fueled boiler)

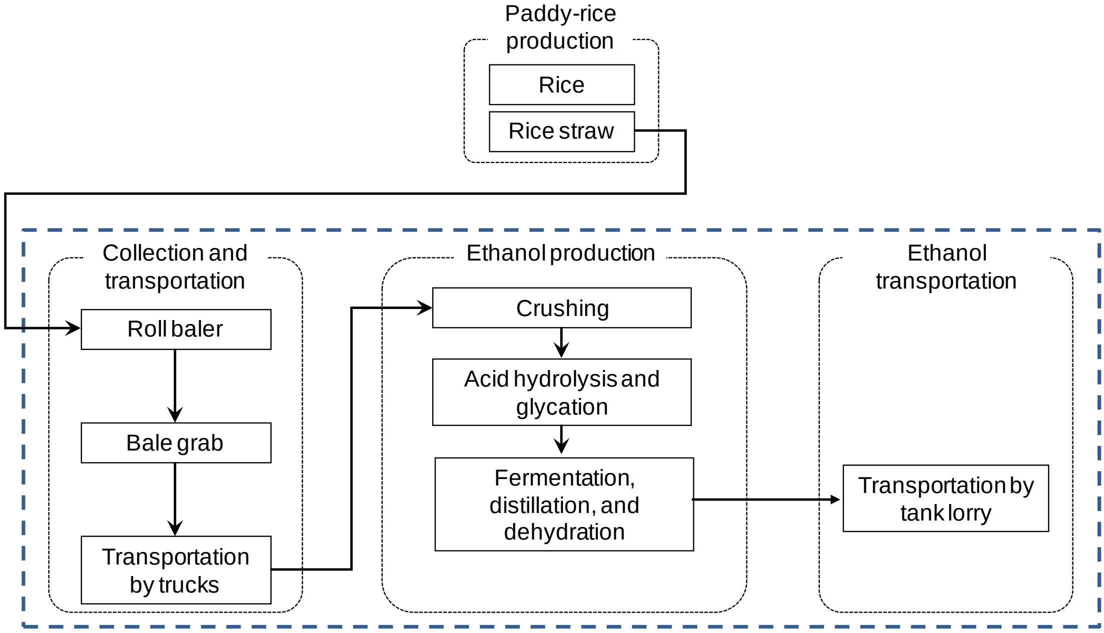

Figure 3.2-2 System boundary for the assessment of ethanol production from rice straw (scenario 2: without a lignin-fueled boiler)

3.4 Note (Processes or Items Excluded from the System Boundary)

Raw material of the assessed ethanol production system (unutilized or low utilized rice straw) is incinerated or plowed into the soil as an agricultural residue. Thus, the production process of rice straw is excluded from system boundary. However, energy and materials used in rice cropping should be allocated to not only rice but also byproducts (rice straw and chaff) in the case of additional rice production for the purpose of utilizing idled arable land. Furthermore, rice straw is widely used for composting, feed production, ethanol, and soil reduction. Allocation to these purposes should also be considered.

4 Inventory Analysis

4.1 Data of a Unit Process

Input data of energy and materials in each process was obtained from the previous case study[1)].

4.2 Background Data

Inputs and outputs data on energy and materials was referred from LCA software (AIST-LCA ver.4).

4.3 Inventory Analysis and List of Analysis Results

Table 4.3-1 shows the results of inventory analysis for each item in two scenarios.

Table 4.3-1 The result of LCI analysis in two scenarios (kg/f.u.)

			Scenario 1 (with a lignin-fueled boiler)				Scenario 2 (without a lignin-fueled boiler)			
			Collection and transportation	Ethanol production	Ethanol transportation	Total	Collection and transportation	Ethanol production	Ethanol transportation	Total
Resources	Al (resource)	kg		6.75E-03		6.75E-03		6.75E-03		6.75E-03
	Cu (resource)	kg		1.05E-01		1.05E-01		1.05E-01		1.05E-01
	Pb (resource)	kg		3.81E-02		3.81E-02		3.81E-02		3.81E-02
	U (resource)	kg	1.25E-08	8.32E-05	1.62E-09	8.32E-05	1.60E-08	2.70E-04	3.24E-09	2.70E-04
	Zn (resource)	kg		2.13E-01		2.13E-01		2.13E-01		2.13E-01
	Quartz sand (resource)	kg		3.45E-02		3.45E-02		3.45E-02		3.45E-02
	Limestone (resource)	kg		3.81E+00		3.81E+00		3.61E+00		3.61E+00
	Crude oil (resource)	kg	1.56E+00	8.52E-01	5.20E-01	2.94E+00	2.69E+00	1.84E+01	1.04E+00	2.21E+01
	Coal	kg	5.80E-04	9.44E-01	2.12E-04	9.45E-01	1.04E-03	2.95E+00	4.24E-04	2.95E+00
	Natural gas (resource)	kg	2.35E-02	5.11E-01	7.80E-03	5.43E-01	4.03E-02	1.87E+00	1.56E-02	1.93E+00
Air	CO_2	kg	5.02E+00	7.98E+00	1.66E+00	1.47E+01	8.62E+00	7.51E+01	3.33E+00	8.70E+01
	CH_4	kg	3.90E-05	1.66E-04		2.05E-04	3.90E-05	1.91E-03		1.95E-03
	N_2O	kg	8.15E-05	2.70E-04	2.69E-05	3.78E-04	1.40E-04	1.65E-03	5.38E-05	1.85E-03
	NMVOC	kg	6.72E-04	3.67E-04	3.09E-04	1.35E-03	1.34E-03	1.15E-03	6.18E-04	3.10E-03
	NOx	kg	5.37E-04	2.86E-03	4.36E-05	3.45E-03	6.32E-04	3.58E-02	8.72E-05	3.65E-02
	NOx (mobile emission source)	kg	1.47E-02	1.07E-03	6.81E-03	2.26E-02	2.95E-02	2.08E-03	1.36E-02	4.52E-02
	SOx	kg	1.30E-04	2.56E-03	2.30E-05	2.71E-03	1.79E-04	9.07E-02	4.60E-05	9.09E-02
	SOx (mobile emission source)	kg	7.36E-04		3.40E-04	1.08E-03	1.47E-03		6.81E-04	2.15E-03
	Dust	kg	5.92E-05	1.67E-04	3.10E-06	2.29E-04	6.59E-05	8.66E-03	6.20E-06	8.73E-03
	PM10 (mobile emission source)	kg	4.71E-04	7.84E-05	2.18E-04	7.67E-04	9.42E-04	1.53E-04	4.35E-04	1.53E-03
	As	kg	7.03E-12	7.44E-08		7.44E-08	7.03E-12	2.42E-07		2.42E-07
	Cd	kg	5.81E-13	6.15E-09		6.15E-09	5.81E-13	2.00E-08		2.00E-08
	Cr	kg	1.28E-11	1.35E-07		1.35E-07	1.28E-11	4.40E-07		4.40E-07
	Hg	kg	8.49E-12	8.98E-08		8.98E-08	8.49E-12	2.92E-07		2.92E-07
	Ni	kg	1.44E-11	1.52E-07		1.52E-07	1.44E-11	4.94E-07		4.94E-07
	Pb	kg	3.37E-11	3.56E-07		3.56E-07	3.37E-11	1.16E-06		1.16E-06
Water	As	kg		6.70E-08		6.70E-08		6.70E-08		6.70E-08
	Cd	kg		1.01E-08		1.01E-08		1.01E-08		1.01E-08
	Cr	kg		2.01E-07		2.01E-07		2.01E-07		2.01E-07
	Hg	kg		6.70E-09		6.70E-09		6.70E-09		6.70E-09
Industrial	Debris (landfill)	kg		1.55E-03		1.55E-03		1.55E-03		1.55E-03
	Slag (landfill)	kg		2.83E-01		2.83E-01		2.83E-01		2.83E-01
	Waste plastics (landfill)	kg		7.80E-04		7.80E-04		7.80E-04		7.80E-04
	Industrial waste and landfill waste (unspecified)	kg		1.84E-02		1.84E-02		1.84E-02		1.84E-02
	Sludge (landfill)	kg		2.00E+00		2.00E+00		4.91E+01		4.91E+01

5 Impact Assessment

5.1 Assessment Steps and Impact Categories

LIME2 (Life cycle Impact assessment Method based on Endpoint modeling 2) was used to assess the impacts of the target product system accoding to the following three steps: characterization, damage assessment, and weighting. Table 5.1-1 shows the target impact categories in each step.

Table 5.1-1 Impact categories in each assessment step

	Characterization	Damage assessment	Weighting
Resource consumption (energy)	○	○	○
Resource consumption (mineral)	○	○	○
Global warming	○	○	○
Urban air pollution	-	○	○
Ozone depletion			
Acidification	○	○	○
Eutrophication	○	○	○
Photochemical oxidant	○	○	○
Human toxicity	○	○	○
Ecotoxicity	○	○	○
Indoor air quality	-		
Noise	-		
Waste	○	○	○
Land use			

5.2 Results of Impact Assessment

5.2.1 Characterization

Characterization results on resource (energy) consumption and waste landfill are shown in Figures 5.2-1 and 5.2-2. A large part of impacts on energy consumption is attributed to crude oil consumption. Significant reduction of energy consumption can be achieved by utilizing lignin as a boiler fuel in scenario 1 (with a lignin-fueled boiler). On the other hand, the impact on waste landfill is also larger in scenario 2 (without a lignin-fueled boiler) compared to scenario 1 due to the increase of landfill volume of wasted lignin. Therefore, the key to successful environmental impact reduction is how to utilize lignin generated during hydrolysis effectively. Utilization of lignin as a boiler fuel is expected to contribute to the reduction of the environmental impacts from the perspectives of both suppressions of energy consumption and waste landfill.

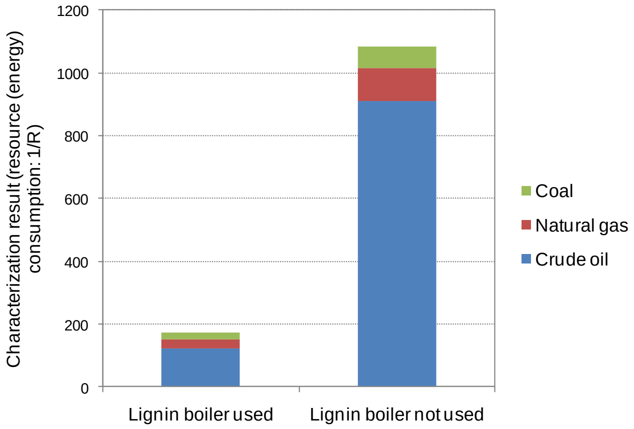

Figure 5.2-1 Characterization result (energy consumption)

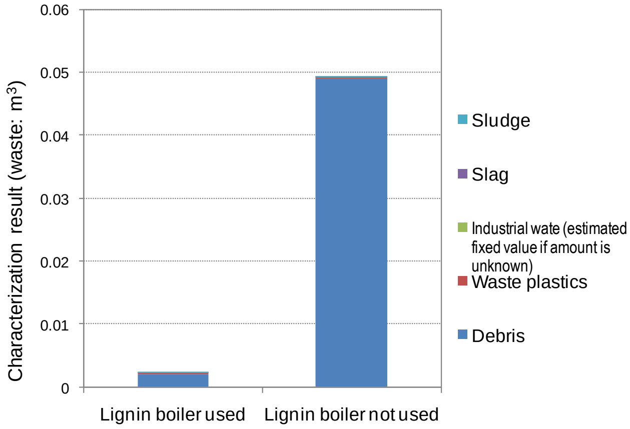

Figure 5.2-2 Characterization result (waste)

5.2.2 Damage Assessment

The results of damage assessment (broken down by substance) for four endpoints are shown in Figure 5.2-3, 5.2-4, 5.2-5, and 5.2-6. The damage on all endpoints can be represed by utilizing lignin as a boiler fuel. Human health is greatly affected by CO_2 emissions, and in the scenario without a lignin-fueled boiler damage caused by sulfur dioxide emission is also large. The damaged on social assets caused by landfill of lignin (sludge landfill) dominate large part of total damage. The same tendency can be observed in both primary production and biodiversity. The results therefore suggest that to avoid the landfill of lignin can greatly contribute to the reduction of overall environmental damage.

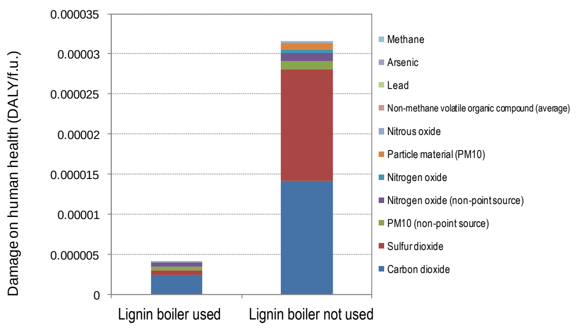

Figure 5.2-3 The result of damage assessment (human health)

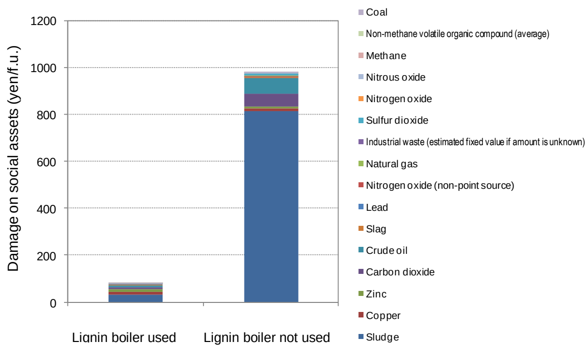

Figure.5.2-4 Damage assessment (social assets)

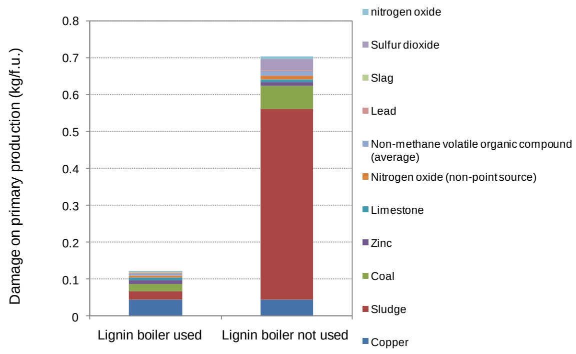

Figure 5.2-5 Damage assessment (primary production)

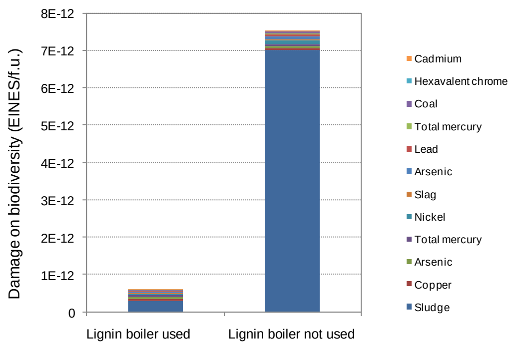

Figure.5.2-6 Damage assessment (biodiversity)

The results of damage assessment for four endpoints are broken down by processes. The production process was responsible for a large part of the overall damage on every endpoint. Landfill of lignin contributes to the increase of the damage on social assets, primary production, and biodiversity as shown in Figures 5.2-4, 5.2-5, and 5.2-6. Concerning on human health, the damage caused by energy consumption for fermentation, distillation, and dehydration dominates large part of total damage, and it can be significantly reduced by utilizing lignin as a boiler fuel (Figures 3.2-1 and 3.2-2).

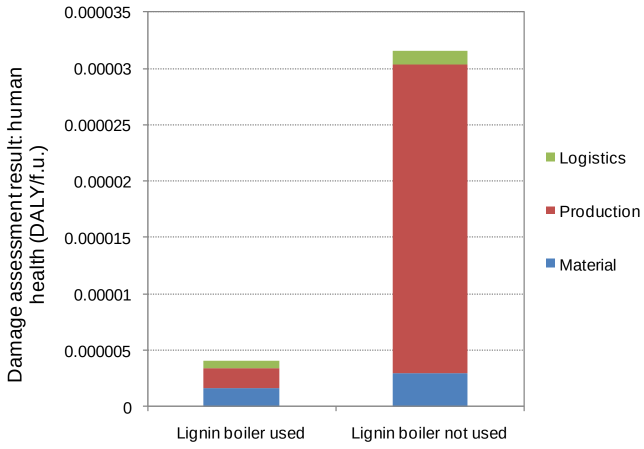

Figure 5.2-7 Damage assessment (human health)

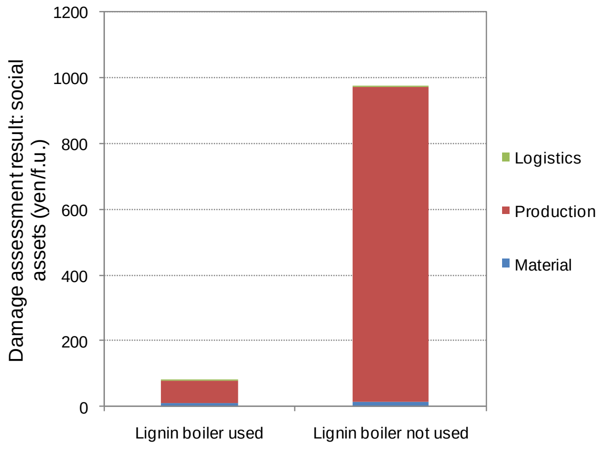

Figure 5.2-8 Damage assessment (social assets)

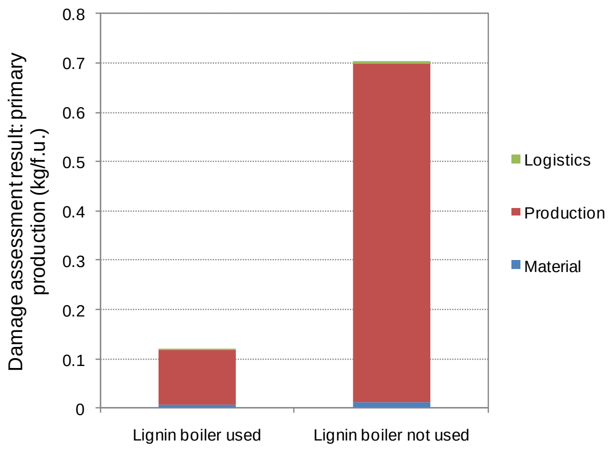

Figure 5.2-9 Damage assessment (primary production)

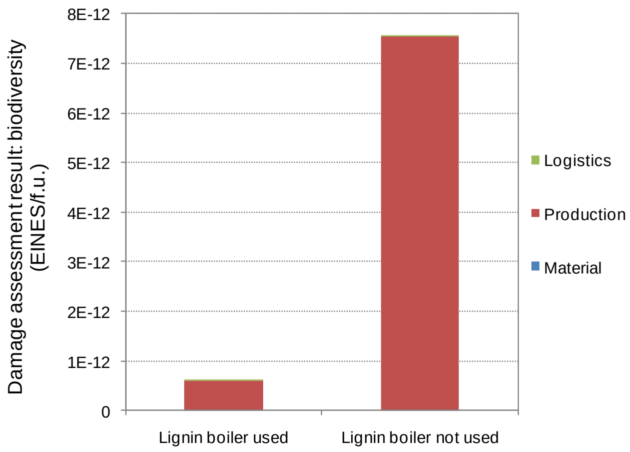

Figure.5.2-10 Damage assessment (biodiversity)

5.2.3 Weighting

Figure 5.2-11 shows the result of weighting (broken down by substances). It clearly indicates that the use of a lignin-fueled boiler could lead to the significant reduction of the overall environmental impact. Especially, the environmental impacts of CO_2 emission, sludge (lignin) landfill, and particle matter (PM10) emission are large, and the effective utilization of lignin can reduce the environmental impacts caused by these substances.

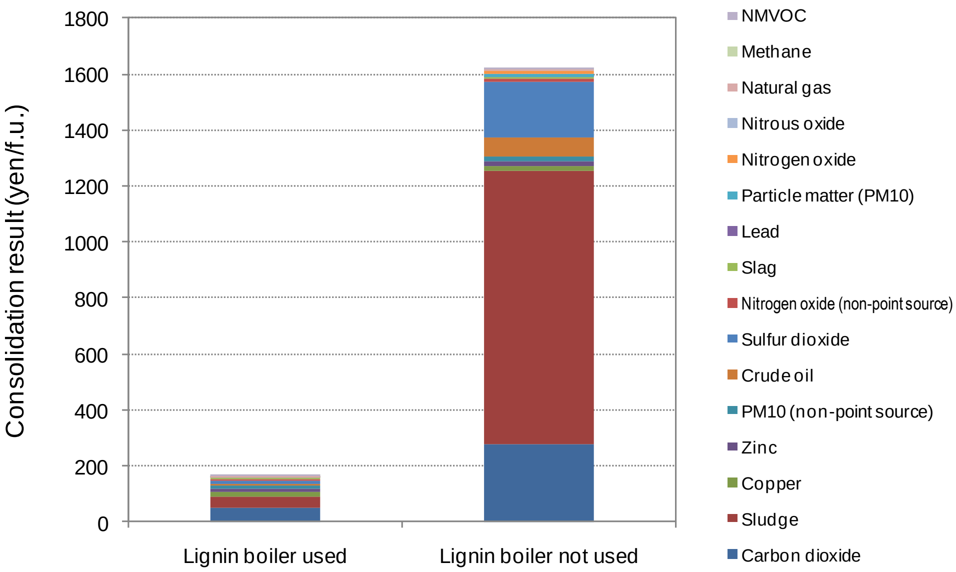

Figure 5.2-11 weighting result (by substance)

5.2.4 Comparison with Gasoline

Figure 5.2-12 and 5.2-13 show CO_2 emissions and the result of weighting in two scenarios and the case of gasoline use. LCI data on gasoline was referred to AIST-LCA ver. 4 and impact assessment was conducted by using LIME2.

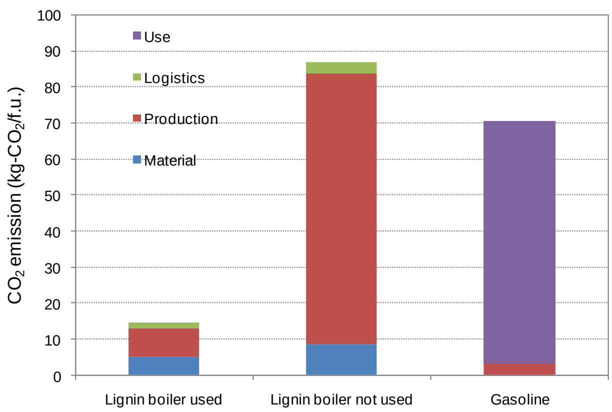

Figure 5.2-12 CO_2 emissions (by life stage)

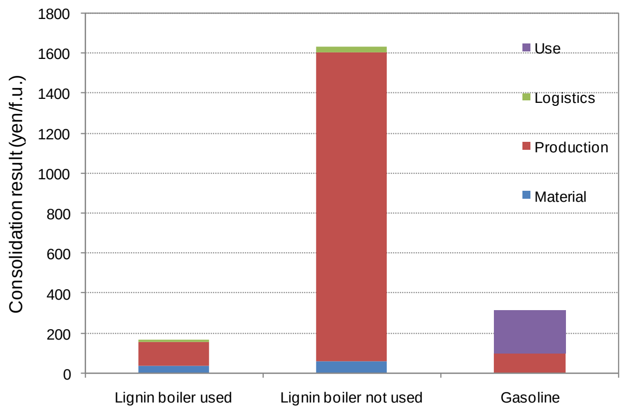

Figure 5.2-13 weighting result (by life stage)

CO_2 emissions from combustion of ethanol made of rice straw are not included in the assessment because of biomass-derived CO_2. Therefore, as shown in Figure 5.2-12, the use of a lignin-fueled boiler can reduce CO_2 emission more than that in the case of gasoline (approximately 1/5). Meanwhile, the result of weighting (Figure 5.2-13) includes the environmental impacts caused not only by CO_2 emissions but also other factors. Thus, the environmental impact of bio-ethanol produced with a lignin-fueled boiler is estimated for approximately half of that in the case of gasoline. The difference between bio-ethanol and gasoline becomes smaller in terms of weighting result than in terms of CO_2 emission. However, note also that it has been pointed out that there is a risk of toxic byproducts emission during bio-ethanol combustion in previous studies. Although this issue was not taken into account in this study, the environmental impact of this toxic byproducts emission may affect the conclusion of this report if it were included in the assessment.

5.2.5 Case Example of Other Types of Bio-Ethanol

As a reference information, Figure 5.2-14 shows the result of weighting on bio-ethanol made of sugar canes by LIME, conducted by Sagisaka, et al (2006). The result shows that bio-ethanol made of sugar canes causes an extremely large environmental impact. In this case, the environmental impact on land use is also assessed, and the result shows that the land use dominates quite a large part of the environmental impact. This suggests that the effect of land use change to produce bio-ethanol will not be negligible. Also, the larger impact of urban air pollution is found in the case of bio-ethanol than the case of gasoline, compared to the difference in the impact of global warming. This seems to be largely caused by the difference of grid mix in the areas of both cases. Therefore, the type of fuel used and grid mix may affect the conclusion of the assessment.

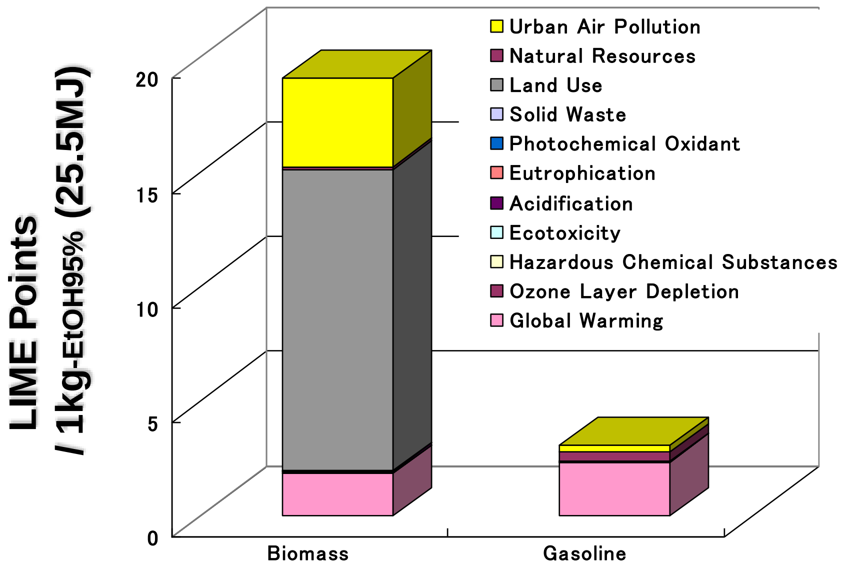

Figure 5.2-14 The result of weighting for sugar cane-derived bio-ethanol and gasoline based on LIME

6 Conclusion

6.1 Summary

The environmental impacts caused by ethanol production from rice straw were assessed by using LIME2 methodology. It was found that energy consumption for fermentation, distillation, and dehydration processes after hydrolysis of rice straw dominated a large part of the overall environmental impact. The utilization of lignin, generated during hydrolysis, as a boiler fuel can reduce the environmental impact of not only energy consumption but also waste landfill and holds the reduction of the overall environmental impact to approximately 1/10.

6.2 Limitations of and Future Tasks

The result showed that the effects of transportation of rice straw and ethanol were not significant. Since the analysis was conducted according to the scenarios assumed standard conditions, it is necessary to calculate the environmental impact of transportation more precisely in each scenario for further improvement of the assessment. Also, it was assumed that the raw material was unutilized or low utilized rice straw (generally incinerated in present situation); therefore, the environmental load of rice cropping was not included in the assessment. For the comparison of the environmental impacts of different fuels, it is necessary to include the environmental loads of raw material production in the assessment. In this case, allocation of environmental loads from rice cropping to products (polished rice, rice straw, and chaff) should be carefully considered.

References

1) C. Yang and M. Sakisaka: Assessment of Bio-Ethanol Production Using Rice Straw, Journal of the Institute of Life Cycle Assessment, Japan, Vol.5, No.4, pp.501-509, 2009

2) Sagisaka, M., T. Ohtani, Y. Kaji, K. Tahara and K Kobayashi: Fluctuation of Environmental Burden Induced by Uncertainty of Biomass Production, Bangkok, 2006

Report on the Method of Filling a PET Bottle Using Lower Water Consumption

June 2010

Dai Nippon Printing Co., Ltd.

1 General

1.1 Evaluators

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1.2 Date of Report Creation

July 17, 2010

2 Study Objective

2.1 Background of the Study

We, Dai Nippon Printing (DNP), offer our customers not only PET bottles (preforms) but also the molding, filling, and packaging system that DNP developed. When filling a PET bottle with a beverage, in addition to utilities such as electricity, a large amount of water is used for cleaning bottles and producing steam for heating. The aseptic filling method that DNP has traditionally used allows filling of PET bottles with a beverage that is sterilized at a high temperature for a short period of time. This method does not require much heat, and furthermore, with the use of a special sterilization method, the amount of water required for washing PET bottles can be reduced.

Recently, we received a number of requests from our customers for development of a new method that would allow more efficient use or saving of water, meaning development of a bottle filling method that would allow further reduction of water use. In the new method we thus developed, a molding machine and an aseptic filling machine are directly connected with each other such that the amount of water required to wash bottles can be reduced to approximately 1/6th compared to the conventional method. The new method also improves energy efficiency to reduce the amount of heat use.

In this study, we examined this new method to compare between the conventional and new methods through LIME2-based environmental impact assessment. In this assessment, we included water, the center of interest of the Water Footprint Network, as a subject of assessment.

2.2 Application of the Study Result

The study result will be used to promote understanding of the environmental impact of each filling method and also to advertise advantages of the new method.

3 Scope of the Study

3.1 Subjects and their Specifications

Two aseptic PET bottle filling systems (from the preform molding phase to the content sterilization, bottle molding, filling, labeling, and disposal phases) using the conventional and the newly developed filling process, respectively.

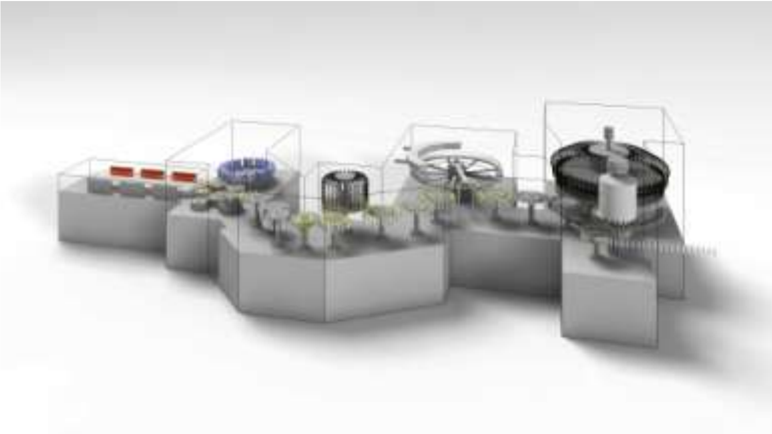

Figure 3.1.1 Image of an aseptic bottle filling system

① Conventional method
This is a Dai Nippon Printing's original sterilizing and filling method in which high-temperature hydrogen peroxide mists are blown into a bottle. This method realizes a high sterilization effect within a short period of time.

② New method
This is the advanced version of the conventional method. With the blow-molding device being directly connected to the aseptic filling device, energy efficiency has been improved and water consumption has been reduced.

3.2 Function and Functional Unit

A functional unit in this system was a system required for filling a PET bottle with 500 ml of low acid beverage (tea).

3.3 System Boundary

The subjects of assessment were the preform molding, content sterilization, bottle molding, filling, labeling, and disposal phases. The beverage itself was not included as a subject of assessment. In inventory analysis, the life cycle was defined as the phases from the beverage (tea) PET bottle preform molding phase to the disposal phase, and the entire life cycle was assessed. Assessment was carried out on 500-ml bottles for the amount produced in an hour (36,000 bottles). Environmental impact assessment was considered as performance assessment; therefore, only the filling phase was assessed.

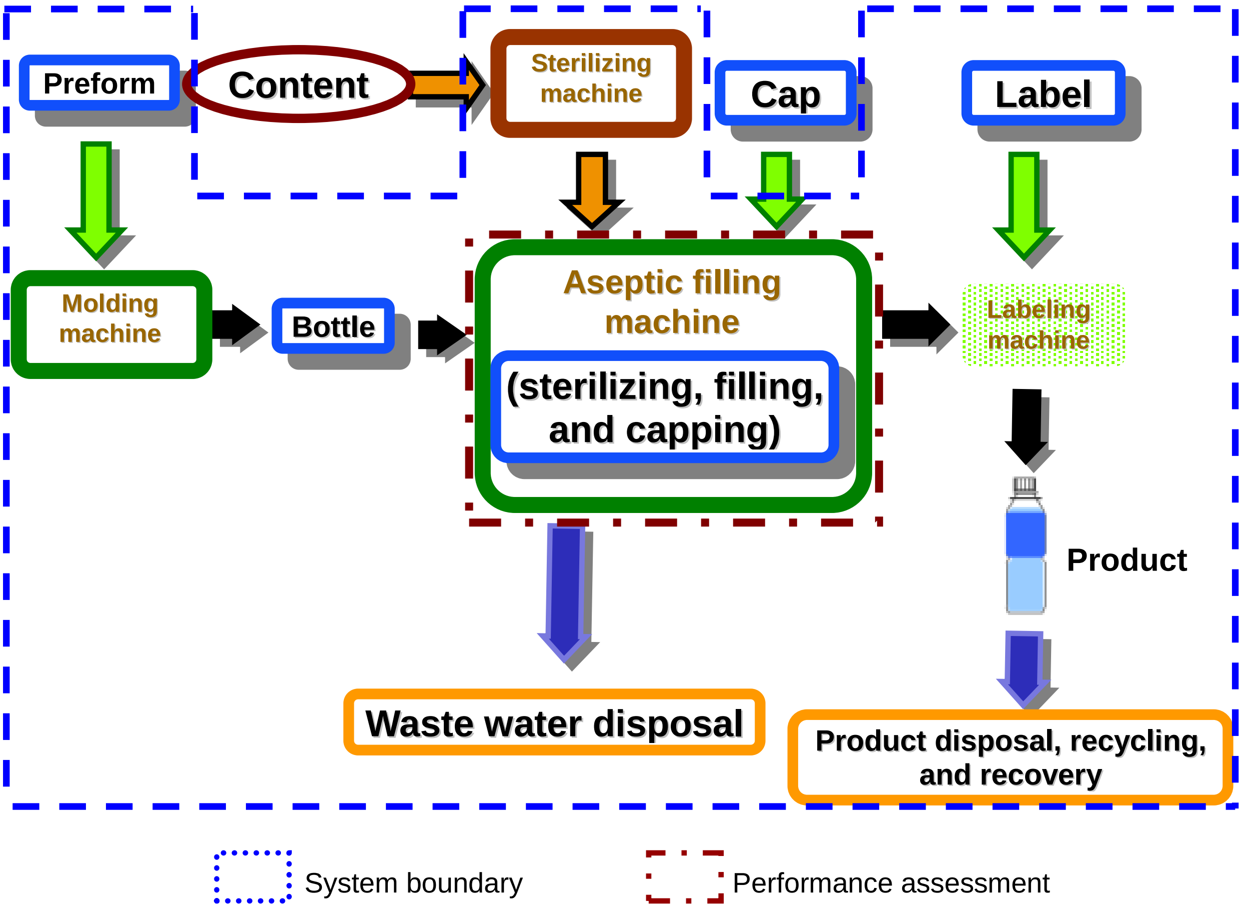

Figure 3.3-1 System boundary

3.4 Note (Processes or Items Excluded from the System Boundary)

Since there has been no established damage assessment coefficient for wastewater, it was excluded from the scope of the study. Energy used to treat wastewater, however, was included.

Also, there is no detailed public data on energy required to dispose of PET bottles, and so this was excluded from the scope of the study (emission data was included however) as well.

4 Inventory Analysis

4.1 Priority Data

We used the FY2008 data on the amount of use of materials, resources, and energy that had been obtained from bottle filling lines already installed at customers' plants.

4.2 Background Data

As background data, we used JEMAI-LCA Pro and JEMAI-LCA Option Datapack. Waste recovery was included in the disposal phase. We also used data provided by the Council for PET Bottle Recycling[1)] on what was involved in handling 1g of used PET bottle and also on industry average recycling data for heat-resistant 500ml bottles (collection rate: 62.3%).

4.3 Subjects of Inventory Analysis and a List of Analysis Results

Table 4.3-1 shows the subjects of inventory analysis of the new aseptic PET bottle filling method and a list of some of the analysis results. The analysis result data for the conventional filling method has been omitted since the subjects of inventory analysis are the same as for the new filling method.

Table 4.3-1 LCI analysis result for the aseptic PET bottle filling system [new system] (in kg/f.u.)

		Item	Unit	Preform molding	Content sterilization	Bottle molding	Filling	Labeling	Disposal
Consumption-related loads	Non-renewable resources	Coal	kg	1.41E+02	6.51E+00	7.46E+01	5.09E+01	3.04E+01	1.26E+01
		Crude oil (resource)	kg	1.16E+03	2.61E+02	1.38E+01	1.64E+02	1.27E+02	4.87E+00
		Natural gas	kg	1.39E+02	3.02E+00	3.47E+01	2.37E+01	1.87E+01	5.99E+00
		Uranium (resource)	kg	1.24E-02	5.72E-04	6.57E-03	4.48E-03	2.67E-03	1.11E-03
		Cu (resource)	kg	2.98E-05	2.70E-03	0.00E+00	1.59E-04	2.64E-05	0.00E+00
		Al (resource)	kg	1.26E-04	1.14E-02		6.70E-04	1.12E-04	
		Pb (resource)	kg	9.61E-07	8.69E-05		5.11E-06	8.52E-07	
		Zn (resource)	kg	5.33E-06	4.82E-04		2.83E-05	4.72E-06	
		Limestone	kg	1.82E-04	1.65E-02		9.70E-04	1.62E-04	
	Recyclable resources	!!Process water	kg	1.26E+04	3.51E+03		4.75E+03	1.47E+03	1.36E+01
		!!Pure water	kg	2.53E+03				1.56E+02	
		!!Cooling water	kg	3.14E+05	2.51E+00		1.47E-01	1.93E+04	6.07E+02
		Water for hydropower generation	kg	4.25E+04	1.97E+03	2.26E+04	1.54E+04	9.19E+03	3.80E+03
Environmental emission-related loads	Outdoor air	CO_2	kg	2.09E+03	8.93E+02	3.42E+02	7.36E+02	4.00E+02	2.35E+02
		As	kg	1.17E-05	5.42E-07	6.24E-06	4.25E-06	2.54E-06	1.05E-06
		Cd	kg	9.70E-07	4.48E-08	5.16E-07	3.51E-07	2.10E-07	8.68E-08
		CH_4	kg	1.10E-01	2.37E-02	7.32E-03	1.87E-02	1.35E-02	1.71E-03
		Cr	kg	2.13E-05	9.86E-07	1.14E-05	7.74E-06	4.62E-06	1.91E-06
		Hg	kg	1.42E-05	6.54E-07	7.53E-06	5.13E-06	3.06E-06	1.27E-06
		N_2O	kg	1.18E-01	1.52E-02	1.48E-02	1.84E-02	1.43E-02	2.75E-03
		Ni	kg	2.40E-05	1.11E-06	1.28E-05	8.69E-06	5.19E-06	2.15E-06
		NMHC	kg	6.06E-02	3.99E-03	2.12E-02	1.57E-02	1.03E-02	4.26E-03
		NOx	kg	9.87E-01	4.49E-01	1.43E-01	3.51E-01	1.89E-01	-3.90E-01
		NOx (mobile emission source)	kg	1.31E-01	3.55E-03	4.03E-02	2.77E-02	1.98E-02	1.23E-02
		Pb	kg	5.62E-05	2.60E-06	2.99E-05	2.04E-05	1.22E-05	5.03E-06
		PM10 (mobile emission source)	kg	9.63E-03	2.61E-04	2.95E-03	2.03E-03	1.45E-03	9.01E-04
		SO_2	kg	1.84E+00	1.31E+00	6.42E-02	7.98E-01	3.92E-01	-4.87E-01
		Dust	kg	1.93E-01	1.28E-01	2.69E-03	7.56E-02	3.81E-02	1.04E-03
	Water	As	kg	1.25E-09	1.13E-07		6.66E-09	1.11E-09	
		Cd	kg	1.88E-10	1.70E-08		9.98E-10	1.66E-10	
		Hg	kg	1.25E-10	1.13E-08		6.66E-10	1.11E-10	
	Waste	Debris (landfill)	kg	3.90E-08	3.53E-06		2.08E-07	3.46E-08	
		Slag (landfill)	kg	5.04E-05	4.56E-03		2.68E-04	4.47E-05	
		Industrial waste (estimated fixed value if amount is unknown)	kg	7.92E+03	5.40E-04	4.60E-03	3.14E-03	4.86E+02	7.94E+01
		Waste plastics (landfill)	kg	1.96E-08	1.78E-06		1.05E-07	1.74E-08	

Carbon dioxide emission

Figure 4.3-1 shows the amount of carbon dioxide emission. The amount of carbon dioxide emission during the filling phase was approximately 20% of the total emission, and the study showed that the new filling method was able to reduce carbon dioxide emission by approximately 300 kg per hour, which would be translated into 7.2 tons per day. This was realized by reduction of use of electricity or steam as a result of energy efficiency improvement. Also note that the carbon dioxide emission decreased in the wastewater treatment phase due to the reduction of the amount of wastewater generated.

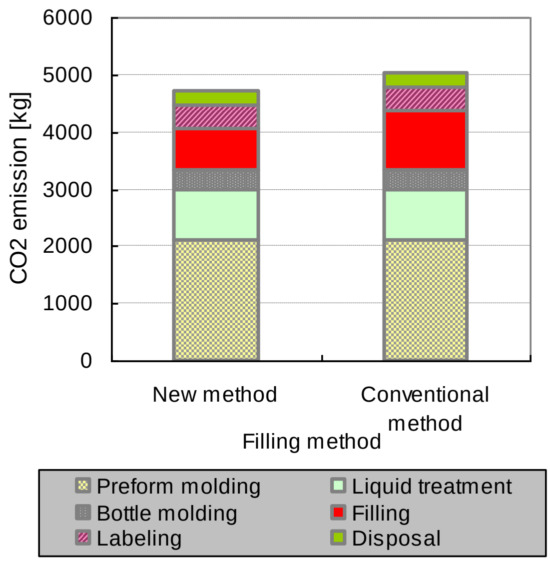

Figure 4.3-1 Carbon dioxide emission

Amount of use of water

Table 4.3-2 and Figure 4.3-2 show the analysis result for the amount of water used in the filling phase.

Table 4.3-2 Amount of water use

Filling method	New	Conventional
Water for hydropower generation (in tons)	17.1	18.7
Water for sterilization and cleaning (in tons)	3.0	18.0
Total	20.1	36.7

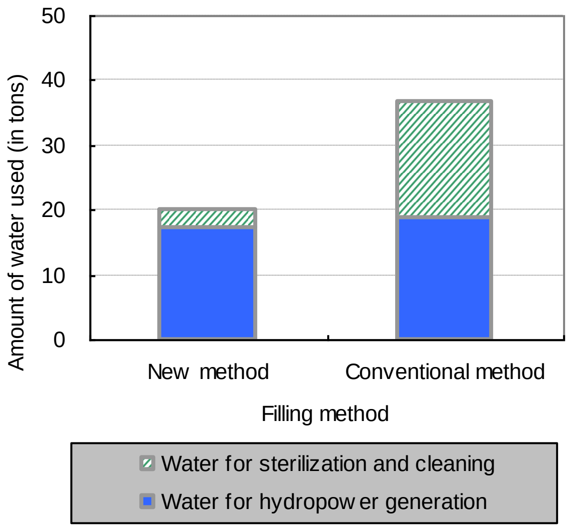

Figure 4.3-2 Amount of water use

Assessment of the amount of use of water indicated that, as shown in Table 4.3-2 and Figure 4.3-2, with the new method, it was possible to reduce the water usage amount to approximately 2/3 of the conventional method.　In particular, the amount of water used in sterilization and cleaning could be reduced to 1/6th of the conventional method, and this could be translated into reduction of the amount of water use by approximately 12 tons per hour.　Meanwhile, the amount of water used for hydropower generation did not decrease as much as the water used for sterilization and cleaning; however, it was still possible to save approximately 1.6 tons of water per hour.

5 Impact Assessment

5.1 Subject Assessment Steps and Areas of Impact

In the impact assessment, LIME2 (Life cycle Impact assessment Method based on Endpoint modeling 2) was used to assess the following three steps: characterization, damage assessment, and weighting.　Table 5.1-1 shows the areas of impact subject to the assessment in each step.

Table 5.1-1　Subject areas of environmental impact and assessment steps

	Damage assessment	Weighting
Resource consumption (energy)	○	○
Resource consumption (mineral)	○	○
Global warming	○	○
Urban air pollution	○	○
Ozone depletion	×	×
Acidification	○	○
Eutrophication	×	×
Photochemical oxidant	○	○
Human toxicity	×	×
Ecotoxicity	○	○
Indoor air quality	×	×
Noise	×	×
Waste	○	○
Land use	×	×
Use of water	○	○

5.2 Impact Assessment Result

5.2.1 Damage Assessment

Assessment of damage induced by water resource consumption was carried out using the two coefficients as follows:

A) "The List of Coefficients for Assessing Health Damage Caused by Water Resource Consumption (Preliminary Edition, as of October 18, 2009)"[2] provided by Mr. Motoshita of the National Institute of Advanced Industrial Science and Technology (AIST)

B) "Using GIS to Evaluate Regional Human Health Impacts from Water Use [3] by Anne-Marie Boulay, Jean-Baptiste Bayart, Cecile Bulle, Manuele Margni, and Louise Deschenes

5.2.1.1 Damage Assessment Using Coefficient A

Using Coefficient A as a coefficient for assessing damage caused by water resource consumption (refer to Section 5.2.1), country-specific damage was assessed for the amount of water used in the filling phase ("water consumption"). Countries selected as subjects of the assessments were the countries where our filling machines have been installed or may be installed in the future, and also the countries with high damage coefficients. We calculated health damage in a yen value by multiplying the health damage coefficient of each country by water consumption per hour. Table 5.2-1, Table 5.2-2, and Figure 5.2-1 show the results.

Table 5.2-1 Water-induced health damaged in countries where the aseptic filling system has been installed (Coefficient A)

Country	Health damage coefficient [DALYs/m^3]	Health damage per hour [yen]	
		New method	Conventional method
World average	9.47E-09	¥0.5	¥2.6
China	1.30E-10	¥0.0	¥0.0
Korea	6.72E-10	¥0.0	¥0.2
America	4.00E-09	¥0.2	¥1.1
Vietnam	5.92E-10	¥0.0	¥0.2
Japan	9.90E-10	¥0.1	¥0.3

Table 5.2-2 Water-induced health damaged in other countries (Coefficient A)

Country	Health damage coefficient [DALYs/m^3]	Health damage per hour [yen]	
		New method	Conventional method
Singapore	1.38E-09	¥0.1	¥0.4
India	1.25E-08	¥0.7	¥3.4
Indonesia	1.84E-09	¥0.1	¥0.5
Myanmar	9.47E-09	¥0.5	¥2.6
Central Africa	1.30E-06	¥68.4	¥355.3

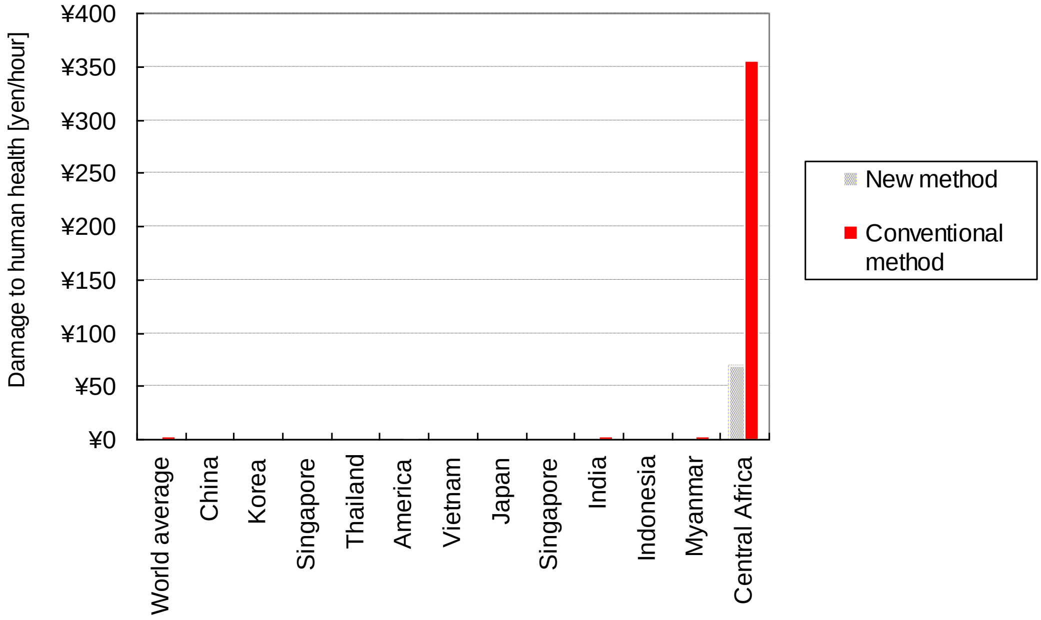

Figure 5.2-1 Water-induced health damage by country (Coefficient A)

Table 5.2-1, Table 5.2-2, and Figure 5.2-1 show that health damage caused by water resource consumption was close to 0 yen in almost all subject countries. However, in Central Africa where the damage coefficient was the highest of all subject countries, the damage was 355 yen in the conventional method and 68 yen in the new method, showing a large difference from other subject countries.

Figure 5.2-2 shows the result of damage assessment in terms of substances. The amount of damage to human health was 1.22E-04 (DALYs) in the new method, meaning that the use of the new method could allow reduction of approximately 1,800 yen of damage per hour. This could be realized by reduction of carbon dioxide and sulfur dioxide emissions. The study has shown that the use of the new method led to improvement of energy efficiency which in turn led to reduction of power consumption.

Meanwhile, the environmental impact of water resource consumption was approximately 0 yen in most of the subject countries. Therefore, carbon dioxide and sulfur dioxide cause a much stronger environmental impact than water resource consumption.

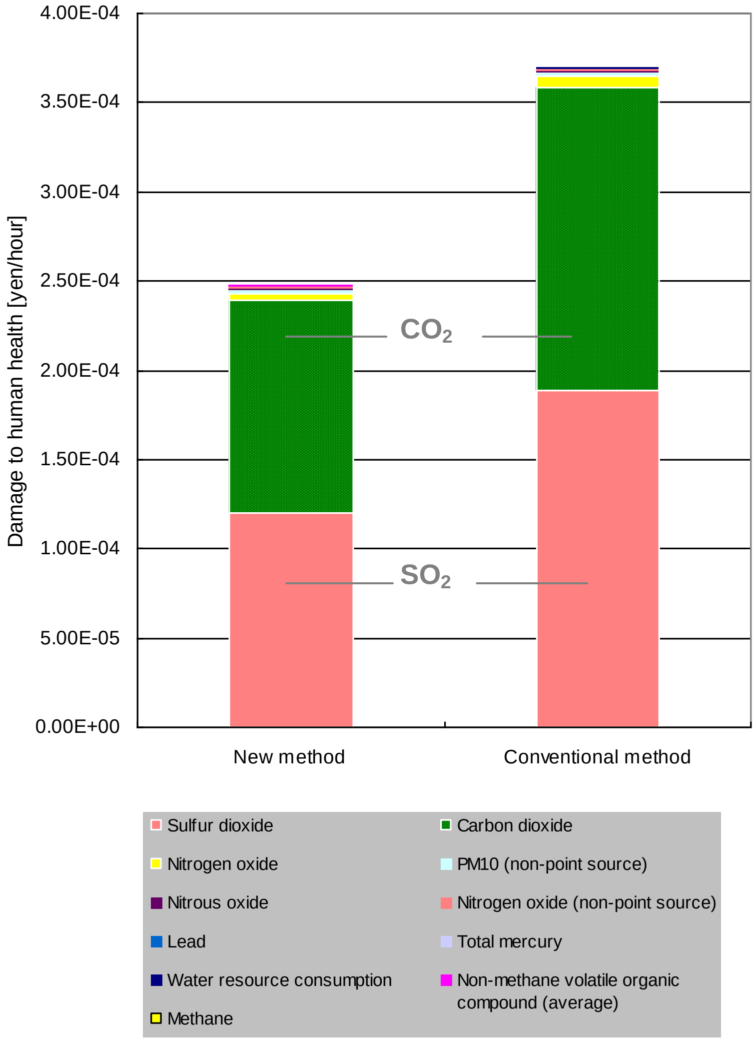

Figure 5.2-2 Damage assessment result by substance (Coefficient A)

5.2.1.2 Damage Assessment Using Coefficient B

Using Coefficient B as a coefficient for assessing damage caused by water resource consumption (refer to Section 5.2.1), region-specific damage was assessed for the amount of water used in the filling phase ("water consumption"). We calculated health damage in a yen value by multiplying the health damage coefficient of each country (mean value) by water consumption per hour. Table 5.2-3 shows the results.

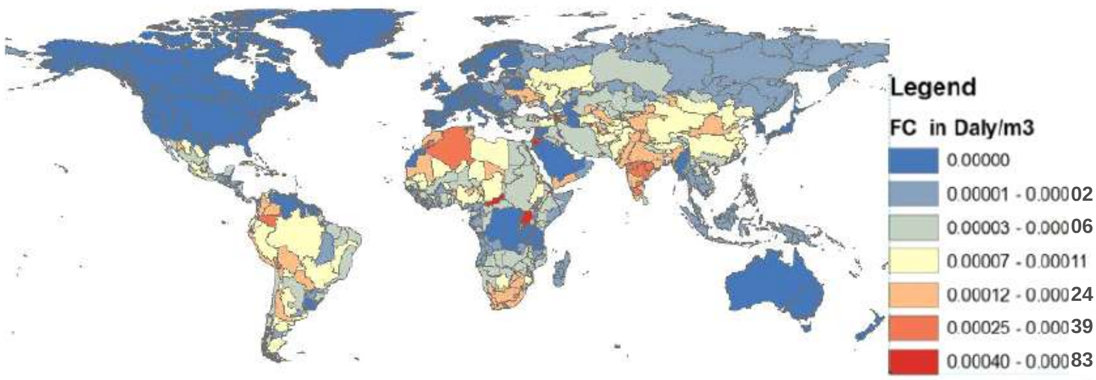

Figure 5.2-3 Characterization factors for human health impacts (water surface 1)

Reference B: Using GIS to Evaluate Regional Human Health Impacts from Water Use

Table 5.2-3 Water-induced health damage region

Legend	Health damage coefficient [DALYs/m^3]	Damage to human health [DALYs]		Damage to human health [Yen]		Difference
		New method	Conventional method	New method	Conventional method	Conventional-new
	0.00E+00	0.00E+00	0.00E+00	¥0	¥0	¥0
	2.80E-04	5.38E-05	2.80E-04	¥789	¥4,100	¥3,311
	8.39E-04	1.61E-04	8.39E-04	¥2,367	¥12,299	¥9,932
	1.68E-03	3.23E-04	1.68E-03	¥4,735	¥24,598	¥19,864
	3.36E-03	6.46E-04	3.36E-03	¥9,469	¥49,197	¥39,728
	5.97E-03	1.15E-03	5.97E-03	¥16,834	¥87,461	¥70,627
	1.15E-02	2.21E-03	1.15E-02	¥32,353	¥168,089	¥135,736

The damage coefficient is zero in Japan, North America, and Europe; therefore, health damage by water resource consumption is zero yen. The study showed that the impact of water resource consumption on health was much higher than the case where Coefficient A was used. In Central Africa, where the damage coefficient is the highest, health damage was 168,089 yen when using the conventional method and 32,353 yen when using the new method, meaning that there was a 135,736 yen difference per hour.

The health damage caused by water resource consumption in regions marked with yellow, such as China, was combined with the substance-specific damage assessment result obtained using LIME2 (Figure 5.2-4).

The result is quite different from the case where Coefficient A was used in which damage by water resource consumption accounted for a large part of health damage.

When the amount of damage was converted into Japanese yen, the damage was approximately 30,000 yen per hour with the conventional method, and the study found that the damage caused by water resource consumption accounted for approximately 82% of the total damage. Meanwhile, with the new method, the damage was approximately 8,000 yen, and the damage caused by water resource consumption accounted for approximately 56% of the total damage.

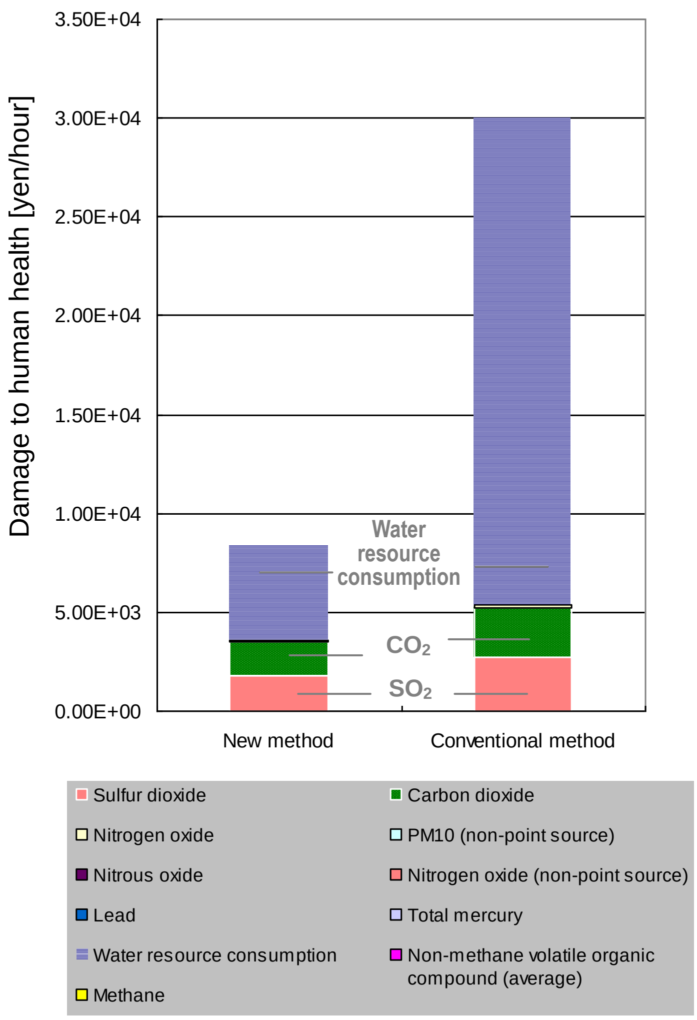

Figure 5.2-4 Damage assessment result by substance (Coefficient B)

5.2.2 Weighting

Figure 5.2-2 shows the weighting result for both filling methods (by substance). For the new method, carbon dioxide had the highest environmental impact followed by sulfur dioxide and crude oil in that order. When converted into a yen value, the environmental impact of the new method was 5,340 yen and that of the conventional method was 7,680 yen.

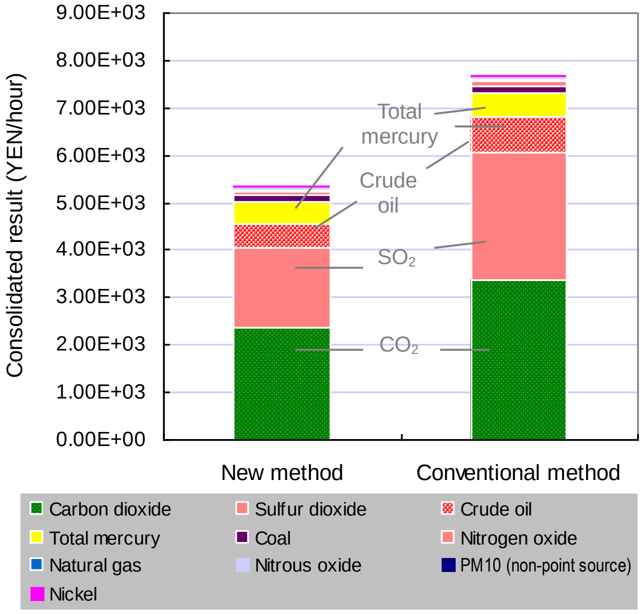

Figure 5.2-5 Weighting result (by substance)

Figure 5.2-3 shows the weighting result by category. The result shows that both methods had high environmental impacts on global warming and urban air pollution. The level of impact of these two categories was lower for the new method.

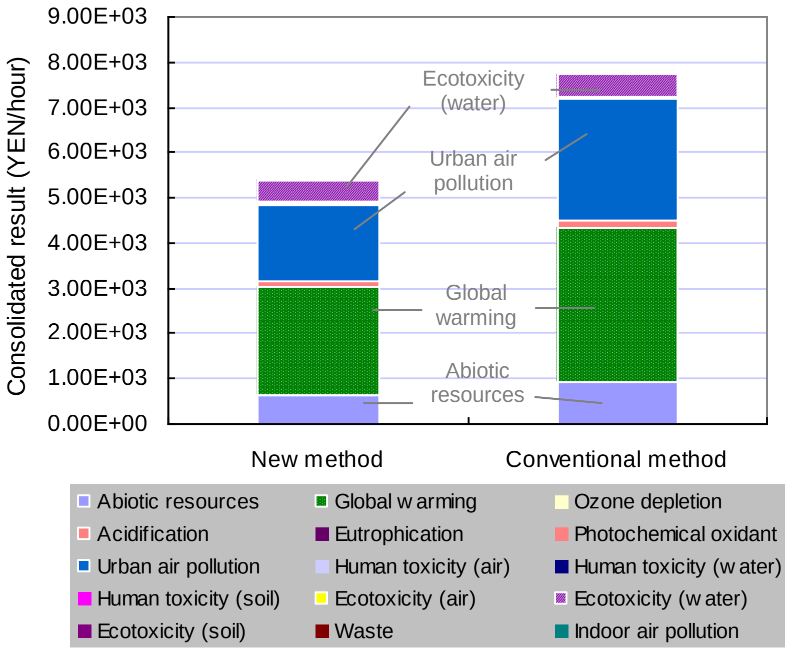

Figure 5.2-6 weighting result (by category)

Health damage calculated using Coefficient B was added to the weighting result by substance obtained using LIME 2 (Figure 5.2-7).

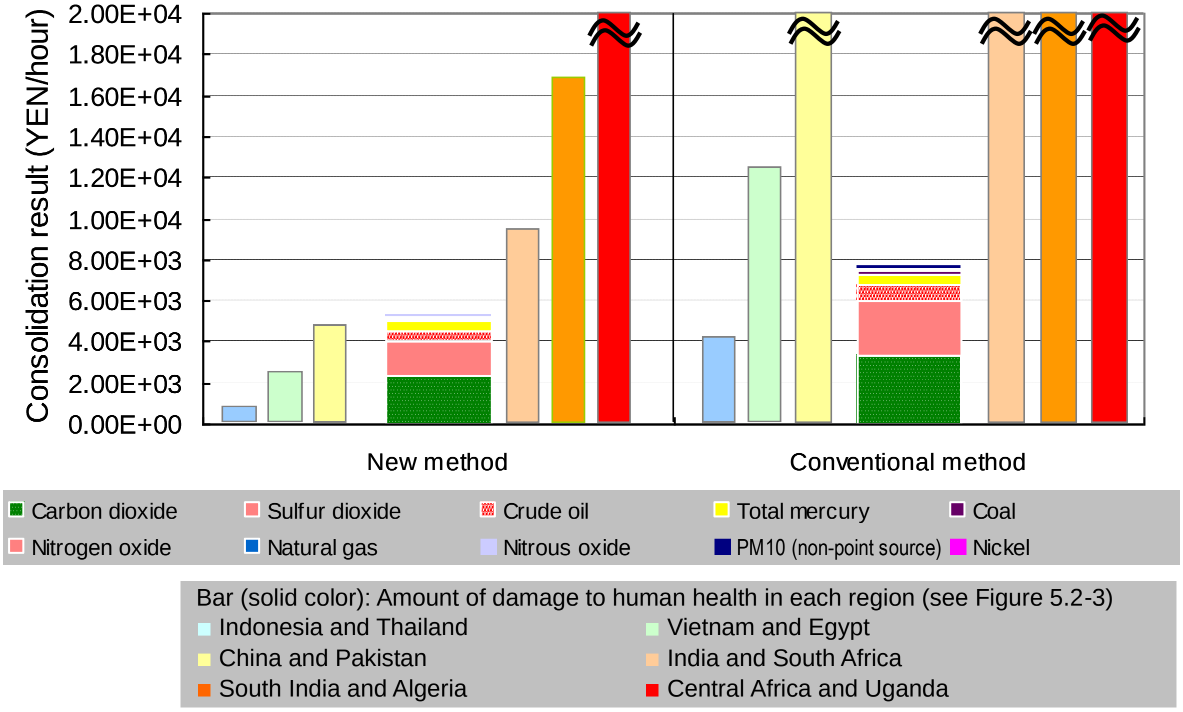

Figure 5.2-7 Weighting result (by substance) and health damage by water resource consumption (Coefficient B)

Figure 5.2-7 shows that the health damage calculated using Coefficient B was much higher than the weighting result. Note that, in the conventional method, the regions marked in green, such as Vietnam, and regions with higher health damage exceeded the damage shown as the weighting result. In the new method, the regions market with light orange, such as India, and regions with higher health damage exceeded the weighting result.

6 Conclusion

6.1 Summary of the Study Result

Japan is a country with abundant water resources, and irrespective to the type of coefficient, damage to human health caused by water resource consumption was almost 0. It should be noted, however, that the study indicated that the new method was an excellent bottle filling method that could significantly reduce the amount of water used and also the damage cause by CO_2 and SO_2.

Meanwhile, assuming that our filling system is introduced to China, India, other Asian countries, or African countries, the study indicated that the amount of damage caused by water resource consumption calculated using Coefficient B was much lower with the new method than with the conventional method.

6.2 Limitations of the Study and Future Tasks

Types and amount of water available are different in different regions across the world. The water used in this assessment was assumed to be industrial water, but it will be necessary to select basic units appropriate for the types of water used in the system. For this, it will be necessary to establish a wide variety of basic water units.

Furthermore, there has not been any established coefficient for assessing damage caused by water resource consumption, and this has caused large discrepancies in calculation results. In order to improve assessment reliability, we hope that coefficients for assessing damage caused by water resource consumption will be established soon.

In the future, we hope to continue improving the efficiency of water resource use and energy use, and also to carry out assessment that is more fact-based.

Reference

1) Japan PET Bottle Association: PET Bottle LCI Analysis Report, pp. 31, 53, 2006

2) The National Institute of Advanced Industrial Science and Technology (provided by Mr. Motoshita): The List of Coefficients for Assessing Health Damage Caused by Water Resource Consumption (Preliminary Edition, as of October 18, 2009)

3) Anne-Marie Boulay, Jean-Baptiste Bayart, Cecile Bulle, Manuele Margni, and Louise Deschenes: Using GIS to Evaluate Regional Human Health Impacts from Water Use, SETAC (2010.5) abstract

Report on Environmental Impact Assessment of a Professional Golf Tournament

March 2010

Dentsu Communication Institute Inc., Dentsu Inc.

Hiroshi Yamaguchi (Itsubo LCA Laboratory, Faculty of Environmental and Information Studies, Tokyo City University)

1 General

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1.2 Date of Report Creation

March 20, 2010

2 Study Objective

2.1 Background of the Study

Eco-friendliness in the field of hosting events conventionally has simply treated physical issues such as waste, noise, and landscape conservation. It usually involves compliance with regulations established in the location of the event, but at the same time, hosting parties often, too, voluntarily take action to address these issues.

The definition of the abovementioned eco-friendliness, however, has been changing with the increase of global awareness of environmental issues such as global warming and conservation of biodiversity.

This change is clearly reflected in how environmental impact assessment is introduced. While it is often introduced to calculate emissions for carbon offset purposes, in many cases, it is introduced because event hosting parties wish to quantitatively understand the effectiveness of their own eco-friendly activities. In conventional eco-friendly measures, hosting parties or event organizers would carry out ad-hoc measures, and effectiveness of these measures would be understood as fragmented information on resources used, output volume (amount of sorted waste), and recognition of the eco-friendly activities (recognition by visitors or amount of media exposure). Introduction of environmental impact assessment; however, should aim to help understand the level of effectiveness of eco-friendly measures implemented to reduce environmental loads that are generated during events. The assessment in this study therefore encourages review of event hosting and organizing activities and also environmental issues from the management point of view. As a result of such review, management methods may be established in future such that environmental measures will be created systematically instead of on an ad-hoc basis as is common at present.

At the same time, since environmental impact assessment methods have been developed targeting mainly the manufacturing industry, it is necessary to examine if these methods can be applied as is to activities carried out in the service industry such as event hosting services.

In this study, based on the abovementioned changes in event-related operations, an event example was assessed using LIME in order to identify: specific constituents of the environmental impact of an event; and possible issues regarding application of conventional environmental impact assessment methods.

First of all, it was important to obtain rough ideas of the type and amount of environmental impact that is generated during an event. Then, applying the existing assessment methods to the subject event, we examined what kind of assessment methods were appropriate for event-related operations and also what kind of preparation, such as database development, was required for assessment.

Note that, in this study project, a professional golf tournament was used as a subject of the study since with this type of event we could easily obtain cooperation of event organizers.

2.2 Application of the Study Result

The study result will be used to help understand the outline of the environmental impact generated in association with a professional golf tournament. It will be also used to identify issues in tournament environmental impact assessment.

3 Scope of the Study

3.1 Subjects and their Specifications

We created an imaginary golf tournament using data of actual professional golf tournaments. In general, a tournament consists of venue preparation, practice by players, actual matches, ancillary events, and cleanup. The Japan Golf Tour Organization (JGTO) provided support in setting tournament conditions.

Duration and location	Duration: one week (two days for practice and four days for the tournament) Location: venue not within walking distance from the nearest station (in the northern Kanto area)
Participants	125 professional players, 100 amateur players, 20,180 spectators(galley) , 445 volunteers, and 260 tournament officials
Scope of assessment	All processes before, during, and after the tournament (details to be described later)

3.2 Function and Functional Unit

A functional unit in this study means the amount of environmental loads generated per person (spectators, player, or tournament official) during the life cycle of a professional golf tournament.

3.3 System boundary

As shown in Figure 3.2-1, the system includes travel by people, preparation of tournament related facilities and equipment, hosting of the tournament, and waste disposal.

[Figure 3.2-1] System boundary

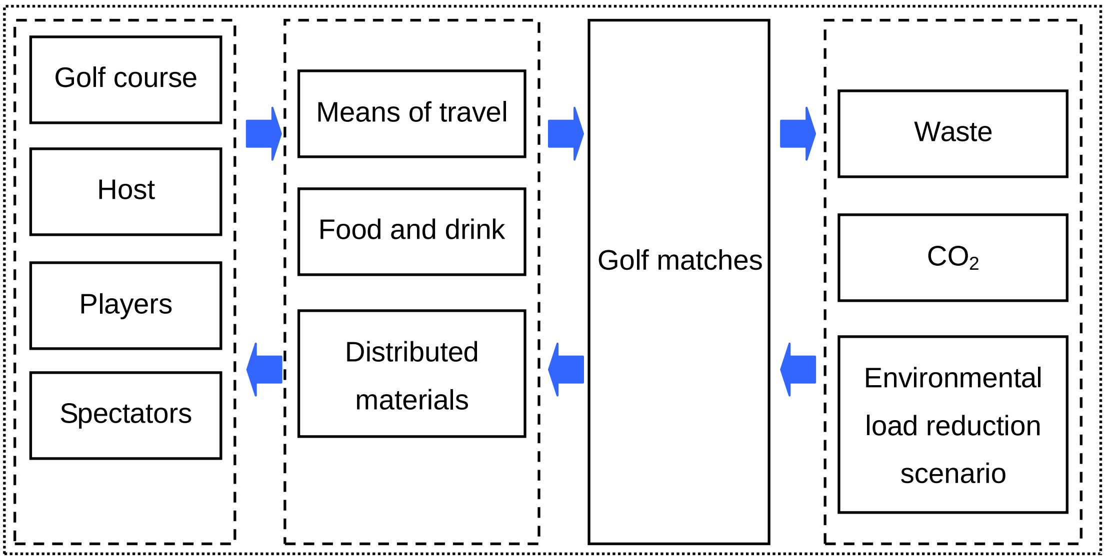


Figure 3.2-1 System and system boundary of a golf tournament

3.4 Note (Processes or Items Excluded from the System Boundary)

Assessment was carried out using 3EID due to the necessity to handle a large number of items subject to assessment and also due to the nature of the objective of this study, but in some parts, we used the aggregation LCA method. As a result, we carried out assessment using our own hybrid method.
Due to the technical restrictions on data acquisition, travel by spectators was estimated using small-sized data that did not necessarily guarantee statistical validity.

4 Inventory Analysis

4.1 Priority Data

An overview of the type and amount of materials and resources used was obtained from the budget list and the tournament manual. Meanwhile, we referred to the data obtained from sponsoring companies for the type and amount of novelty items, food, and drinks distributed to spectators.

4.2 Background Data

The environmental load data based on the input-output table was used. CO_2 data was obtained from 3EID of the National Institute for Environmental Studies. The data on resource and energy consumption, excluding crude oil, was obtained from the database created by Tokyo City University. The data on crude oil was obtained from the database created by the National Institute of Advanced Industrial Science and Technology. The data on travel by people was obtained from the statistical data by Ministry of Land, Infrastructure, Transport and Tourism and Ministry of the Environment.

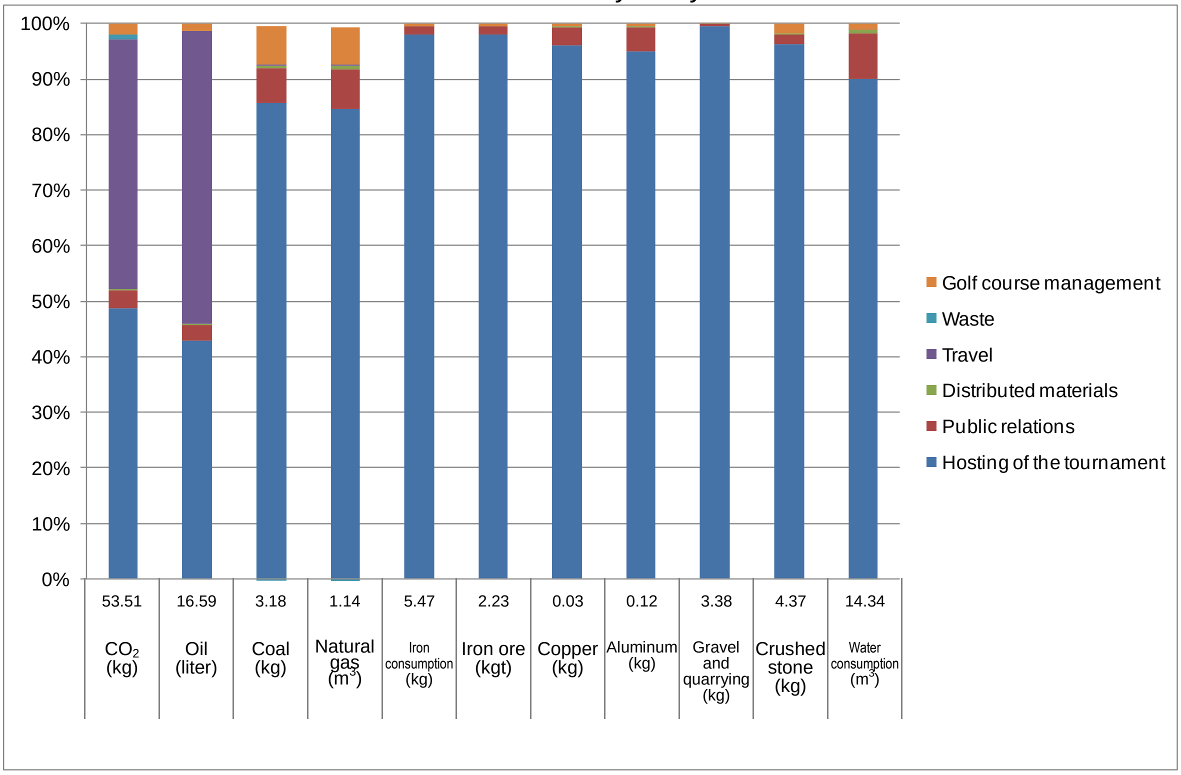
4.3 Subjects of Inventory Analysis and List of Analysis Results

Table 4.3-1 shows the subjects of professional golf tournament inventory analysis, and Table 4.3-2 shows the list of analysis results.

Table 4.3-1 Subjects of inventory analysis

Large category	Medium category	Small category	Item	Number of items	Basic unit	Subject group			
						Players	Spectators	Hosting party	Venue
Hosting of a championship	Hosing of a tournament	Equipment and supplies required in the tournament and use thereof	Tents, pavilions, temporary lavatories, and stands	531	Input-output table			○	
		Signboards	Arches, banners, signboards, and theme boards	101				○	
		Food and drinks	Food, drinks, and lunchboxes	79		○	○	○	
		Staff members	Temporary staff members, transportation security, and weather forecaster	39				○	
		Green Festival	Electricity and lighting work, and sound equipment installation	7				○	
		Expenses of the tournament office	Accident insurance premiums, copy machines, photo development	8				○	
	Public relations		Dealing with the press, communication, events for fans, and printing	69				○	
	Distributed materials		Mugs, polo shirts, winner's jackets	7	Aggregation method and input-output analysis combined		○	○	
Travel	Players	(including amateur players)	Planes and cars	133	Aggregation method	○			
	Spectators		Trains, buses, and cars	9			○		
	Volunteers		Trains and buses	291				○	
	Bus tour		Buses	5			○		
	Staff members		Cars	19				○	○
	Part-timers		Trains and buses	8				○	
Waste			Combustible waste, noncombustible waste, PET bottles, and cardboard boxes	4	Aggregation method		○	○	
Golf course management			Utilities, landscaping, seeds, fertilizers, and chemicals	20	Aggregation method and input-output analysis combined				○

Table 4.3-2 Inventory analysis result



5. Impact Assessment

5.1 Subject Assessment Steps and Areas of Impact

In the impact assessment, LIME2 (Life cycle Impact assessment Method based on Endpoint modeling 2) was used to assess the following three steps: characterization, damage assessment, and weighting. Table 5.1-1 shows the areas of impact subject to the assessment in each step.

Table 5.1-1 Subject areas of environmental impact and assessment steps

	Characterization	Damage assessment	Weighting
Resource consumption (energy)	○	○	○
Resource consumption (mineral)	○	○	○
Global warming	○	○	○
Urban air pollution	-	-	-
Ozone depletion	-	-	-
Acidification	-	-	-
Eutrophication	-	-	-
Water	○	○	○
Photochemical oxidant	-	-	-
Human toxicity	-	-	-
Ecotoxicity	-	-	-

Indoor air quality	-	-	-
Noise	-	-	-
Waste	○	○	○
Land use	○	○	○

5.2 Impact Assessment Result

5.2.1 Characterization

As the result of characterization of a golf event, Figure 5.2-1 shows the result by major tournament elements in terms of the global warming, resource (energy) consumption, and water consumption. Figure 5.2-2- shows the result by substance emitted or consumed.

The result shows that hosting of the tournament was responsible for a large part of the global warming, resource (energy) consumption, and water consumption. Note also that travel was another major contributing factor to the global warming effect. Meanwhile, public relations, involving creation of printed materials, accounted for a relatively large part of the water consumption.

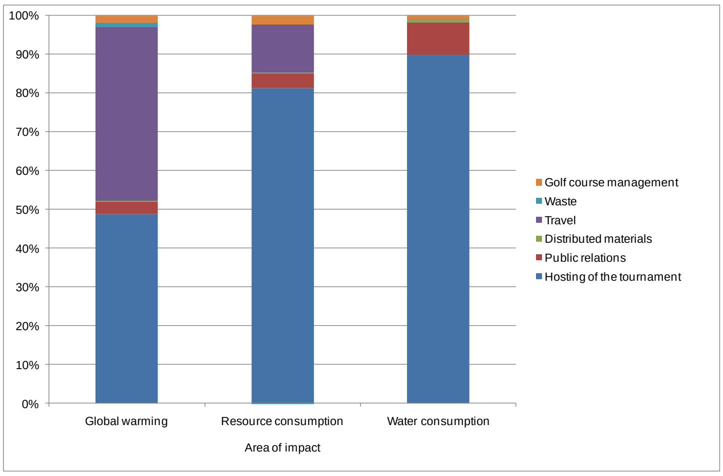


Figure 5.2-1 Characterization result (by major tournament element)

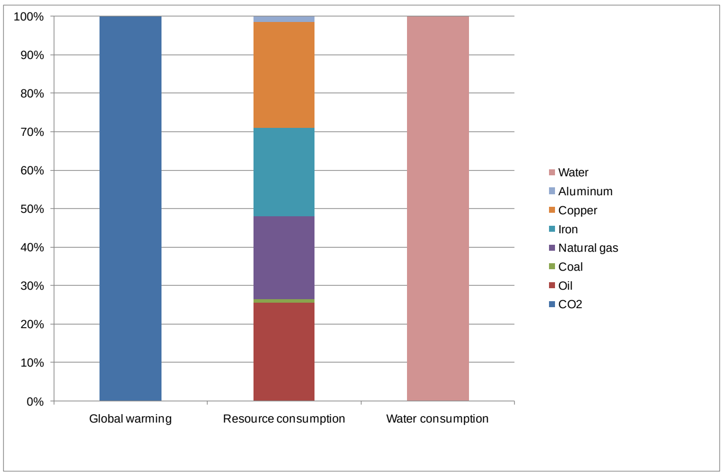


Figure 5.2-2 Characterization result (by substance emitted or consumed)

5.2.2 Damage Assessment

The damage assessment result (by substance) for the four areas to be protected was: organized in terms of major tournament elements as shown in Figure 5.2-3; and organized in terms of substances emitted or consumed as shown in Figure 5.2-4.

For the major tournament elements, hosting of the tournament was more responsible than any other elements for the damage to all areas to be protected. In particular, it accounted for 90% of damage caused in primary production and biodiversity. In social assets and human health, hosting of the tournament and travel accounted for 90% of the damage. Within the area of human health, hosting of the tournament accounted for 70% of the damage, but travel and public relations were also responsible for relatively large parts of the damage. When the damage assessment result was organized in terms of substances emitted or consumed, substances such as coal, copper, and iron were responsible for a large part of the damage in primary production and biodiversity, and CO_2 and oil accounted for a large part of the damage in social assets and human health.

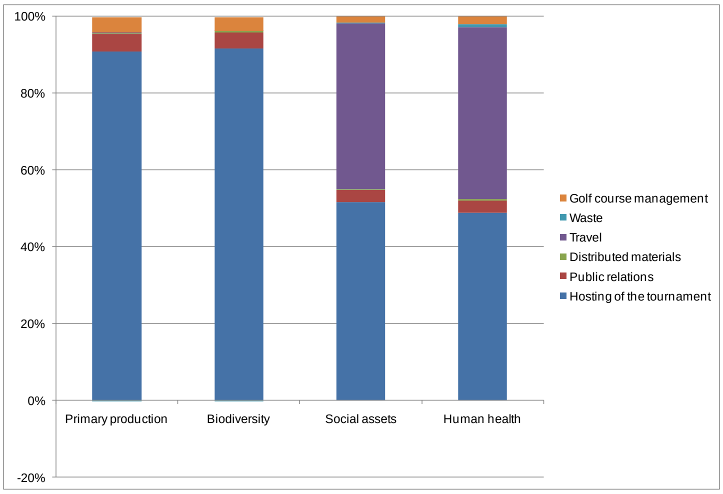


Figure 5.2-3 Damage assessment result (by major tournament element)

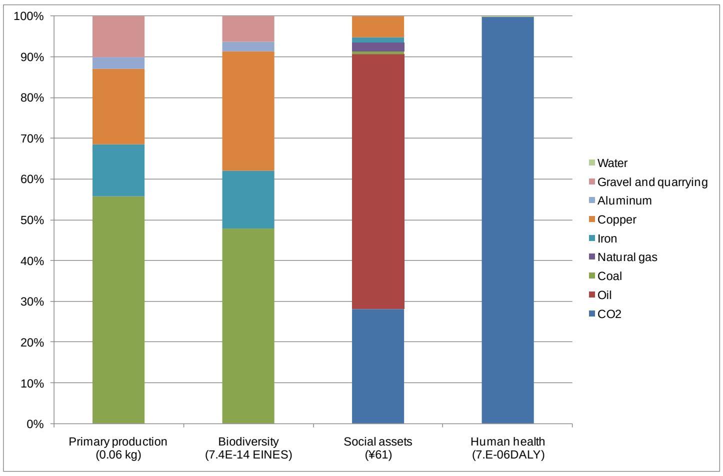


Figure 5.2-4 Damage assessment result (by substance emitted or consumed)

5.2.3 Weighting

The weighting social cost was 175 yen per person (3.7 million yen for the entire tournament). Figure 5.2-5 shows the weighting result by major tournament element. The social cost of hosting of the tournament was 91 yen per person, accounting for more than half of the entire social cost (1.92 million yen for the entire tournament), followed by travel, which was 74 yen per person (1.56 million yen for the entire tournament). Figure 5.2-6 shows the weighting result by substance emitted or consumed. The social cost of CO_2 emission per person was 125 yen (2.63 million yen for the entire tournament), accounting for 70% of the entire social cost, followed by oil, which was 37 yen (780,000 yen for the entire tournament). Figure 5.2-7 shows the weighting result by the areas to be protected. The social cost was 107 per person in the area of human health (2.27 million yen for the entire tournament), followed by 64 yen in the area of social assets (1.35 million yen for the entire tournament).

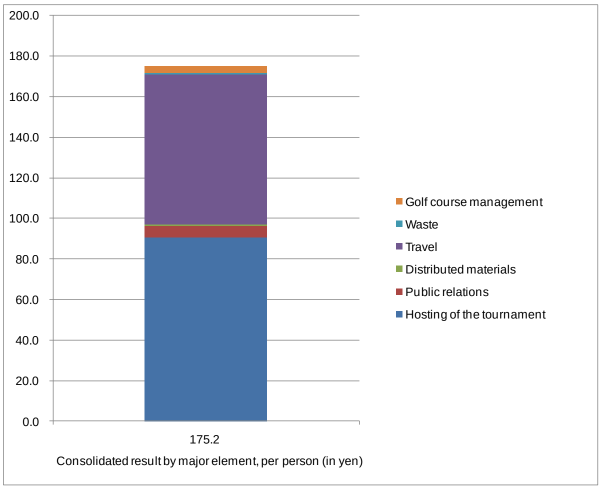


Figure 5.2-5 weighting result (by major tournament element)

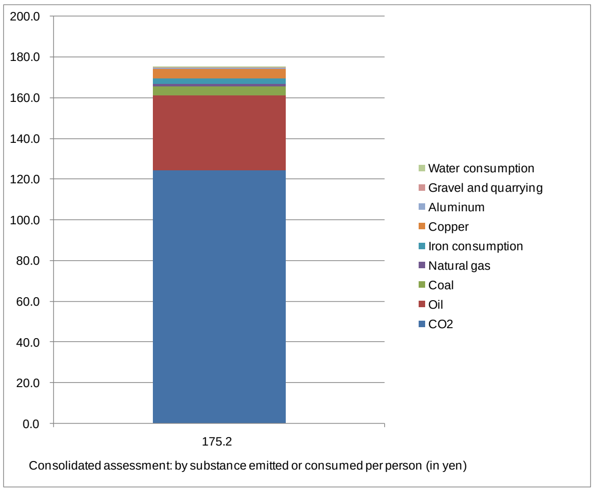


Figure 5.2-6 weighting result (by substance emitted or consumed)

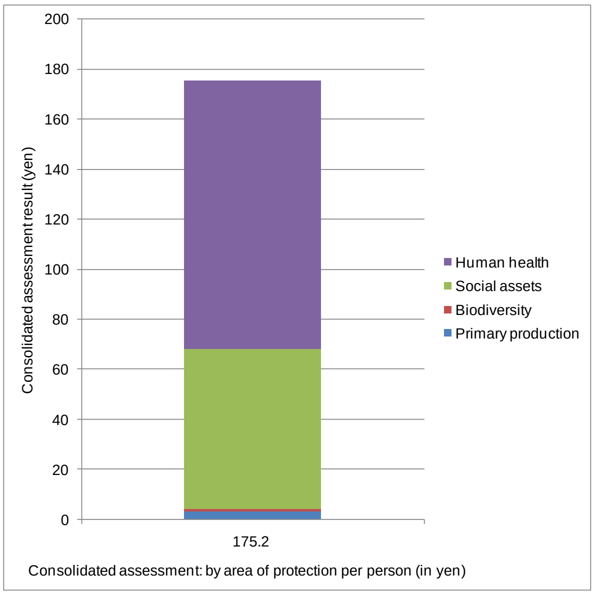


Figure 5.2-7 weighting result (by area of protection)

6 Conclusion

6.1 Summary of the Study Result

Using the input-output analysis database, we obtained the amount of CO_2 emission and resource consumption (oil, coal, natural gas, iron, copper, aluminum, gravel, and water). The study found that approximately 50% of CO_2 emission and oil consumption were attributed to hosting of the tournament and travel, and more than 85% of resource consumption other than oil was attributed to hosting of the tournament. Also, more than 40% of water consumption was attributed to equipment and supplies required in the tournament and use thereof, and also to food and drinks. Furthermore, the study indicated that copper consumption was attributed to the use of the TrackMan system (radio communication equipment), and gravel consumption was attributed to preparation of temporary stands and lavatories (concrete).

We conducted LIME2-based environmental impact assessment using the inventories described above.

The characterization result showed that hosting of the tournament and travel had a large impact on the global warming (CO_2 emission) and the resource consumption. Meanwhile, hosting of the tournament and public relations (production of printed material) were both responsible for high water consumption. When the characterization result was viewed from the substance point of view, CO_2 accounted for a large part of the global warming, and consumption of oil, copper, natural gas, and iron constituted a large part of resource consumption.

The damage assessment result indicated that the hosting of the tournament accounted for more than 90% of damage to the primary consumption and biodiversity. Hosting of the tournament and travel each accounted for more than 45% of damage to the social assets. Finally, hosting of the tournament, travel, and public relations were responsible for damage to human health in that order. When the damage assessment was examined from the substance point of view, oil, coal, copper, iron, and natural gas accounted for a large part of damage to the primary production and biodiversity. Meanwhile, oil, CO_2, and copper accounted for a large part of damage to the social assets, and CO_2 was responsible for a large part of damage to human health. Water had a much lower environmental impact.

The weighting result showed that the social cost was 175 yen per person (3.7 million yen for the entire tournament). The social cost of hosting of the tournament was 91 yen per person (1.92 million yen for the entire tournament), and travel was 74 yen per person (1.56 million yen for the entire tournament). In terms of substances, the social cost of CO_2 emission per person was 125 yen (2.63 million yen for the entire tournament), accounting for most of the total social cost, and oil was 37 yen (780,000 yen for the entire tournament). In terms of areas to be protected, the social cost was 107 per person in the area of human health (2.27 million yen for the entire tournament), followed by 64 yen in the area of social assets (1.35 million yen for the entire tournament).

6.2 Limitations of the Study and Future Tasks

First of all, based on the nature of this type of event where most of the facilities and equipment used during a tournament is rented, it is necessary to improve the assessment method by developing basic units for rented items. Also, as the number of substances subject to assessment increases, the reliability of environmental impact assessment must improve accordingly.

The assessment result in this study indicated that hosting of the tournament, travel, and public relations (printing) had large environmental impacts. For public relations (printing), use of electronic media could be applied immediately. It is, however, difficult to establish appropriate environmental impact reduction measures for hosting of the tournament and travel. For these, the only realistic way to reduce the environmental impact is to reduce the size of the tournament, but this would be meaningless when the purpose and the function of the event, which is considered as communication in a broad sense, are considered. It could be possible to select a venue that is easily accessible by public transportation systems, but this would lead to a concentration of venues in the central area of a town or in a city. This is not a favorable situation in terms of the social aspect of the Triple Bottom Line.

As described earlier, an event is a communication tool. A large number of stakeholders are involved, and things occur during that event are quickly shared by society. Therefore, desirable ways of using the result of environmental impact assessment of an event will be: ① as an index to prevent further increase of environmental loads, and ② as quantitative data to raise environmental awareness of stakeholders including spectators.

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Report on Comparison of Environmental Impact of Substations

April 2010

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1 General

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1.2 Date of Report Creation

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2 Study Objective

2.1 Background of the Study

Substations are built in a wide variety of places such as in mountains and cities. They may be outdoor substations or underground substations. In general, substations tend to be built in outdoor suburban areas since it is difficult to secure the land in urban areas. In many cases, these outdoor substations are built in mountain areas. A switchgear installed in an outdoor substation may be either a gas insulated switchgear (GIS) that uses SF_6 gas as an insulating medium or an air insulated switchgear (AIS) that secures a certain distance as a means of insulation instead of using SF_6 gas. Since the GIS insulates SF_6 gas well, the GIS is smaller than the AIS. The AIS is the type that has been in use for a long time.

Therefore, in this assessment, we compared a GIS and an old type AIS assuming they are used in a 145kV substation built in a mountain area. Through the comparison, we quantified the amount of reduction of the environmental impact due to reduction of the substation area. Note that this quantification was carried out based not only on the conventional assessment, such as assessment of the environmental impact on global warming, but also on the environmental impact of forest use on biodiversity and primary production as well as the environmental impact of industrial waste disposal on biodiversity, primary production, and social assets.

2.2 Application of the Study Result

In the comparison between a 145kV GIS substation and an AIS substation, important elements in an eco-friendly substation design were identified through inventory analysis of the environmental impact on global warming, biodiversity, and so on, so that the obtained result can provide useful tips for substation designs.

3 Scope of the Study

3.1 Subjects and their Specifications

Among a wide variety of substations, the subject of the study was a 145kV switchgear (4 lines and Bus Section) and its single line diagram as shown in Figure 3.1-1. The specific equipment subject to assessment was the switchgear (consisting of the circuit breaker (CB), disconnecting switch / earth switch (DS / ES), current transformer (CT), voltage transformer (VT), lightning arrester (LA), bushing (Bg), frame, and electric wire).

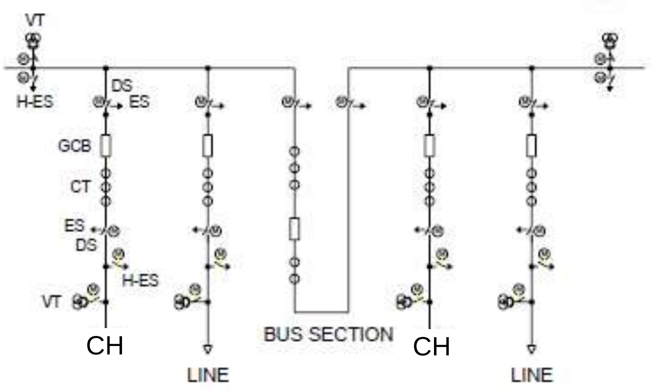


Figure 3.1-1 145kV switchgear single-line diagram

Note that, for this switchgear, the rated voltage was 145 kV, the rated current was 3,150A, and the rated short-time current was 40 kA.

3.2 Function and Functional Unit

A functional unit in this study was the entire lifecycle of a substation (a switchgear and its concrete foundation). Tables 3.2-1 and 3.2-2 show the assessment conditions. Figure 3.2-1 shows the image of occupation area comparison between the old-type and new substations.

Table 3.2-1 Assessment condition (common condition)

Duration of use	30 years
Service life of a concrete foundation	90 years
Rated current	3150A
Load factor	50%
SF_6 gas leakage (during operation)	0.05%/year
SF_6 gas leakage (when breakers are open)	1% each time
Number of times the breakers are opened	1 time (during removal)

Table 3.2-2 Assessment condition

	Old-type AIS	GIS	GIS / old-type AIS
Total equipment mass (in tons)	80	28	34.9%
Amount of concrete (m^3) Note	350	23	6.7%
Occupation area (m^2)	3,000	100	3.3%
SF_6 emission (kg/30 years)	0	29	

Note: The amount of concrete shown in the table is 1/3 of the actual amount used since its service life is 3 times longer than the GIS.

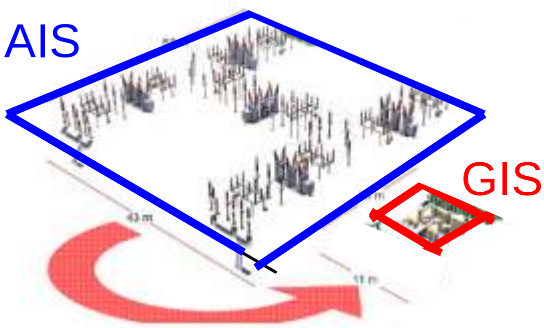


Figure 3.2-1 Image of downsizing of a substation

3.3 System boundary

Figure 3.3-1 shows the system boundary. It includes foundation building, manufacturing, current loss, SF_6 gas leakage, and disposal.

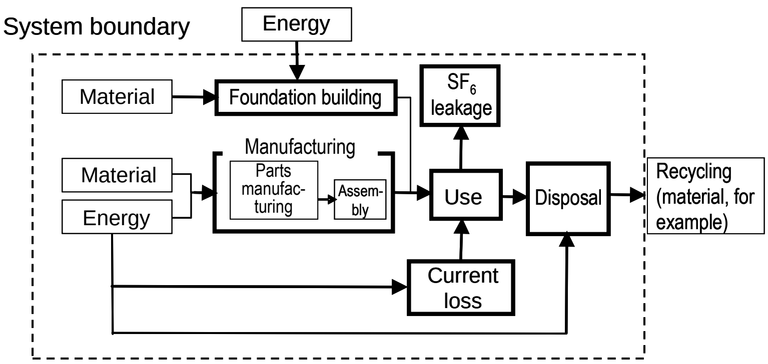


Figure 3.3-1 System boundary

3.4 Note (Processes or Items Excluded from the System Boundary)

Among the equipment that constitutes a substation, a transformer, secondary equipment, the main building and its devices, and the steel tower were not included as the subjects of assessment.

4 Inventory Analysis

4.1 Priority Data

Survey data on the amount of concrete used in the foundation building phase, the amount of materials, resources, and energy used in the material phase, and the amount of current loss and SF_6 gas leakage during the use phase was used.

4.2 Background Data

To obtain basic units required for each phase, we used the database created based on the 2000 input-output analysis, including overseas load data, available in Easy-LCA.

4.3 Subjects of Inventory Analysis

Table 4.3-1 shows the list of subjects of inventory analysis.

Table 4.3-1 Subjects of inventory analysis

		Unit
Consumption-related load	Energy	MJ
Air emission-related load (greenhouse gases)	CO_2	kg
	HFC	kg
	HFC23	kg
	PFC	kg
	SF6	kg
Air emission-related load	SOx	kg
	NOx	kg
	Dust	kg
Water emission-related load	BOD	kg
	COD	kg
	SS	kg
	T-N	kg
	T-P	kg
Resource consumption-related load	Crude oil raw material	L
	Crude oil fuel	L
	Coal	kg
	Natural gas	kg
	Iron	kg
	Copper	kg
	Lead	kg
	Zinc	kg
	Aluminum	kg
	Manganese	kg
	Chrome	kg
	Nickel	kg
	Crushed stone	kg
	Gravel and quarrying	kg
	Limestone	kg
	Material (wood)	m^3
Land use	Footprint	m^2
Disposal	Equipment	kg
	Foundation	m^3

5 Impact Assessment

5.1 Subject Assessment Steps and Areas of Impact

In the impact assessment, LIME2 (Life cycle Impact assessment Method based on Endpoint modeling 2) was used to asses the following 3 steps: characterization, damage assessment, and weighting. Table 5.1-1 shows the areas of impact subject to the assessment in each step. The areas to be protected are human health, social assets, primary production, and biodiversity. In land use, protection of primary production and biodiversity was focused on through protection of forests, while in foundation and equipment disposal, protection of social assets, primary production, and biodiversity was emphasized.

Table 5.1-1 Subject areas of environmental impact and assessment steps

	Characterization	Damage assessment	weighting
Resource consumption (energy)	○	○	○
Resource consumption (mineral)	○	○	○
Global warming	○	○	○
Urban air pollution		○	○
Ozone depletion			
Acidification	○	○	○
Eutrophication	○	○	○
Photochemical oxidant	○	○	○
Human toxicity			
Ecotoxicity			
Indoor air quality			
Noise			
Waste	○	○	○
Land use	○	○	○

5.2 Impact Assessment Result

5.2.1 Characterization

Figure 5.2-1 shows the characterization result with regard to global warming for the substation with the GIS and the substation with the old-type AIS. Inventory for this analysis included CO_2, HFC, HFC23, PFC, and SF_6.

For the substation with the old-type AIS, current loss was the major factor for global warming, and for the substation with the GIS, it was SF_6 gas leakage. Note that the current loss caused twice as much damage as SF_6 gas leakage. The overall characterization result shows that the environmental impact of the substation with the GIS was 38% of that of the substation with the old-type AIS. Other contributing factors were equipment materials (from CB to electric wire/Bg in the graph) and the foundation.

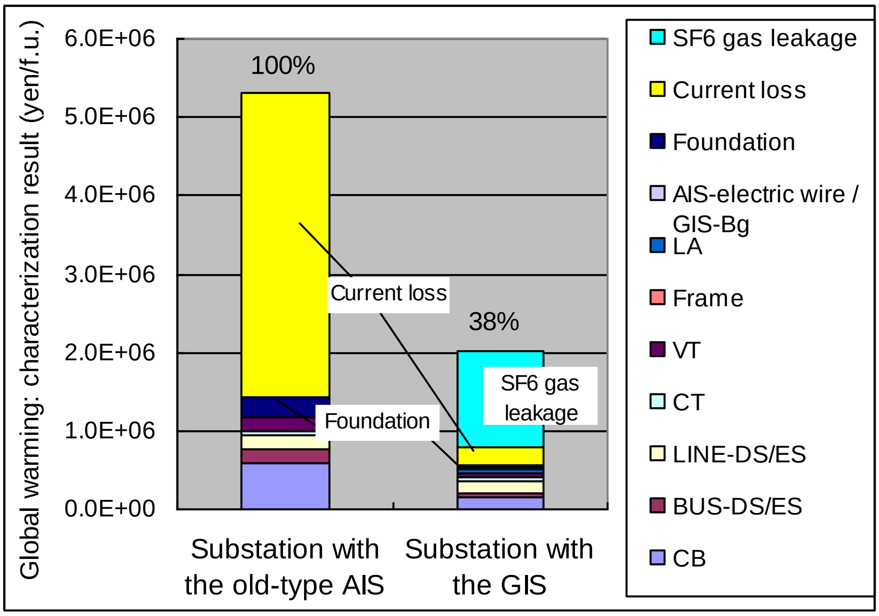


Figure 5.2-1 Characterization result (global warming)

5.2.2 Damage assessment

Figures 5.2-2 through 5.2-5 show the damage assessment results with regard to the four areas to be protected. In all areas, the GIS had a lower environmental impact than the old-type AIS. Meanwhile, the damage tendency for human health was different from that for other areas. This is attributed to the fact that foundation disposal and use of forests had no impact on human health.

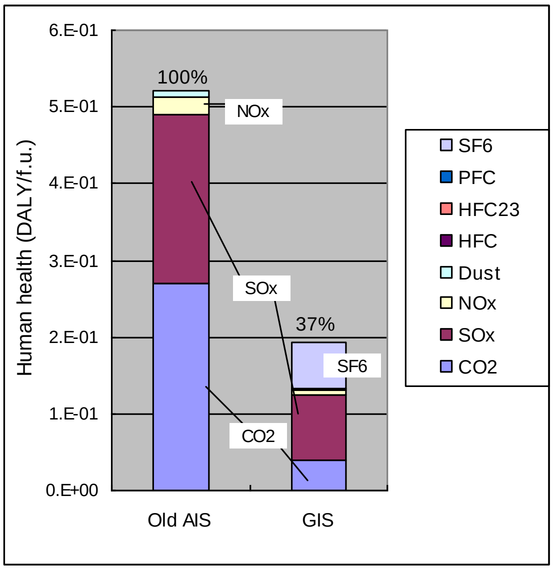


Figure 5.2-2 Damage assessment result (human health)

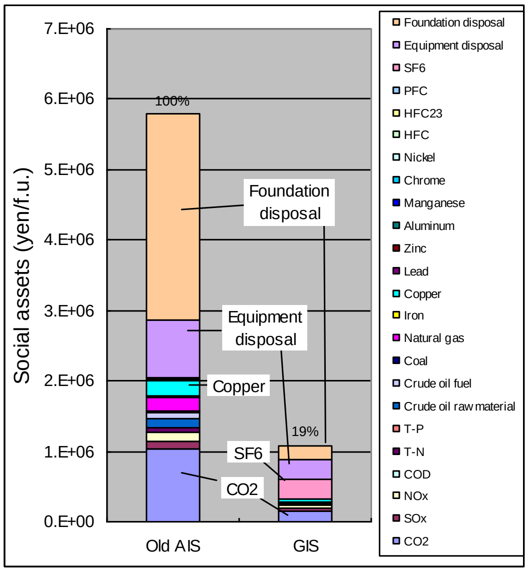


Figure 5.2-3 Damage assessment result (social assets)

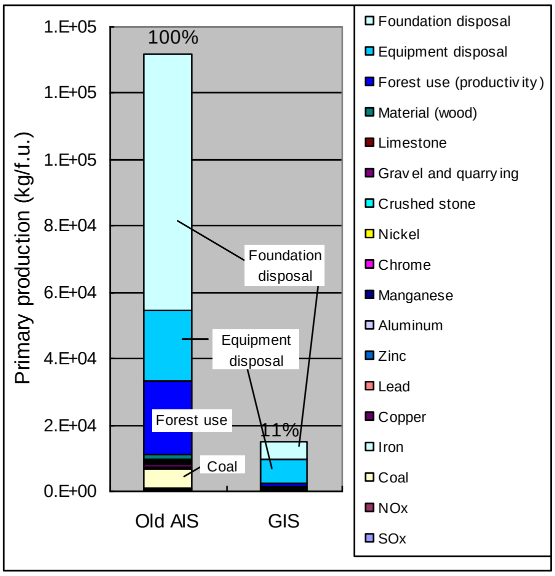


Figure 5.2-4 Damage assessment result (primary production)

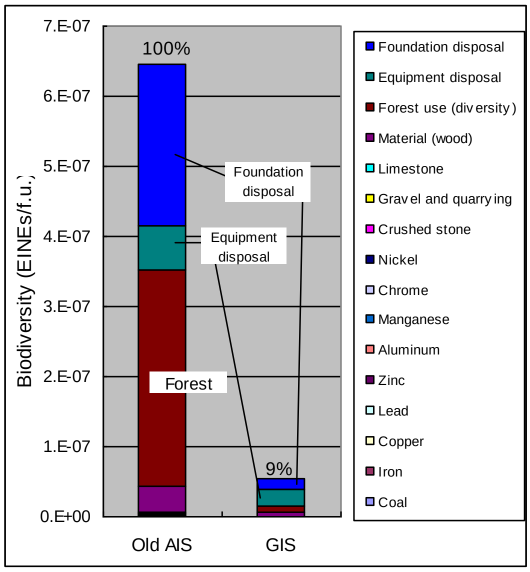
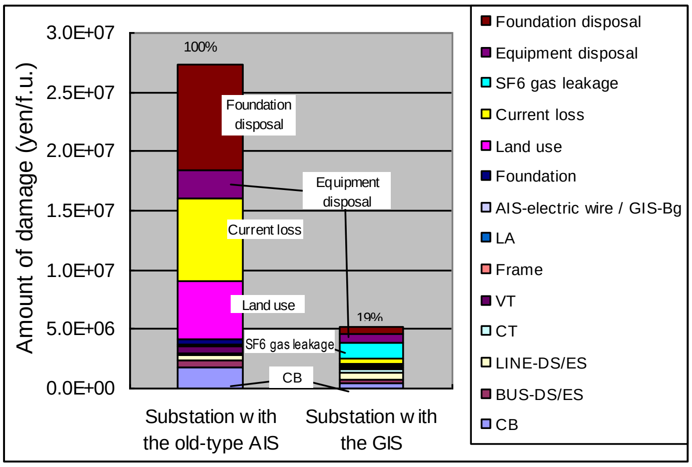


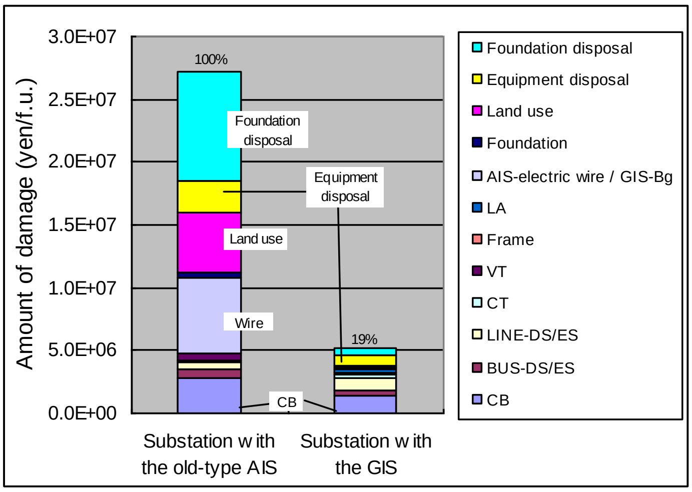
Figure 5.2-5 Damage assessment result (biodiversity)

5.2.3 Weighting

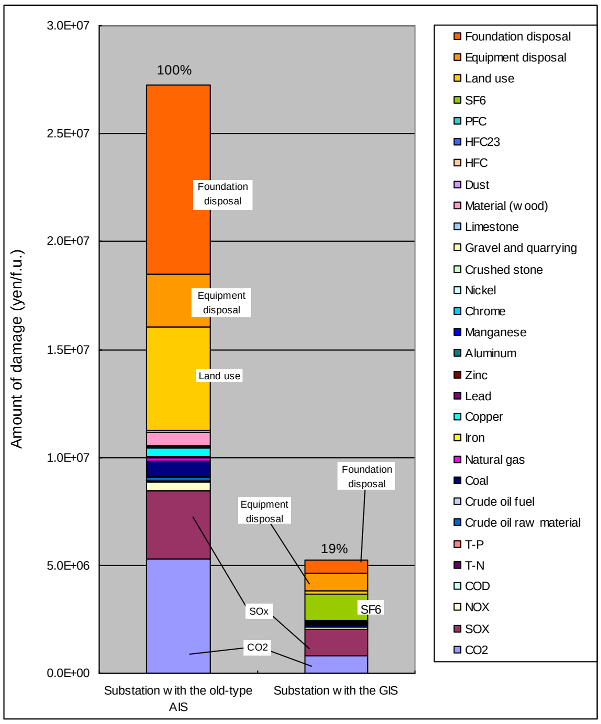
Figure 5.2-6 shows the weighting result. The environmental impact of the substation using the GIS was 20% lower than that of the substation using the old-type AIS. Figure 5.2-6 (a) shows the weighting result by process (material, land use, operation, and disposal processes). The environmental impact of foundation disposal, current loss, and land use of the substation using the old-type AIS was higher than the environmental impact of SF_6 gas leakage at the substation using the GIS. This result therefore suggests that the reduction of occupation area as a result of installing a switchgear using SF_6 gas would have a positive effect on the environment. Figure 5.2-6 (b) shows the weighting result by device. The result here shows that current loss of electric wires at the substation using the old-type AIS had a large environmental impact. Figure 5.2-6 (c) shows the result by inventory. The result indicated that foundation disposal and land use of the substation using the old-type AIS had a large environmental impact, while SF_6 and SOx had a large environmental impact at the substation using the GIS.



(a) By process



(b) By device



(c) By inventory

Figure 5.2-6 Weighting result

Figure 5.2-7 shows a comparison of damage to the areas to be protected. This figure shows that for both the substations using the old-type AIS and the GIS, the largest impact was on biodiversity followed by human health, social assets, and primary production in this order.

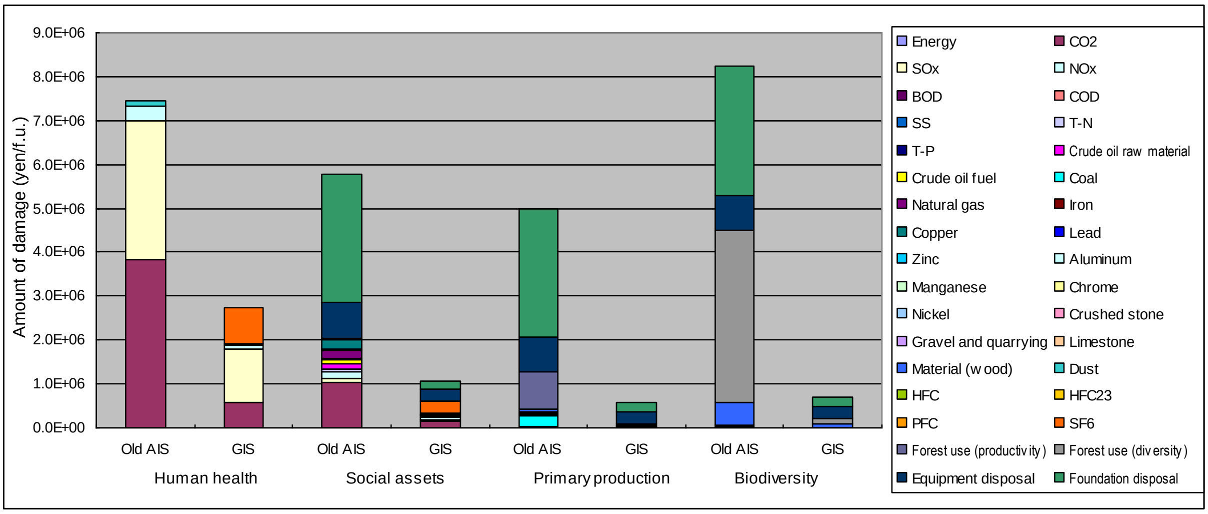


Figure 5.2-7 Weighting result (by the area to be protected)

5.2.4 Comparison between the weighting result and the characterization result in terms of global warming

Comparison between Figure 5.2-1 and Figure 5.2-6 indicates that the environmental impact of the substation using the GIS was 38% of that of the substation using the old-type AIS according to the characterization result in terms of global warming, but it was 19% according to the weighting result. This is mainly because the environmental impact of land use and foundation disposal was not included in characterization for global warming. Therefore, when comparing facilities that use land in very different ways, GHG assessment alone may not cover all important points, and it is thus desirable that the environmental impacts on biodiversity and primary production also be included in analysis to the fullest extent possible.

6 Conclusion

6.1 Summary of the Study Result

With a 145-kV substation using the GIS and a substation using the old-type AIS as the subjects of study, we quantified the environmental impact of the life cycle of each substation (land development (booked 1/3 of the actual volume), manufacturing, use (50% load factor for 30 years), and disposal).

The major factors of the environmental impact were foundation, current loss, and land use for the substation with the old-type AIS. The environmental impact of these factors was much larger than SF_6 gas leakage at the substation with the GIS, indicating that the reduction of occupation area as a result of selecting a switchgear using SF_6 gas had a positive effect on the environment. Also, current loss of electric wires at the substation using the old-type AIS was larger than the current loss by the inner conductor of the GIS, and when the substation has operated for 30 years at 50% of the load factor, the current loss would become the major environmental factor of the substation using the old-type AIS.

When the weighting result and the characterization result in terms of global warming were compared, the environmental impact of the substation using the GIS was 19% of that of the substation using the old-type AIS according to the weighting result and 38% according to the characterization result. This suggests that when comparing facilities that use land in very different ways, it is desirable that the environmental impact on biodiversity and primary production be assessed in addition to global warming. It is desirable, therefore, that biodiversity and primary production data be prepared and improved.

6.2 Limitations of the Study and Future Tasks

This study included all important processes (foundation building, material procurement, manufacturing, operation, and disposal) as the subjects of the assessment; therefore, we believe that the validity of the assessment result can be guaranteed. However, the background data described earlier was used in assessment of the environmental impact of concrete material and the disposal process, both of which had a large environmental impact. Although it is not clear how the use of the background data would influence the assessment result, it is still desirable that the priority data be used as much as possible. Furthermore, for current loss, which was one of the major contributing factors to the environmental impact caused by the substation using the old-type AIS, the load factor depends on how the substation is operated. Therefore, it is desirable to examine the operational status first and then define the assessment condition based on the examination result.

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Report on Environmental Impact Assessment of HYDROTECT Coating

June 2010

TOTO LTD.

1 General

1.1 Evaluators

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1.2 Date of Report Creation

June 3, 2010

2 Study Objective

2.1 Background of the Study

An air pollutant nitrogen oxide (NOx) not only has an adverse effect on the human body but also is known as a substance that causes photochemical smog or acid rain. NOx is generated in a wide variety of places such as factories, thermal power plants, cars, and houses, and it is thus difficult to completely control its generation. A photocatalyst exposed with UV rays contained in sunlight generates unique effects such as decomposition and hydrophilic properties. Our product, HYDROTECT coating, is a type of coating that uses such a photocatalytic function to realize a highly durable coating, self-cleaning (dirt prevention) and air purification (NOx removal) effects.

In this study, we conducted environmental impact assessment of a life cycle of HYDROTECT coating (trade name: ECO-EX) and an ordinary coating (acrylic silicone coating) in order to understand the environmental characteristics of HYDROTECT coating and also to compare environmental performance between these two types of coating.

2.2 Application of the Study Result

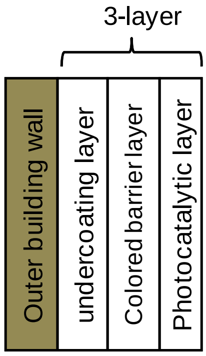
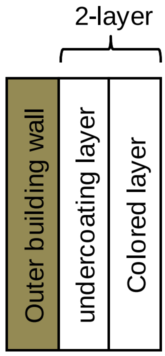
Through the comparison of the environmental impact between HYDROTECT coating and the ordinary coating, we intend to understand the environmental characteristics of HYDROTECT coating and also to provide information thereof.

3 Scope of the Study

3.1 Subjects and their Specifications

The subjects of the study were: HYDROTECT coating (trade name: ECO-EX (white)) and an ordinary coating (acrylic silicone coating (white)), which was produced, applied, and used as coating on walls inside Japan, by the amount sufficient for coating an area of 1,000 m^2. Table 3.1-1 shows a comparison of specifications between HYDROTECT coating and the ordinary coating. HYDROTECT coating consists of an undercoating layer, a colored barrier layer, and a photocatalytic layer, while an ordinary coating consists only of an undercoating layer and a colored layer. In this study, the entire coating film structure was treated as the subject of assessment. The colored barrier layer of HYDROTECT coating is a coating film that is less susceptible to degradated than the colored layer of the ordinary coating, and it needs to be reapplied only once every 20 years. Also, HYDROTECT coating has special functions such as self-cleaning and air purification. The effectiveness of the self-cleaning function would lead to a decreased necessity to clean outer walls. However, since it is often the case that the users of outer walls rarely if ever clean them, the self-cleaning function was excluded from the scope of the study. As a result, only the air purification effects were included as the subject of the study.

Table 3.1-1 Comparison of specifications between HYDROTECT coating and the ordinary coating

	HYDROTECT coating	Ordinary coating
Structure		
Years before re-applied	20 years*	10 years
Amount of coating used	375 kg	355 kg
Self-cleaning	Yes	No
Air purification	Yes	No

*In-house assessment: passed the accelerated weathering test SWOM for 6,000 hours (equivalent to 20 years of use)

The photocatalytic air purification effects refers to a process in which NOx in the air sticks to the coating film surface, NOx becomes NO_3^- through photocatalytic reactions, and NO_3^- is removed from the air when it is washed off in rain. This process is characterized by efficient removal of even low-concentration NOx at room temperature.[1] Note, however, the amount of NOx that can be removed largely depends on the NOx concentration, wind direction, wind velocity (diffusion), and the amount of solar radiation (UV rays), and it is thus difficult to generalize the amount of removal in the actual environment. For this reason, we calculated the amount of NOx removal by converting** actual HYDROTECT coating NOx removal performance data (JIS R 1701-1)[2]. Note also that the amount of NO_3^- generated on the HYDROTECT coating surface was excluded from the assessment since it would be the same as what is generated in the usual nitrogen cycle as long as the air purification effects is examined from the nitrogen cycle point of view (Figure 3.1-2).

**Converting the NOx removal performance data (JIS R 1701-1) into the amount of NOx removal
Major determinants of the amount of NOx removal are concentration and diffusion status of NOx and also the irradiated amount of UV rays. The NOx concentration was set to 1ppm in accordance with the JIS measurement condition, and this was higher than the concentration in the actual environment. For this reason, we assumed that a sufficient amount of NOx was already present and the amount of removal thus depended only on the irradiated amount of UV rays. Since a constant amount of UV rays were irradiated using a BLB lamp during the JIS measurement, we obtained the amount of NOx removal by scaling the amount of UV rays irradiation in the actual environment in proportion to the amount UV rays irradiated. Using the standard climate and sunlight radiation data (METPV-3)[3], the amount of UV rays in the actual environment was obtained by: averaging the amount of sunlight irradiated onto applied surfaces (from four directions to a vertically installed outer wall) in February, May, August, and November in the years from 1990 to 2003; and multiplying the obtained average value by the UV ray content that can be handled by a photocatalyst.

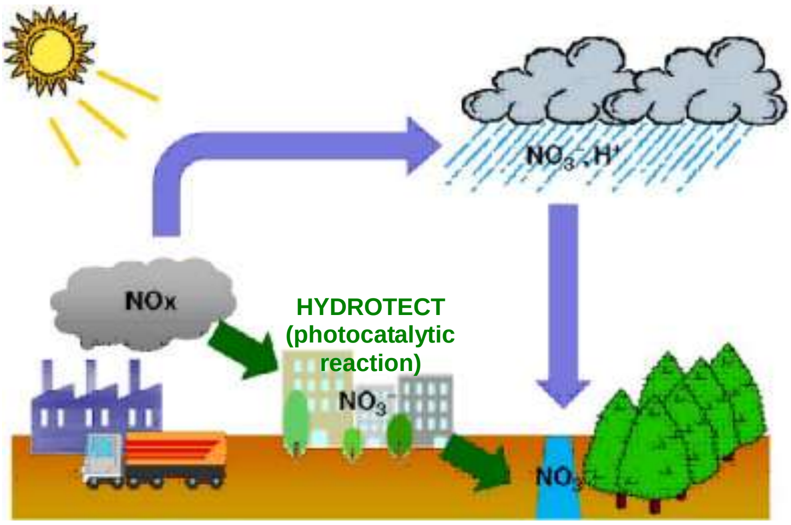


Figure 3.1-2 Conceptual diagram of the nitrogen cycle involving HYDROTECT coatin

3.2 Function and Functional Unit

For both HYDROTECT coating and the ordinary coating, the functional unit was as follows: white coating color, coating area of 1,000 m^2, and 20 years of use. HYDROTECT coating is designed to be highly durable and is required to be re-applied only once every 20 years; therefore, in the years of use set in this assessment, which was 20 years, HYDROTECT coating was assumed to be coated only once without having to be recoated (total amount of coating used: 375 kg). On the other hand, the ordinary coating is designed to be re-applied every 10 years, and therefore, it was assumed in the assessment that it was recoated once during the assessment years. As a result, it was assumed that the ordinary coating was coated twice during the assessment (total amount of coating used: 710 kg).

3.3 System boundary

A system included the phases from material production to transportation, application, and use as coating on walls (Figure 3.3-1).

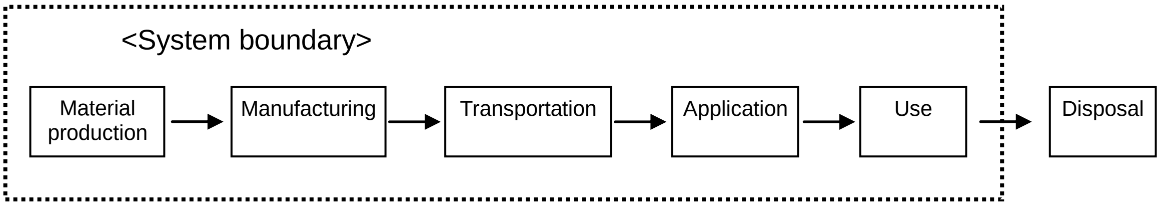


Figure 3.3-1 System boundary for HYDROTECT coating and the ordinary coating

3.4 Note (Processes or Items Excluded from the System Boundary)

Coatings are disposed of as coated building walls, meaning that there is no disposal of only coating films. Therefore, disposal of the coatings was excluded from the scope of the assessment. Also, outer wall cleaning, which is expected to be carried out within the use phase through high-pressure washing or by using cleansers, was excluded from the scope of the assessment since it is often that case that users do not wash the subject walls at all

4 Inventory Analysis

4.1 Priority Data

We used the data obtained in our surveys on HYDROTECT coating material composition, transportation, energy used in application, and use of walls (amount of NOx removal). We obtained the amount of NOx removal based on the value of 1.35 μmol (JIS R 1701-1), which was the NOx removal capability value for HYDROTECT coating (trade name: ECO-EX) certified by the Photocatalysis Industry Association of Japan.

4.2 Background Data

Inventory data for coating raw materials, electricity, and trucks for transportation was obtained from the JEMAI-LCA Pro database and the Option Datapack. Data on the amount of energy used in coating manufacturing and waste quantity was obtained from the acrylic emulsion production process data for a synthetic resin emulsion designed for building construction created by the Japan Paint Manufacturers Association. This data was available in the LCA database developed by the Life Cycle Assessment Society of Japan (JLCA). Data on raw materials of the ordinary coating was based on the white synthetic resin emulsion (water-based) data obtained from the LCA Guidebook[5)] issued by the Japan Paint Manufacturers Association.

4.3 Subjects of Inventory Analysis and Lists of Analysis Results

Tables 4.3-1 and 4.3-2 show the inventory analysis results for HYDROTECT coating and the ordinary coating.

Table 4.3-1 HYDROTECT coating LCI analysis result (kg/f.u.)

			Material production	Manufacturing	Transportation	Application	Use	Σ
Consumption-related environmental load	Exhaustible resources	Coal	3.90E+01	4.40E-01	2.07E-03	1.11E-01		3.95E+01
		Crude oil	1.94E+02	8.16E-02	1.06E+01	2.07E-02		2.04E+02
		Natural gas	3.79E+01	2.05E-01	9.61E-04	5.18E-02		3.82E+01
		Uranium	1.86E-03	3.87E-05	1.82E-07	9.81E-06		1.91E-03
		Copper	2.30E-06					2.30E-06
		Aluminum	1.11E-05					1.11E-05
		Lead	8.46E-08					8.46E-08
		Zinc	4.69E-07					4.69E-07
		Limestone	1.33E+02					1.33E+02
		Rock (excluding limestone)	3.17E+00					3.17E+00
		Titanium	2.84E+01					2.84E+01
Discharge-related environmental load	Outdoor air	Carbon dioxide	6.08E+02	2.02E+00	3.40E+01	5.11E-01		6.44E+02
		Sulfur dioxide	3.69E-01	3.78E-04	7.37E-03	9.58E-05		3.77E-01
		Nitrogen oxide	2.24E-01	8.41E-04	8.51E-04	2.13E-04	-9.45E+01	-9.43E+01
		Nitrous oxide	2.56E-02	8.74E-05	5.47E-04	2.21E-05		2.62E-02
		Methane	1.88E-02	4.31E-05	2.03E-07	1.09E-05		1.89E-02
		Non-methane volatile organic compound (average)	9.78E-03	1.25E-04	3.75E-02	3.16E-05		4.74E-02
		Particle matter (PM10)	4.61E-02	1.58E-05	5.86E-05	4.01E-06		4.62E-02
		Arsenic	1.52E-06	3.68E-08	1.73E-10	9.31E-09		1.57E-06
		Cadmium	1.26E-07	3.04E-09	1.43E-11	7.70E-10		1.30E-07
		Hexavalent chrome	2.77E-06	6.69E-08	3.14E-10	1.69E-08		2.85E-06
		Total mercury	1.84E-06	4.44E-08	2.08E-10	1.12E-08		1.90E-06
		Nitrogen oxide (non-point source)	1.59E-02	2.37E-04	1.82E-01	6.01E-05	-1.16E+02	-1.16E+02
		Nickel	3.12E-06	7.52E-08	3.53E-10	1.90E-08		3.21E-06
		PM10 (non-point source)	1.17E-03	1.74E-05	1.90E-02	4.41E-06		2.02E-02
		Lead	7.30E-06	1.76E-07	8.27E-10	4.46E-08		7.52E-06
	Water	COD	2.54E-02					2.54E-02
		Arsenic	1.10E-10					1.10E-10
		Cadmium	1.65E-11					1.65E-11
		Hexavalent chrome	3.30E-10					3.30E-10
		Total mercury	1.10E-11					1.10E-11
	Soil	Debris	3.44E-09					3.44E-09
		Industrial waste (estimated fixed value if amount is unknown)	1.46E-03	2.71E-05	1.27E-07	6.86E-06		1.49E-03
		Waste plastics	1.00E+00	1.00E+00				2.00E+00
		Slag	4.44E-06					4.44E-06

Table 4.3-2 Ordinary coating LCI analysis result (kg/f.u.)

			Material production	Manufacturing	Transportation	Application	Use	Σ
Consumption-related environmental load	Exhaustible resources	Coal	5.09E+01	8.09E-01	3.91E-03	2.23E-01		5.19E+01
		Crude oil	3.29E+02	1.50E-01	2.01E+01	4.13E-02		3.50E+02
		Natural gas	5.30E+01	3.77E-01	1.82E-03	1.04E-01		5.34E+01
		Uranium	2.69E-03	7.13E-05	3.44E-07	1.96E-05		2.78E-03
		Copper	4.59E-06					4.59E-06
		Aluminum	2.22E-05					2.22E-05
		Lead	1.69E-07					1.69E-07
		Zinc	9.38E-07					9.38E-07
		Limestone	2.99E+02					2.99E+02
		Rock (excluding limestone)	1.37E-06					1.37E-06
		Titanium	6.60E+01					6.60E+01
Discharge-related environmental load	Outdoor air	Carbon dioxide	9.75E+02	3.71E+00	6.43E+01	1.02E+00		1.04E+03
		Sulfur dioxide	5.84E-01	6.96E-04	1.39E-02	1.92E-04		5.99E-01
		Nitrogen oxide	3.41E-01	1.55E-03	1.61E-03	4.26E-04		3.45E-01
		Nitrous oxide	3.85E-02	1.61E-04	1.03E-03	4.43E-05		3.98E-02
		Methane	3.16E-02	7.94E-05	3.83E-07	2.19E-05		3.17E-02
		Non-methane volatile organic compound (average)	1.38E-02	2.30E-04	7.09E-02	6.33E-05		8.50E-02
		Particle matter (PM10)	7.06E-02	2.92E-05	1.11E-04	8.02E-06		7.07E-02
		Arsenic	2.18E-06	6.76E-08	3.26E-10	1.86E-08		2.27E-06
		Cadmium	1.80E-07	5.60E-09	2.70E-11	1.54E-09		1.88E-07
		Hexavalent chrome	3.98E-06	1.23E-07	5.94E-10	3.39E-08		4.14E-06
		Total mercury	2.64E-06	8.16E-08	3.94E-10	2.25E-08		2.74E-06
		Nitrogen oxide (non-point source)	1.88E-02	4.36E-04	3.44E-01	1.20E-04		3.63E-01
		Nickel	4.46E-06	1.38E-07	6.68E-10	3.81E-08		4.64E-06
		PM10 (non-point source)	1.39E-03	3.20E-05	3.60E-02	8.82E-06		3.74E-02
		Lead	1.05E-05	3.24E-07	1.56E-09	8.92E-08		1.09E-05
	Water	COD	9.30E-03					9.30E-03
		Arsenic	2.20E-10					2.20E-10
		Cadmium	3.30E-11					3.30E-11
		Hexavalent chrome	6.60E-10					6.60E-10
		Total mercury	2.20E-11					2.20E-11
	Soil	Debris	6.88E-09					6.88E-09
		Industrial waste (estimated fixed value if amount is unknown)	2.20E-03	4.98E-05	2.40E-07	1.37E-05		2.26E-03
		Waste plastics	1.30E+00	1.84E+00				3.14E+00
		Slag	8.88E-06					8.88E-06

5 Impact Assessment

5.1 Subject Assessment Steps and Areas of Impact

In the impact assessment, LIME2 (Life cycle Impact assessment Method based on Endpoint modeling 2) was used to assess the following three steps: characterization, damage assessment, and weighting. Table 5.1-1 shows the areas of impact subject to the assessment in each step.

Table 5.1-1 Subject areas of impact and assessment steps

	Characterization	Damage assessment	Consolidation
Resource consumption (energy)	○	○	○
Resource consumption (mineral)	○	○	○
Global warming	○	○	○
Urban air pollution	-	○	○
Ozone depletion			
Acidification	○	○	○
Eutrophication	○	○	○
Photochemical oxidant	○	○	○
Human toxicity	○	○	○
Ecotoxicity	○	○	○
Indoor air quality	-		
Noise	-		
Waste	○	○	○
Land use	*	*	*

Cells with the * symbol mean that the LIME calculation sheet did not support them.
Cells with the - symbol mean that the LIME coefficient was not available.

5.2 Impact Assessment Result

5.2.1 Characterization

Figures 5.2-1 through 5.2-3 show the characterization results for HYDROTECT coating and the ordinary coating in terms of global warming, resource (mineral) consumption, and acidification. For both HYDROTECT coating and the ordinary coating, carbon dioxide was responsible for a large part of the global warming, and titanium was responsible for a large part of the resource (mineral) consumption. According to the LCI analysis results shown in Tables 4.3-1 and 4.3-2, the values for these substances were high in the material production phase. These values were lower for HYDROTECT coating than the ordinary coating because the ordinary coating had to be coated twice while HYDROTECT coating had to be coated only once during the 20 years of use, meaning that the amount of use of HYDROTECT was half that of the ordinary coating. In both HYDROTECT and the ordinary coating, the type of titanium contributing to the resource (mineral) consumption was mainly titanium dioxide in white pigments of the coating. Although HYDROTECT coating contains not only titanium dioxide in white pigments but also photocatalytic titanium dioxide, the amount of titanium dioxide is only 0.2% of the amount of titanium dioxide in white pigments, and the environmental impact of the special titanium dioxide is therefore small. Note that, in the graph for HYDROTECT coating, the acidification bar was extending significantly to the negative side because the air purification effects removed NOx.

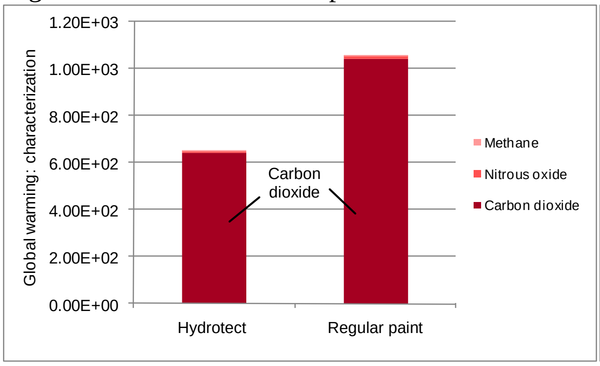


Figure 5.2-1 Characterization result (global warming)

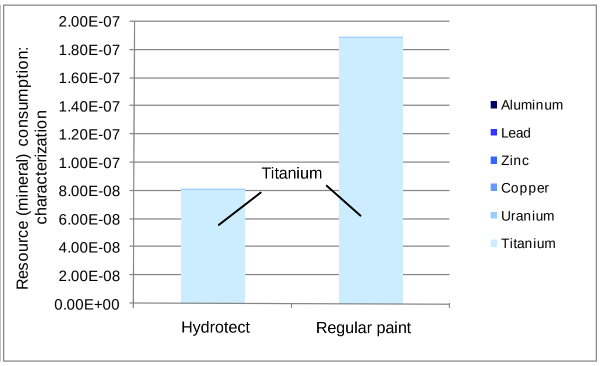


Figure 5.2-2 Characterization result (resource (mineral) consumption)

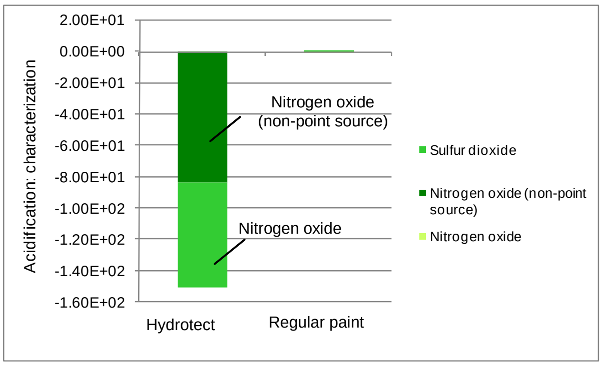


Figure 5.2-3 Characterization result (acidification)

5.2.2 Damage Assessment

Figures 5.2-3 through 5.2-6 show the result of damage assessment (by substance) in the four areas to be protected. One of the major characteristics of the damage assessment result for HYDROTECT coating is that the amount of damage to human health, social assets, and primary production resulting from nitrogen oxide and nitrogen oxide (non-point source) is a negative figure. This is attributed to NOx removal due to the air purification effects of HYDROTECT coating. Meanwhile, for both HYDROTECT coating and the ordinary coating, titanium accounted for a large part of damage to social assets, primary production, and biodiversity.

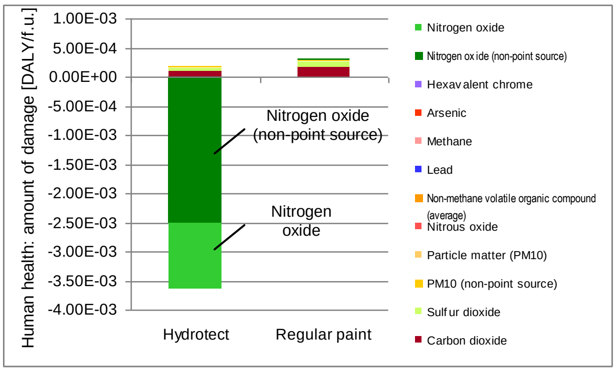


Figure 5.2-3 Damage assessment result (human health)

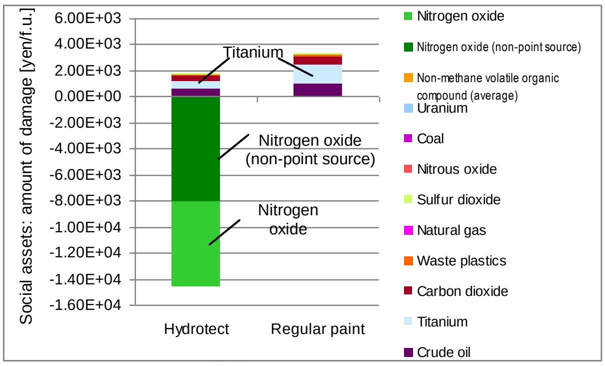


Figure 5.2-4 Damage assessment result (social assets)

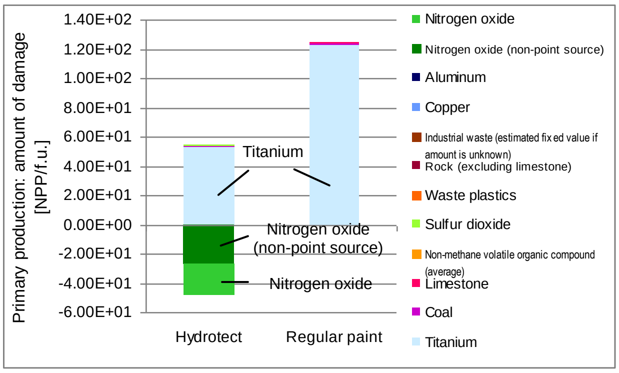


Figure 5.2-5 Damage assessment result (primary production)

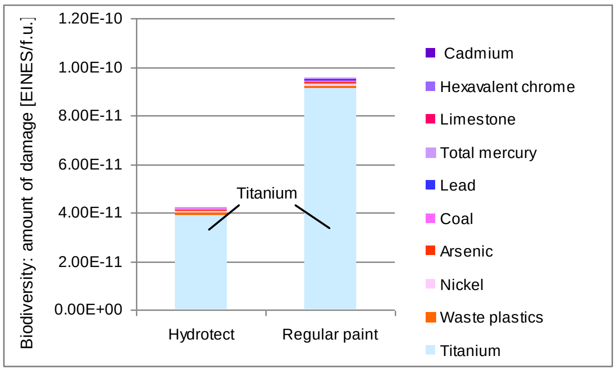


Figure 5.2-6 Damage assessment result (biodiversity)

5.2.3 Weighting

Figures 5.2-7 through 5.2-9 show the weighting results for HYDROTECT coating and the ordinary coating by substance, process, and the area of impact. For HYDROTECT coating, nitrogen oxide and nitrogen oxide (non-point source) in the result by substance, the product use phase in the result by process, and urban air pollution and acidification in the result by area of impact showed large negative figures. This is attributed to the fact that NOx was removed by the air purification effects of HYDROTECT coating, which was one of its major characteristics. Figure 5.2-10 is the weighting result for HYDROTECT coating and the ordinary coating showing social costs of the phases from material production to application (the total of the material production, manufacturing, transportation, and application phases), the product use phase, and the combined total (the entire cycle meaning the total of the material, manufacturing, transportation, application, and product use phases). The social cost of the phases from material production to application for HYDROTECT coating was about half that of the ordinary coating, and this is attributed to the fact that HYDROTECT coating is twice as durable as the ordinary coating. Also, since NOx was removed during the product use phase of HYDROTECT coating, the value significantly extended to the negative side of the graph, making the resulting social cost a negative figure, showing a large difference in the environmental impact between the two types of coatings.

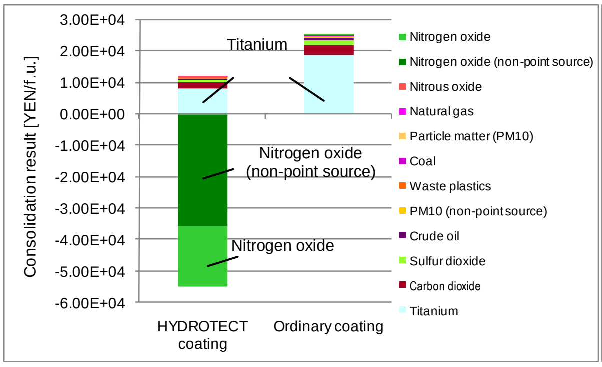


Figure 5.2-7 Weighting result (by substance)

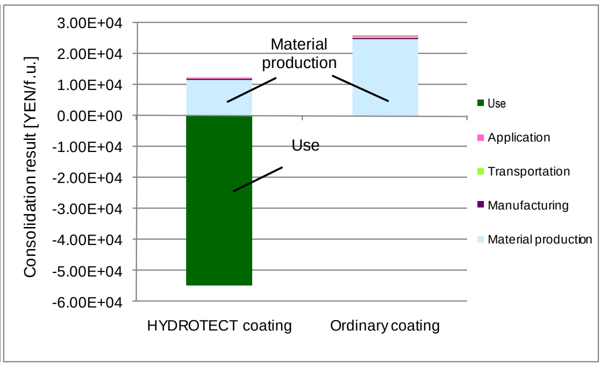


Figure 5.2-8 Weighting result (by process)

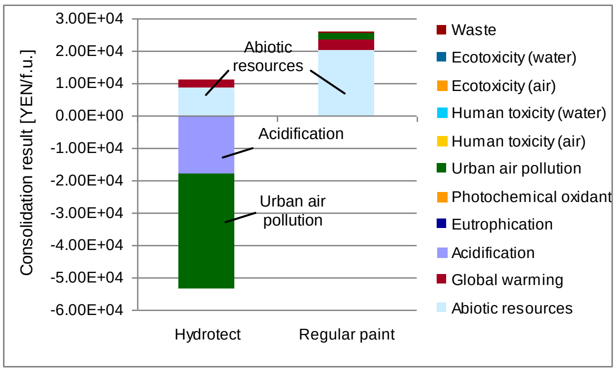


Figure 5.2-9 Weighting result (by area of impact)

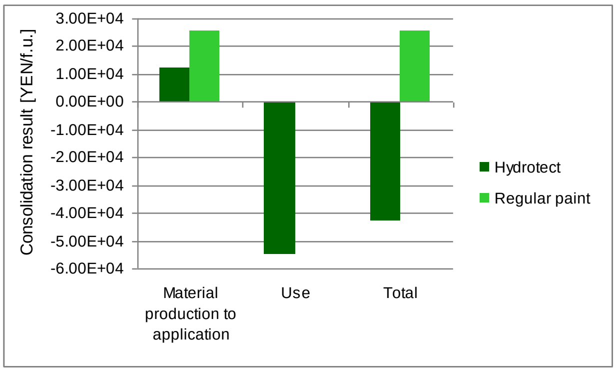


Figure 5.2-10 Weighting result (by coating)

6 Conclusion

6.1 Summary of the Study Result

In this study, we assessed the environmental impact of the entire life cycle (from the material production phase to the manufacturing, transportation, application, and use phases; application on the surface area of 1,000 m^2; and product use for 20 years) of HYDROTECT coating and an ordinary coating. The environmental impact in terms of social costs was -43,000 yen for HYDROTECT coating and 26,000 yen for the ordinary coating. This difference was largely due to: high durability of HYDROTECT coating leading to reduction of frequency of recoating; and the photocatalytic air purification effects. In order to further reduce the environmental impact, it is expected that improvement of coating durability and improvement of the NOx removal capability will both be effective. Also, the negative figures obtained in HYDROTECT coating-related assessment indicated that HYDROTECT coating had positive effects on the environment.

6.2 Limitations of the Study and Future Tasks

The assessment conducted in this study included all important processes as the subjects of the study (material production, manufacturing, transportation, application, and use), and therefore, we believe that the validity of the study result can be guaranteed. HYDROTECT coating contains not only titanium dioxide in white pigments but also photocatalytic titanium dioxide. Since we were unable to estimate the energy consumption in production of the photocatalytic titanium dioxide, we used the white pigment titanium dioxide as the basic units of both types of titanium dioxide. Note, however, that the amount of the photocatalytic titanium dioxide contained was small such that it would not have much influence on the assessment result. Similarly, we were unable to obtain detailed data on coating containers (cans) and supplies used in application; therefore, these items were also excluded from the assessment. The amount of NOx removal was calculated using the NOx removal performance data (JIS R 1701-1) on the assumption that it would be reaction rate-controlling and rely only on the amount of light since it was difficult to assess it uniformly considering the fact that it would greatly vary depending on the environment. It is also worth considering that, although only the NOx removal effects were examined as a photocatalytic reaction, SOx could also be removed through the photocatalytic reaction. Nevertheless, there was insufficient experimental data on SOx removal by photocatalyst and the amount of its removal therefore could not be examined. For this reason, the SOx removal performance was not included as the subject of the study. The points made above will have to be reviewed and examined for future studies.

Reference

1) Ministry of International Trade and Industry. Development of Removal Techniques of Air Pollutants using a Photocatalyst, 1997.
2) Japanese Standards Association. Fine Ceramics (Advanced Ceramics, Advanced Technical Ceramics) -- Test Method for Air Purification Performance of Photocatalytic Materials -- Part 1: Removal of Nitric Oxide (JIS R 1701-1).
3) New Energy and Industrial Technology Development Organization (NEDO). Standard Climate and Solar Radiation Data (METPV-3)
4) K. Shibata and Z. Uchijima, ed. Distribution and Measurement of Solar Energy. Japan Scientific Societies Press, 1987.
5) Japan Paint Manufacturers Association: LCA Guidebook by Japan Paint Manufacturers Association vol. 1, 2002.

Report on Comparison of the Environmental Impact of Various Types of Containers

May 2010

Toyo Seikan Kaisha, Ltd.

1 General

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1.2 Date of Report Creation

May 31, 2010

2 Study Objective

2.1 Background of the Study

Containers are necessary for saving, protecting, and providing their contents to consumers. Since the containers are disposable, it is necessary to select recyclable materials or to reduce container weight in order to reduce the environmental loads.

Since different containers are made with different materials, it is believed that they have different levels of environmental impact. Therefore, to reduce the environmental impact of containers, it is necessary to examine such differences. For this reason, we conducted LCA to examine the environmental impact of the entire life cycle of a wide variety of containers (aluminum cans, a PET bottle, and a stand-up pouch) to understand their environmental efficiency.

2.2 Application of the Study Result

The study result will be used to improve the understanding of the environmental impact of each type of container, identify differences of the environmental impact of different containers, and reduce the environmental impact.

3 Scope of the Study

3.1 Subjects and their Specifications

The subjects of the study were two types of aluminum cans (DWI can and aTULC), a PET bottle, and a stand-up pouch that were all manufactured, used, and disposed of inside Japan. Table 3.1-1 shows the specifications and characteristics of the subject containers.

Table 3.1-1 Specifications and characteristics of subject containers

Container	Specifications and characteristics	Weight
Aluminum can (DWI can) 	• conventional aluminum can • 350 ml and for carbonated drinks • Shaped by the draw and wall ironing (DWI) method • A lubricant is applied when shaping the can • A coating is applied on the inner surface after the can is shaped	15.5 g
Aluminum can (aTULC)  	• The name stands for Aluminum Toyo Ultimate Can • 350 ml and for carbonated drinks • Uses polyester film laminated aluminum plate as a can material; therefore, application of a lubricant or a coating on the inner surface is unnecessary	14.2 g
PET bottle 	• A heat-resistant bottle that can be filled with tea (a 350-ml bottle for carbonated drinks was not available) • 350 ml • Formed by resin injection and blowing • The cap and label are included as the subjects of the assessment	29.1 g
Stand-up pouch  	• A pouch containing detergent refill (a 350-ml pouch for beverages was not available) • 350 ml • Manufacturing of the pouch involves the plastic film printing, lamination, and forming processes	8.2 g

3.2 Function and Functional Unit

A functional unit in this assessment was one container to be filled with 350 ml of contents, protected, and provided to a consumer.

3.3 System boundary

The system boundary in this assessment included from the material production phase to the product manufacturing, filling, use, disposal, and recycling phases. The contents of the containers were excluded from the scope of the assessment (Figure 3.3-1).

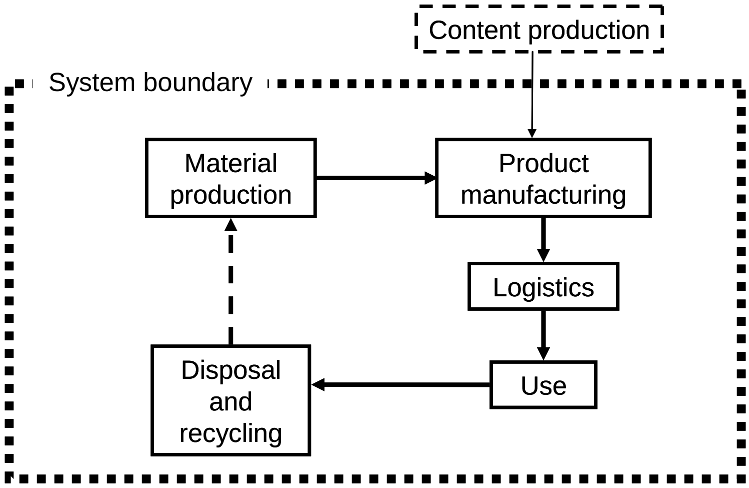

Figure 3.3-1 System boundary for a container

3.4 Note (Processes or Items Excluded from the System Boundary)

The aluminum cans used in this assessment were designed for carbonated drinks, but a 350-ml PET bottle and a 350-ml stand-up pouch designed for carbonated drinks were not available; therefore, a PET bottle and a stand-up pouch designed for different purposes were used. Also, although aluminum cans and other types of container require different filling methods, the method used for aluminum cans was applied to other types of container in this assessment.

4 Inventory Analysis

4.1 Priority Data

We referred to the FY2008 Toyo Seikan measurement data to obtain data on the amount of materials, resources, and energy used in manufacturing of the body and the lid of an aluminum can, manufacturing of a PET bottle, and manufacturing of a stand-up pouch.

4.2 Background Data

The LCA data for the manufacturing of material and product, logistics, use, disposal, and recycling phases for the aluminum cans was obtained in accordance with the EcoLeaf Product Category Rule (PCR) "Metal Cans for beveragis and Foods" (PCR number: BC-01). The scenario created for the aluminum cans was applied to the other types of containers to obtain the data. Note, however, the PET bottle disposal and recycling scenario was created based on the study report issued by the Institute for Policy Sciences [1], and the stand-up pouch disposal and recycling scenario was created based on the study report issued by the Japan Containers and Packaging Recycling Association. [2]

Although the calculation method is specified in the EcoLeaf PCR "Flexible Packaging Materials Made Mainly with Plastic Materials" (PCR number: CX-01) to obtain the stand-up pouch data, we instead used the PCR "Metal Cans for beveragis and Foods" in order to align its system setting to that of the aluminum cans.

Also note that, in this assessment, we used the EcoLeaf basic units.

4.3 Subjects of Inventory Analysis and List of Analysis Results

Table 4.3-1 shows the subjects of inventory analysis for the aluminum (DWI) can and the list of the analysis results. Analysis results for other types of containers were omitted since the same inventory was used.

Table 4.3-1 Aluminum (DWI) can LCI analysis result (kg/can)

Input-output items				Life cycle state	Unit	Manufacturing		Logistics	Use	Disposal and recycling
						Material	Product			
Inventory analysis	Consumption-related environmental load	Non-renewable resources	Energy resources	Coal	kg	2.63E-02	2.21E-03	2.57E-07	5.49E-04	-1.73E-02
				Crude oil (fuel)	kg	1.41E-02	5.61E-03	2.40E-03	5.02E-03	-4.22E-03
				LNG	kg	1.31E-02	4.94E-03	3.72E-05	3.43E-04	-1.74E-03
				Uranium ore (U)	kg	9.66E-09	1.50E-07	1.74E-11	3.71E-08	1.51E-09
			Mineral resources	Crude oil (raw material)	kg	6.14E-04	0	0	0	0
				Iron ore (Fe)	kg	0	0	0	0	0
				Copper ore (Cu)	kg	0	0	0	0	0
				Bauxite (Al)	kg	6.30E-03	0	0	0	-4.21E-03
				Nickel ore (Ni)	kg	0	0	0	0	0
				Chrome ore (Cr)	kg	0	0	0	0	0
				Manganese ore (Mn)	kg	0	0	0	0	0
				Lead ore (Pb)	kg	0	0	0	0	0
				Tin ore (Sn)	kg	0	0	0	0	0
				Zinc ore (Zn)	kg	0	0	0	0	0
				Gold ore (Au)	kg	0	0	0	0	0
				Silver ore (Ag)	kg	0	0	0	0	0
				Quartz sand	kg	0	0	0	0	0
				Rock salt	kg	7.85E-04	0	0	0	-4.28E-04
				Limestone	kg	1.05E-03	0	0	0	-7.00E-04
				Soda ash (natural)	kg	0	0	0	0	0
				Other	kg	-	-	-	-	
		Recyclable resources		wood	kg	9.27E-04	0	0	2.04E-02	0
				water	kg	3.80E-01	1.96E+00	1.93E-04	1.66E+00	-8.81E-03
	Emission-related environmental load	To the air		CO2	kg	8.61E-02	3.69E-02	7.75E-03	1.82E-02	-3.60E-02
				SOx	kg	2.45E-04	1.85E-05	9.52E-06	4.57E-06	-2.41E-04
				NOx	kg	1.49E-04	1.02E-04	1.19E-04	3.35E-05	-7.33E-05
				N2O	kg	5.35E-07	1.34E-05	1.40E-07	7.55E-07	1.59E-07
				CH4	kg	8.03E-08	4.01E-07	4.66E-11	9.97E-08	4.05E-09
				CO	kg	4.50E-07	3.00E-05	4.75E-05	9.97E-07	1.68E-07
				NMVOC	kg	1.47E-07	1.90E-05	9.15E-11	1.95E-07	7.93E-09
				CxHy	kg	2.61E-07	3.44E-06	2.40E-06	3.34E-07	9.76E-08
				dust	kg	1.48E-04	5.74E-06	9.52E-06	4.89E-07	-9.88E-05
		To the water		BOD	kg	1.12E-06	-	-	-	-3.84E-09
				COD	kg	3.02E-06	-	-	-	-1.58E-07
				Total N	kg	4.82E-07	-	-	-	
				Total P	kg	6.67E-08	-	-	-	
				SS	kg	8.36E-06	-	-	-	-4.86E-06
		To the soil		Unspecified solid waste	kg	2.61E-03	4.38E-06	0	2.56E-04	0
				Slag	kg	0	0	0	0	0
				Sludge	kg	0	0	0	0	0
				Low radioactive waste	kg	4.60E-09	1.05E-07	1.22E-11	2.60E-08	1.06E-09

5 Impact Assessment

5.1 Subject Assessment Steps and Areas of Impact

In the impact assessment, LIME2 (Life cycle Impact assessment Method based on Endpoint modeling 2) was used to asses the following 3 steps: characterization, damage assessment, and weighting. Table 5.1-1 shows the areas of impact subject to the assessment in each step.

Table 5.1-1 Subject areas of environmental impact and assessment steps

	Characterization	Damage assessment	Weighting
Resource consumption (energy)	○	○	○
Resource consumption (mineral)	○	○	○
Global warming	○	○	○
Urban air pollution	○	○	○
Ozone depletion	○	○	○
Acidification	○	○	○
Eutrophication	○	○	○
Photochemical oxidant	○	○	○
Human toxicity	○	○	○
Ecotoxicity	○	○	○
Indoor air quality	-	○	○
Noise	*	*	*
Waste	○	○	○
Land use	*	*	*

*: Cells with the * symbol mean that the LIME calculation sheet did not support them.
-: Cells with the - symbol mean that the LIME coefficient was not available.

5.2 Impact Assessment Result

5.2.1 Characterization

Characterization results for containers with regard to resource consumption, global warming, and photochemical oxidant are shown in Figures 5.2-1 through 5.2-3, respectively.

With regard to resource consumption, consumption of crude oil and natural gas were high for the aluminum cans. For the PET bottle and the stand-up pouch, crude oil consumption was high but the ratio of natural gas was not as high as for the aluminum cans. Consumption of natural gas accounted for high percentages in resource consumption for the aluminum cans due to how aluminum plates were manufactured. When the PET bottle and stand-up pouch, both using resins as main raw materials, were compared, the stand-up pouch was found to use a smaller amount of resources than the PET bottle due to the difference in the amount of resin use.

With regard to global warming, characterization results were different from the resource consumption results; all types of containers had similar results. The stand-up pouch had lower resource consumption than other types of containers because it required less material for manufacturing. However, since this type of pouch is made with compound materials, it is unlikely to be recycled and is most likely incinerated. This leads to the situation where the resin of the pouch generates more carbon dioxide than other types of container, and the analysis result indicated that the level of global warming was after all about the same as other types of containers.

With regard to photochemical oxidant, the stand-up pouch showed a significant effect. Manufacturing of a standing pouch requires more solvents than any other types of containers due to printing and laminating of the package, and these solvents are volatilized using dryers. Dried solvents are then incinerated and detoxified using exhaust gas treatment equipment, but realistically speaking, it is not possible to collect and process 100% of them. Although only a little, the dried solvents are thus emitted to the air to cause generation of photochemical oxidant.

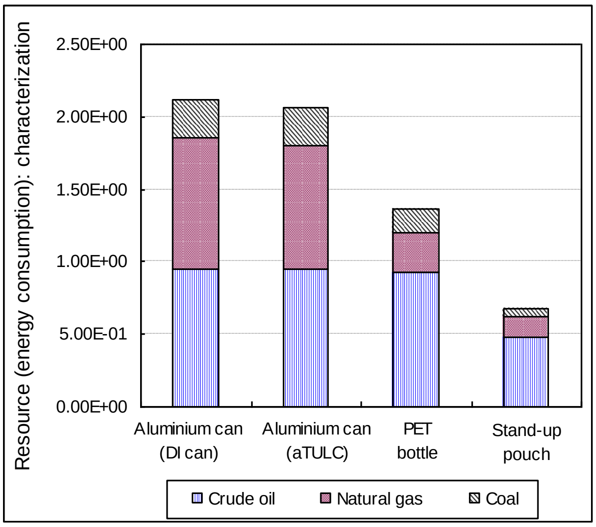

Figure 5.2-1 Characterization result (resource consumption)

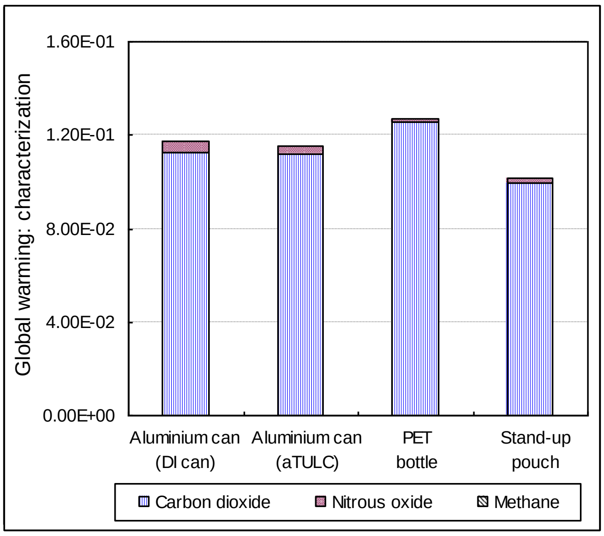

Figure 5.2-2 Characterization result (global warming)

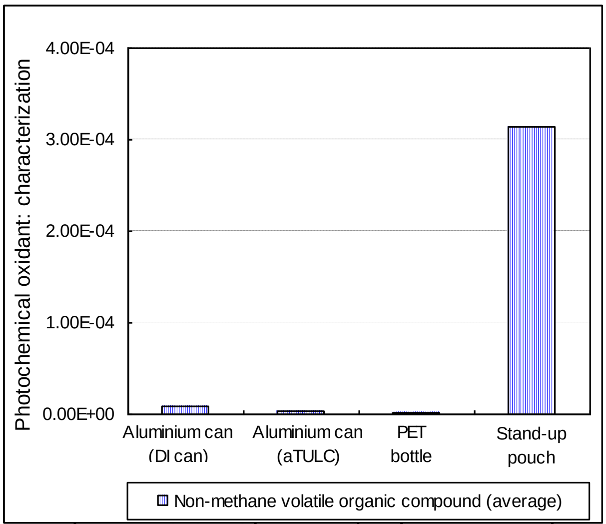

Figure 5.2-3 Characterization result (photochemical oxidant)

5.2.2 Damage Assessment

Figures 5.2-4 through 5.2-7 show the results of damage assessment (by substance). With regard to the damage to human health, sulfur dioxide used in the PET bottle had more impact than that of other types of containers. Similarly, the non-methane volatile organic compound used in the stand-up pouch had more impact than that of other types of containers. This is because a lot of energy (electricity) is used in the PET bottle shaping process, which in turn generates a lot of sulfur dioxide. Meanwhile, the reason why the non-methane volatile organic compound used in the stand-up pouch had a large impact was that, as described in the characterization result, there were solvents that could not be collected and processed by exhaust gas treatment equipment. The same result was indicated for the damage assessment result with regard to primary production.

As for the damage to social assets and biodiversity, the aluminum cans had a larger waste impact than the PET bottle and the stand-up pouch. This was due to waste generation during the course of manufacturing of aluminum plates, which were the raw material of the aluminum cans.

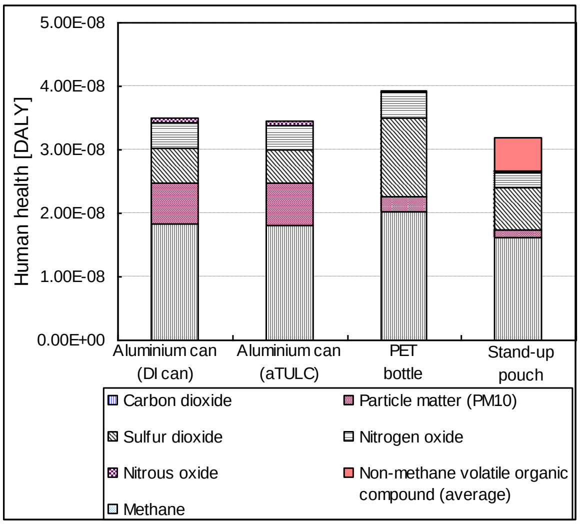

Fig. 5.2-4 Damage assessment result (human health)

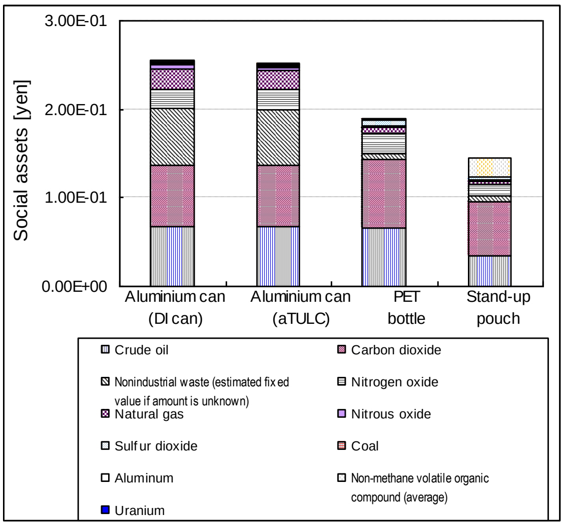

Fig. 5.2-5 Damage assessment result (social assets)

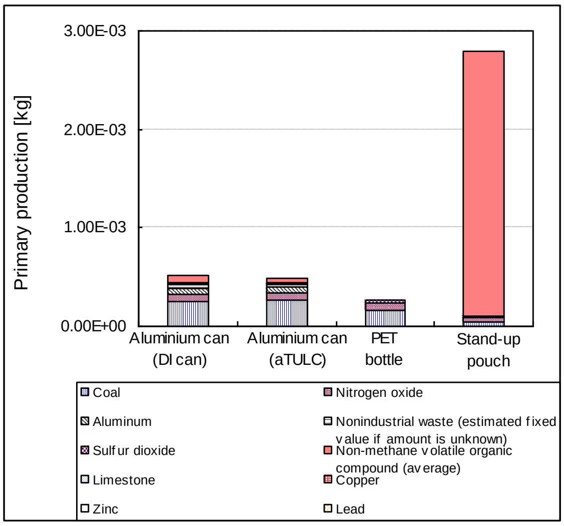

Fig. 5.2.6 Damage assessment result (primary production)

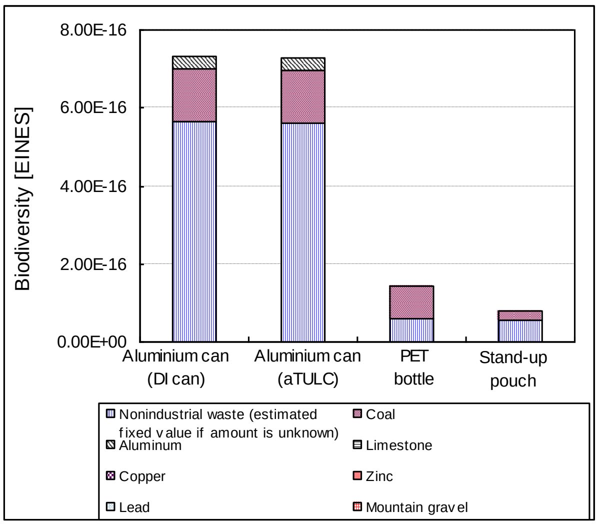

Fig. 5.2.7 Damage assessment result (biodiversity)

5.2.3 Weighting

Figure 5.2-8 shows the weighting result (by substance) for each type of container.

There were no large differences in the total values for all the types of subject container. For all of them, carbon dioxide emissions accounted for the largest part of the environmental impact. Other significant factors of the impact were: sulfur dioxide emissions for the PET bottle; and non-methane volatile organic compound emissions for the stand-up pouch.

Figure 5.2-9 shows the weighting result by the area of impact. The aluminum cans had a larger impact than other types of container on a biotic resources and waste, and the stand-up pouch had a significant impact on photochemical oxidant.

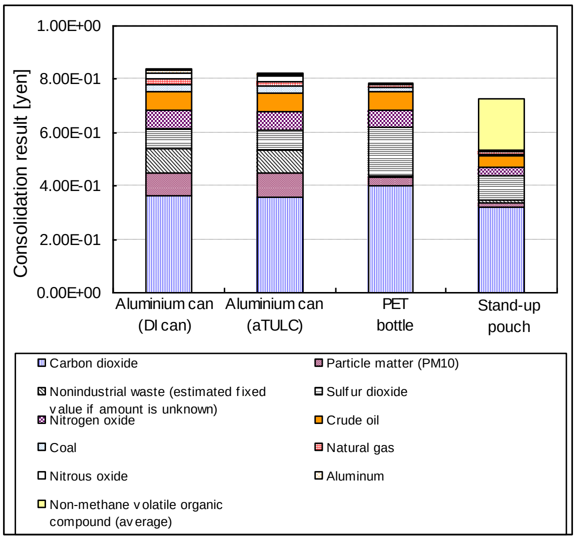

Figure 5.2-8 Weighting result (by substance)

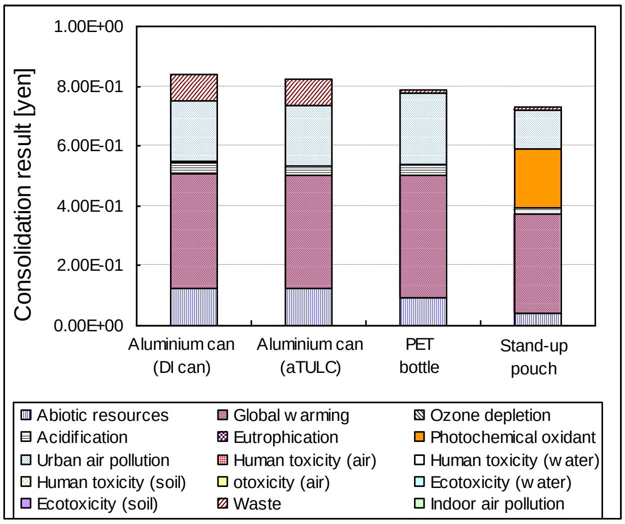

Figure 5.2-9 Weighting result (by area of impact)

6 Conclusion

6.1 Summary of the Study Result

We assessed the environmental impact of the entire life cycle (material production, product manufacturing, logistics, use, disposal and recycling) of two types of aluminum can (DWI can and aTULC), a PET bottle, and a stand-up pouch in order to examine the differences in the environmental impact among them.

The total values in the weighting results did not show any significant differences among the subject containers. However, the breakdown of the environmental impact by substance showed some differences. The aluminum cans had a large impact on waste, the PET bottle had a large impact on sulfur dioxide, and the stand-up pouch had a large impact on the non-methane volatile organic compound.

In order to reduce the environmental impact of containers in general, it is necessary to incorporate the study result described above when establishing environmental impact reduction measures customized for each type of container. For example, a measure for reducing processing energy can be established for the PET bottle, and a measure for reducing the amount of use of solvents can be established for the stand-up pouch.

6.2 Limitations of the Study and Future Tasks

In order to make the system boundary uniform across all types of container, we included the content filling process in the assessment. However, since we were unable to obtain data on the filling process for PET bottles and stand-up pouches, we used aluminum can filling data. Also, the subjects of the assessment were different types of container designed for different uses; therefore, the study result has not accurately reflected the functions and characteristics of the subject containers, meaning that the result of comparison of these containers should not be generalized. In future, comparison must be made under more controlled conditions.

Reference

1) The Institute for Policy Sciences: Investigation Report on Life Cycle Assessment of Container and Packaging (2005)
2) The Japan Containers and Packaging Recycling Association: Examination of the Environmental Load Involved in the Method to Recycle Plastic Packaging and Containers

Report on Comparison of the Environmental Impacts of Business Activities

May 2010

Fujitsu Laboratories Ltd.

1 General

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1.2 Date of Report Creation

May 15, 2010

2 Study Objective

2.1 Background of the Study

We conducted LCA of the environmental impact of our business activities to clarify the breakdown and chronological changes of the environmental impact.

2.2 Application of the Study Result

We will use the study result to encourage implementation of eco-friendly business activities based on the understanding of the environmental impact of business activities from the life cycle and the supply chain points of view. The study result will also be used to identify chronological changes in the environmental impact and to provide information as tips for reduction of the environmental impact.

3 Scope of the Study

3.1 Subject and the Specifications

The subject of the study is manufacturing of the leading products* in the Fujitsu group business activities in FY2007 and FY2008.
*Leading products: 15 types of product such as PCs, mobile phones, and servers

3.2 Function and Functional Unit

The functional unit in this study is the life cycle of leading products manufactured and shipped in each subject fiscal year.

3.3 System boundary

The system includes the raw material procurement (material), manufacturing, and logistics phases (Figure 3.2-1).

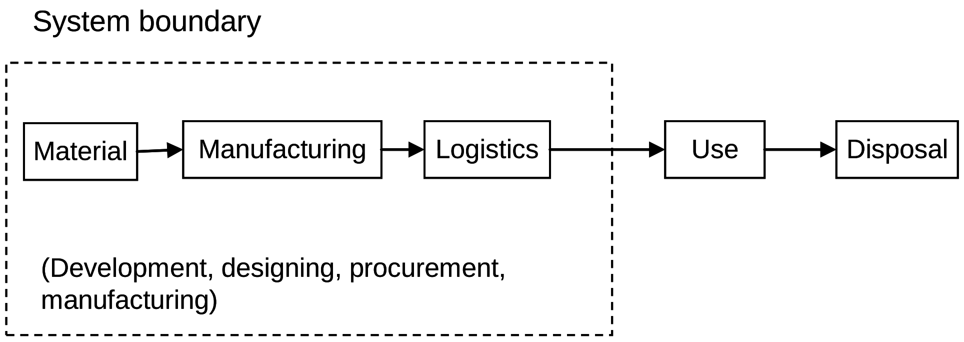

Figure 3.2-1 Business activity system and system boundary

3.4 Note (Processes or Items Excluded from the System Boundary)

We excluded the use and disposal phases from the scope of the assessment in order to focus on the environmental impact of manufacturing of the leading products in our business activities.

4 Inventory Analysis

4.1 Priority Data

We referred to our own survey data and the sustainability report[1) 2)] for the amount of materials, resources, and energy used from the material phase to the manufacturing phase of the leading products.
We also used the survey results disclosed and provided by research companies to obtain data on the volume of shipment of the leading products.[3) 4) 5)]

4.2 Background data

We used our own database created based on the input-output table to obtain the basic unit data for energy and materials.

4.3 Subjects of Inventory Analysis and Lists of Analysis Results

Tables 4.3-1 and 4.3-2 show the subjects of inventory analysis of FY2007 and FY2008 business activities and the lists of the analysis results.

Table 4.3-1 FY2007 business activities LCI analysis result

					Unit	Manufacturing		Logistics
						Material	Product	
Consumption energy					MJ	1.57E+10	2.50E+08	1.52E+08
					Mcal	-	-	-
Inventory analysis	Consumption-related environmental load	Non-renewable resources	Energy resources	Coal	kg	2.07E+08	2.83E+06	2.80E+05
				Crude oil (fuel)	kg	1.48E+08	1.23E+06	4.48E+06
				Natural gas	kg	6.28E+07	1.31E+06	1.07E+05
				Uranium ore (U)	kg			
			Mineral resources	Crude oil (raw material)	kg			
				Iron ore (Fe)	kg	5.19E+07	3.06E+04	5.49E+04
				Copper ore (Cu)	kg	5.88E+06	4.42E+02	7.46E+02
				Bauxite (Al)	kg	1.52E+07	2.63E+03	5.60E+03
				Nickel ore (Ni)	kg			
				Chrome ore (Cr)	kg			
				Manganese ore (Mn)	kg			
				Lead ore (Pb)	kg			
				Tin ore (Sn)	kg			
				Zinc ore (Zn)	kg			
				Gold ore (Au)	kg	5.52E+03	0.00E+00	0.00E+00
				Silver ore (Ag)	kg	0.00E+00	0.00E+00	0.00E+00
				Sand	kg			
				Limestone	kg	-	-	-
				Soda ash (natural)	kg			
				Other	kg	-	-	-
		Recyclable resources		Wood	kg	-	-	-
				Water	kg	-	-	-
	Emission-related environmental load	To the air		CO2	kg	1.13E+09	1.68E+07	1.05E+07
				SOx	kg	1.08E+06	7.90E+03	1.02E+04
				NOx	kg	1.78E+06	1.24E+04	6.89E+04
				N2O	kg			
				CH4	kg			
				CO	kg	-	-	-
				NMVOC	kg			
				CxHy	kg	-	-	-
				dust	kg			
		To the water		BOD	kg	6.97E+06	2.51E+03	9.02E+03
				COD	kg	7.96E+06	3.28E+03	9.74E+03
				T-P	kg	3.24E+05	5.78E+01	1.46E+02
				T-N	kg	2.81E+06	1.35E+03	2.36E+03
				SS	kg	5.22E+06	2.01E+03	6.32E+03
		To the soil		Unspecified solid waste	kg			
				Slag	kg			
				Sludge	kg			
				Low radioactive waste	kg	-	-	-

Table 4.3-2　FY2008 business activities LCI analysis result

					Unit	Manufacturing: Material	Manufacturing: Product	Logistics
Consumption energy					MJ	1.33E+10	1.99E+08	1.30E+08
					Mcal	-	-	-
Inventory analysis	Consumption-related environmental load	Non-renewable resources	Energy resources	Coal	kg	1.75E+08	2.23E+06	2.39E+05
				Crude oil (fuel)	kg	1.25E+08	1.01E+06	3.82E+06
				Natural gas	kg	5.32E+07	1.03E+06	9.15E+04
				Uranium ore (U)	kg			
			Mineral resources	Crude oil (raw material)	kg			
				Iron ore (Fe)	kg	4.42E+07	2.42E+04	4.69E+04
				Copper ore (Cu)	kg	5.00E+06	3.49E+02	6.37E+02
				Bauxite (Al)	kg	1.30E+07	2.07E+03	4.78E+03
				Nickel ore (Ni)	kg			
				Chrome ore (Cr)	kg			
				Manganese ore (Mn)	kg			
				Lead ore (Pb)	kg			
				Tin ore (Sn)	kg			
				Zinc ore (Zn)	kg			
				Gold ore (Au)	kg	4.82E+03	0.00E+00	0.00E+00
				Silver ore (Ag)	kg	0.00E+00	0.00E+00	0.00E+00
				Sand	kg			
				Limestone	kg	-	-	-
				Soda ash (natural)	kg			
				Other	kg	-	-	-
		Recyclable resources		Wood	kg	-	-	-
				Water	kg	-	-	-
	Emission-related environmental load	To the air		CO2	kg	9.51E+08	1.34E+07	8.93E+06
				SOx	kg	9.11E+05	6.23E+03	8.71E+03
				NOx	kg	1.50E+06	9.84E+03	5.88E+04
				N2O	kg			
				CH4	kg			
				CO	kg	-	-	-
				NMVOC	kg			
				CxHy	kg	-	-	-
				dust	kg			
		To the water		BOD	kg	5.89E+06	1.98E+03	7.69E+03
				COD	kg	6.74E+06	2.59E+03	8.31E+03
				T-P	kg	2.75E+05	4.57E+01	1.24E+02
				T-N	kg	2.38E+06	1.07E+03	2.02E+03
				SS	kg	4.40E+06	1.59E+03	5.39E+03
		To the soil		Unspecified solid waste	kg			
				Slag	kg			
				Sludge	kg			
				Low radioactive waste	kg	-	-	-

5. Impact Assessment

5.1 Subject Assessment Steps and Areas of Impact

In the impact assessment, LIME2 (Life cycle Impact assessment Method based on Endpoint modeling 2) was used to assess the following three steps: characterization, damage assessment, and weighting. Table 5.1-1 shows the areas of impact subject to the assessment in each step.

Table 5.1-1 Subject areas of environmental impact and assessment steps

	Characterization	Damage assessment	Weighting
Resource consumption (energy)	○	○	○
Resource consumption (mineral)	○	○	○
Global warming	○	○	○
Urban air pollution	-	○	○
Ozone depletion			
Acidification	○	○	○
Eutrophication	○	○	○
Photochemical oxidant			
Human toxicity			
Ecotoxicity			
Indoor air quality			
Noise			
Waste			
Land use			

5.2 Impact Assessment Result

5.2.1 Characterization

Figures 5.2-1 through 5.2-3 show the FY2007 and FY2008 business activity characterization results with regard to resource and energy consumption, mineral consumption, and eutrophication, respectively.

The amount of the environmental impact in FY2008 decreased from FY2007. Although the number of units shipped varied for each type of product, the total shipment volume decreased, resulting in the decrease of the environmental impact.

In both years, the impact of crude oil consumption accounted for a large part of energy consumption.

Meanwhile, gold consumption accounted for a large part of mineral consumption, and this seemed to be attributed to gold-plating of boards or electronic parts. As for the environmental impact on water, total nitrogen accounted for more than 60% of eutrophication.

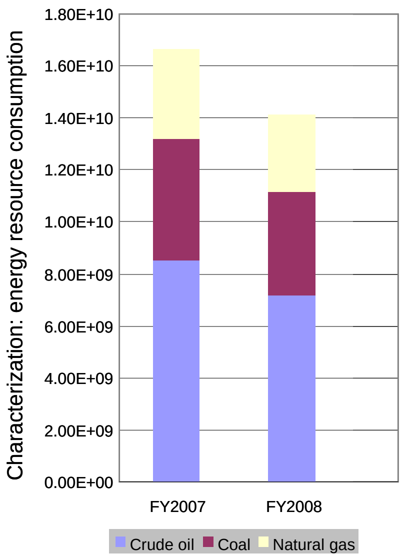

Figure 5.2-1 Characterization result (energy consumption)

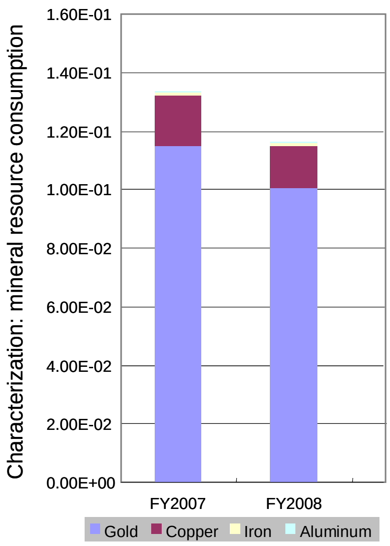

Figure 5.2-2 Characterization result (mineral consumption)

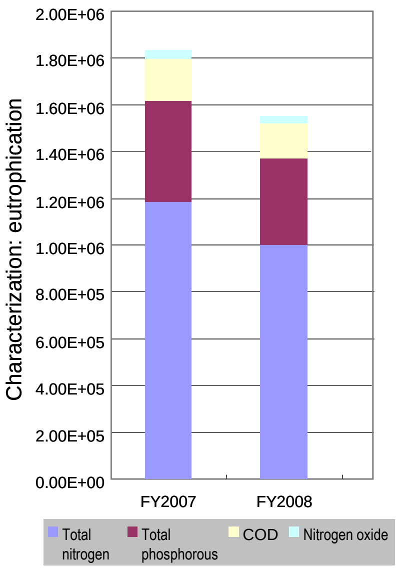

Figure 5.2-3 Characterization result (eutrophication)

5.2.2 Damage Assessment

Figures 5.2-4 through 5.2-7 show the damage assessment results (by substance) for the four areas to be protected.

For human health, the overall damage was halved by the two major causes, carbon dioxide and sulfur dioxide.

For social assets, gold accounts for more than half of the entire damage, and the rest of the damage was attributed to carbon dioxide, crude oil, and copper.

For primary production and biodiversity, coal, gold, and copper caused large damage

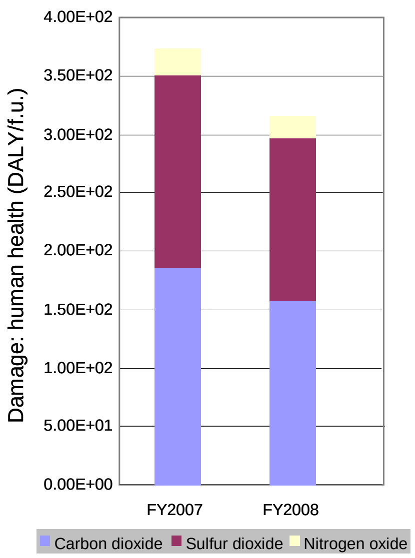

Figure 5.2-4 Damage assessment result (human health)

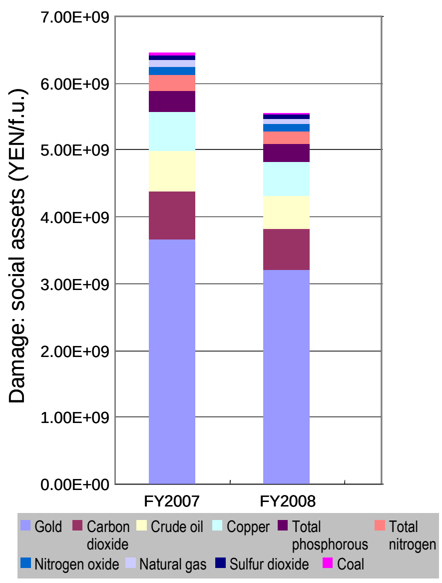

Figure 5.2-5 Damage assessment result (social assets)

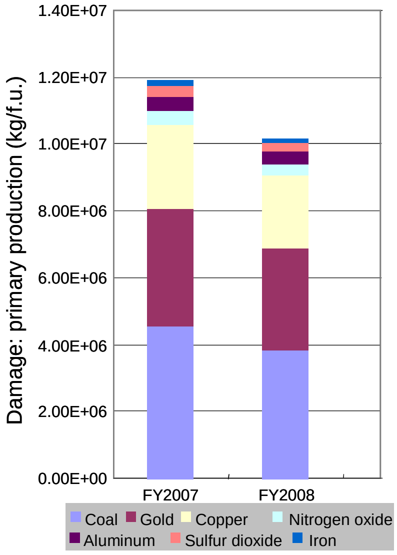

Figure 5.2-6 Damage assessment result (primary production)

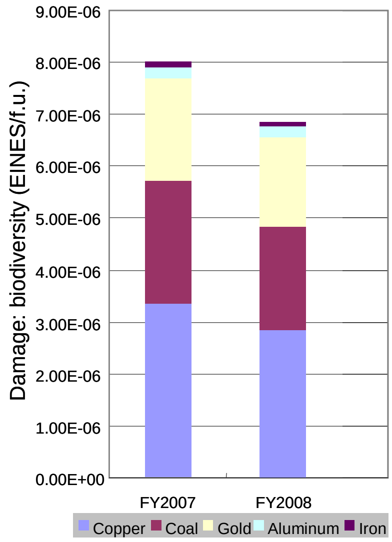

Figure 5.2-7 Damage assessment result (biodiversity)

Figures 5.2-8 and 5.2-9 show the damage assessment results by process. The material phase (raw material procurement) accounted for most of the damage, and the ratio of the damage of the manufacturing or logistics was only about 1%.

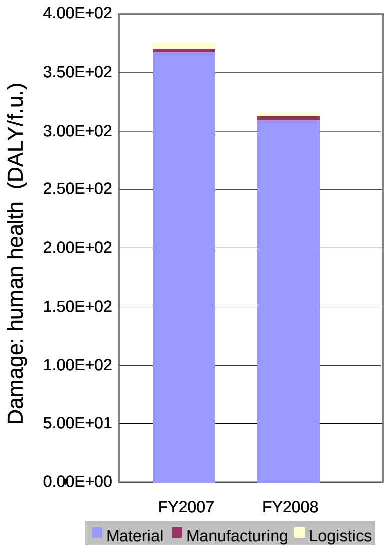

Figure 5.2-8 Human health damage assessment by process

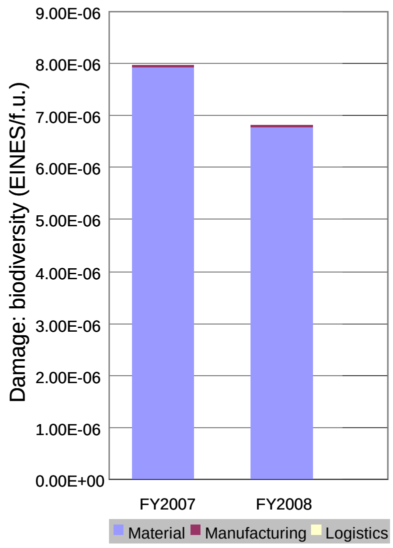

Figure 5.2-9 Biodiversity damage assessment by process

Figures 5.2-10 through 5.2-13 show the damage assessment results by area of impact.

The global warming and the urban air pollution by carbon dioxide and sulfur dioxide almost caused almost equal damage to human health. For social assets, damage to abiotic resources caused by energy and mineral consumption accounted for more than 70% of the overall damage, and the global warming and eutrophication accounted for 10%, respectively.

Also, abiotic resource consumption accounted for almost all damage to primary production and biodiversity.

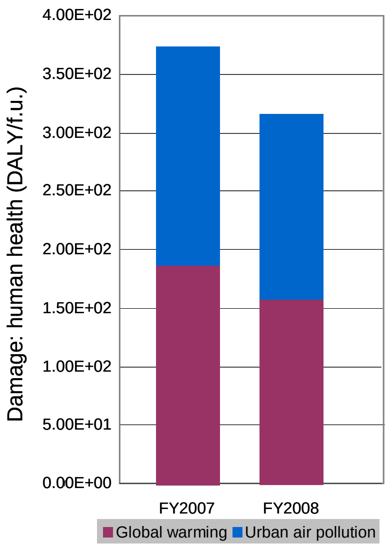

Figure 5.2-10 Damage to human health (assessment by area of impact)

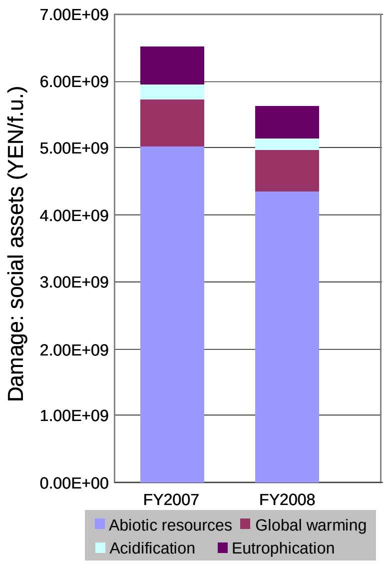

Figure 5.2-11 Damage to social assets (assessment by area of impact)

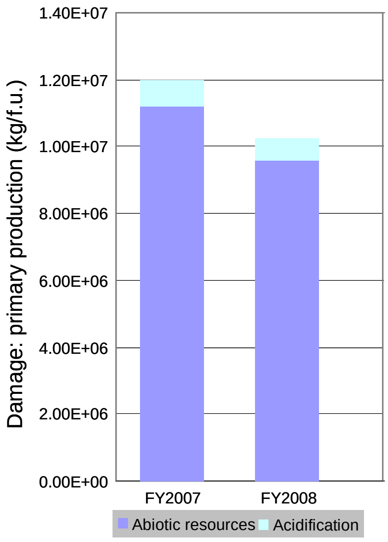

Figure 5.2-12 Damage to primary production (assessment by area of impact)

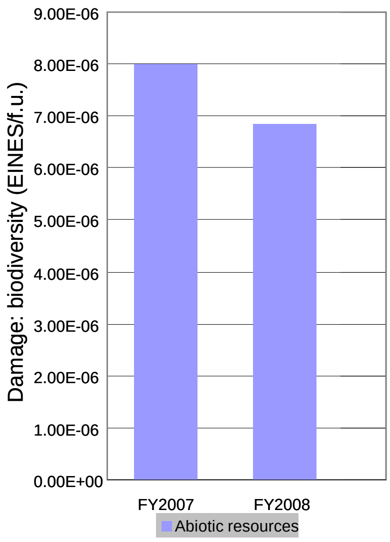

Figure 5.2-13 Damage to biodiversity (assessment by area of impact)

5.2.3 Weighting

Figure 5.2-14 shows the weighting result by substance, and Figure 5.2-15 shows the weighting result by area of impact.

There was no significant difference in the breakdown of the result between FY2007 and FY2008, but the overall social costs were lower for FY2008.

The major factors responsible for the amount of consolidated damage in terms of the substance were: consumption of gold that had a large environmental impact on social assets; and emissions of carbon dioxide and sulfur dioxide to the air that had a large impact on human health and social assets.

The major factors responsible for the amount of consolidated damage in terms of areas of impact were: consumption of abiotic resources such as gold, coal, and copper; and the global warming and urban air pollution caused by carbon dioxide and sulfur dioxide.

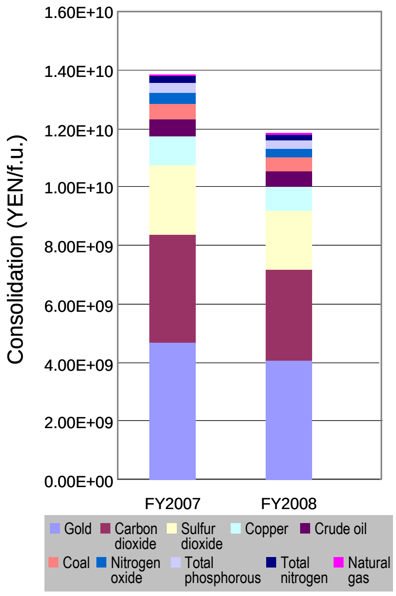

Figure 5.2-14 Weighting result (by substance)

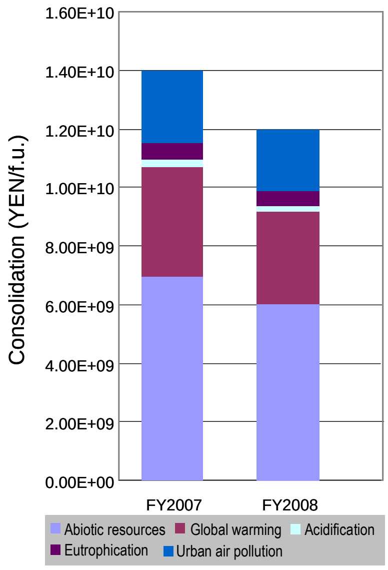

Figure 5.2-15 Weighting result (by areas of impact)

6 Conclusion

6.1 Summary of the Study Result

We assessed the environmental impact of the material to manufacturing phases of the leading products of our business activities such as PCs, mobile phones, and servers. The assessment result indicated that the overall damage was lower in FY2008 than in FY2007.

More specifically, the factors contributing to the environmental impact were mainly the consumption of crude oil and gold, followed by global warming and urban air pollution caused by carbon dioxide and sulfur dioxide emissions.

Mobile phones require more gold than PCs or servers per product unit weight.

Damage to the social assets will therefore decrease and the environmental impact caused by resource consumption can be controlled if the amount of gold use can be controlled and reduced in the manufacturing phase or earlier.

Also, in the four areas to be protected, social assets were the most susceptible to the environmental impact while biodiversity was highly unlikely to be affected by it.

6.2 Limitations of the Study and Future Tasks

In this study, only the selected phases were assessed (material, manufacturing, and logistics), and the use and the disposal processes were not included. Therefore, not all existing phases were covered. However, if the product use phase was included in the assessment, the assessment would show a huge environmental impact of electricity used during the product use, making the environmental impact of manufacturing less visible. For this reason, we limited the scope of assessment to the manufacturing phase and the earlier phase. Also, chemical substances were not included as the subjects of the assessment; therefore, it is not clear how these substances would affect the study result. Because of these exclusions, it is possible to say that the assessment did not sufficiently include all important substances. Furthermore, we attempted to incorporate the result of our forestation activities into the assessment to examine their effect on biodiversity, but we eventually decided to exclude them from the scope of the assessment because we were unable to obtain sufficient data on the pre- and post activity status. We hope to continue our study on the effect of forestation since we expect that biodiversity will attract more attention in the future.

Reference

1) Fujitsu Group Sustainability Report (2009): Operating Activities and Environmental Loads
2) Fujitsu Group Sustainability Report (2008): Operating Activities and Environmental Loads
3) MM Research Institute. Overview of Domestic PC Shipments for FY2007 and FY2008.
4) IDC Japan. Overview of Domestic Mobile Phone Shipments for FY2007 and FY2008.
5) Nork Research. Overview of Domestic PC Server Shipments for FY2007 and FY2008.

Report on Comparison of the Environmental Impact between a Traditional Adult Diaper and the Humany Automatic Urine Suction System

June 2010

Unicharm Humancare Corporation

1 General

1.1 Evaluators

Names: Nobuaki Kosugi
Organization: Unicharm Humancare Corporation
Contact: nobuaki-kosugi@unicharm.com

1.2 Date of Report Creation

June 17, 2010

2 Study Objective

2.1 Background of the Study

We started sale of an automatic urine suction system, Humany, as a toileting assistance product for adult users. We believe this product can change the basic approach to toileting assistance and also will have a positive impact on the environment. Therefore, in this study, we compared the environmental efficiency between a traditional toileting assistance product and Humany.

2.2 Application of the Study Result

Based on the examination of environmental advantages of our product, we will disclose the result of this study and also use this to raise internal as well as external motivation.

3 Scope of the Study

3.1 Subjects and their Specifications

Humany machine: mass of 2 kg, power consumption of 10 W during suction, power consumption of 1 W while in stand-by mode, and tank capacity of 1 liter
Medium-sized adult diaper with side tapes: product mass of approximately 110 g
Humany pad: product mass of approximately 40 g
Urine collection pad: product mass of approximately 40 g

3.2 Function and Functional Unit

A functional unit set for this study was 1 day of use of a toileting assistance system for an adult, and we conducted the assessment on the entire life cycle of a paper diaper required for that system operation.
Adult toileting assistance consists of:

- Traditional toileting assistance: 1.5 paper diapers with side tapes, 6 urine collection pads, and 1 time use of a flush toilet
- Humany: Humany system, 0.1 pieces of a Humany net (replaced every 10 days), 1 paper diaper with

side tapes, 1 Humany pad, and 2 times use of a flush toilet

3.3 System boundary

A system for this study included from the manufacturing to the use and then disposal stages. Note that the manufacturing process of the Humany system itself and the transportation process were excluded from the study. It was assumed in this study that used paper diapers were all incinerated (Figure 3.3-1).

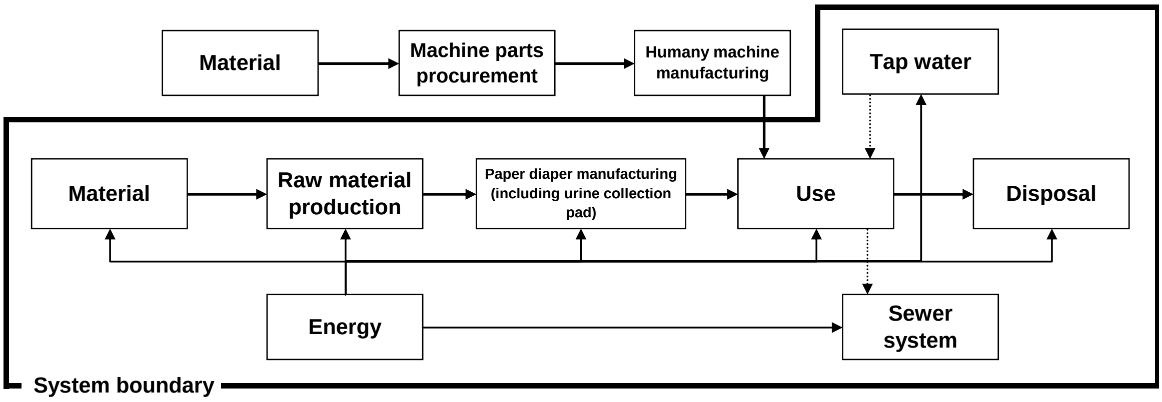

Figure 3.3-1 Humany life cycle assessment system boundary

3.4 Note (Processes or Items Excluded from the System Boundary)

The environmental impact of production of parts, assembly, and transportation of the Humany system was marginal for the life cycle; therefore, they were excluded from the study. The following factors were also excluded from the study: construction, maintenance, and disposal of factories involved in product and fuel manufacturing; tools and parts required in system maintenance; and construction, maintenance, and removal of roads and related infrastructure required for transportation.

For the product use stage, we assumed that stools would be disposed of in a flush toilet as recommended by the Japan Hygiene Products Industry Association.

4 Inventory Analysis

4.1 Priority Data

We obtained the data on the amount of materials and resources used based on our product specifications and manufacturing specifications. As for the amount of energy used in the manufacturing phase, we referred to the measurement data obtained at our factory. Data on disposal and incineration was obtained from data we obtained from our own study. The system was assumed to be used under our recommended conditions.

4.2 Background Data

We used the Life Cycle Assessment Society of Japan (JLCA) database to obtain the waste disposal data.

Other data was obtained from JEMAI-LCA Pro data.

4.3 Subjects of Inventory Analysis and Lists of Analysis Result

Tables 4.3-1 and 4.3-2 show the subjects of inventory analysis and lists of analysis results for Humany-based toiletry assistance and the traditional toiletry assistance.

Table 4.3-1 LCI analysis result for Humany-based toiletry assistance (kg/day)

			Manufacturing	Fuel manufacturing	Transportation	Maintenance	Disposal
Consumption-related loads	Non-renewable resources	Coal	7.00E-03	3.06E-03	0.00E+00	4.26E-03	1.68E-05
		Crude oil (fuel)	6.38E-02	5.68E-04	0.00E+00	8.23E-04	9.91E-06
		Natural gas	4.03E-03	1.42E-03	0.00E+00	2.02E-03	7.80E-06
		Uranium	3.65E-07	2.70E-07	0.00E+00	3.75E-07	1.48E-09
	Recyclable resources	Wood	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Water	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Emission-related loads	Outdoor air	CO_2	1.36E-01	1.90E-02	0.00E+00	1.97E-02	5.01E-02
		N_2O	5.04E-06	6.08E-07	0.00E+00	4.52E-06	3.69E-09
		NOx	1.38E-04	5.85E-06	0.00E+00	9.05E-06	7.11E-06
		PM10	9.53E-06	0.00E+00	0.00E+00	0.00E+00	6.15E-07
		SOx	1.05E-04	2.22E-06	0.00E+00	3.55E-06	3.17E-06
	Water	COD	3.63E-04	0.00E+00	0.00E+00	6.00E-05	0.00E+00
		T-P	0.00E+00	0.00E+00	0.00E+00	7.44E-06	0.00E+00
		T-N	0.00E+00	0.00E+00	0.00E+00	8.46E-05	0.00E+00
	Soil	Waste landfill	4.06E-03	0.00E+00	0.00E+00	5.67E-05	8.99E-04

Table 4.3-2 LCI analysis result for toiletry assistance using a paper diaper and a pad (kg/day)

			Manufacturing	Fuel manufacturing	Transportation	Maintenance	Disposal
Consumption-related loads	Non-renewable resources	Coal	4.31E-02	1.70E-02	0.00E+00	4.04E-04	5.39E-04
		Crude oil (fuel)	2.51E-01	3.16E-03	0.00E+00	1.25E-04	3.19E-04
		Natural gas	2.90E-02	7.92E-03	0.00E+00	2.42E-04	2.51E-04
		Uranium	1.37E-06	1.50E-06	0.00E+00	3.56E-08	4.75E-08
	Recyclable resources	Wood	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Water	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Emission-related loads	Outdoor air	CO_2	6.35E-01	9.85E-02	0.00E+00	2.22E-03	1.03E+00
		N_2O	2.55E-05	3.38E-06	0.00E+00	5.59E-06	1.19E-07
		NOx	2.99E-03	3.25E-05	0.00E+00	2.15E-06	2.29E-04
		PM10	7.11E-05	0.00E+00	0.00E+00	0.00E+00	1.98E-05
		SOx	7.11E-04	1.23E-05	0.00E+00	9.96E-07	1.02E-04
	Water	COD	3.80E-03	0.00E+00	0.00E+00	9.00E-05	0.00E+00
		T-P	0.00E+00	0.00E+00	0.00E+00	1.12E-05	0.00E+00
		T-N	0.00E+00	0.00E+00	0.00E+00	1.27E-04	0.00E+00
	Soil	Waste landfill	2.95E-02	6.36E-05	0.00E+00	8.50E-05	2.89E-02

5 Impact Assessment

5.1 Subject Assessment Steps and Areas of Impact

In the impact assessment, LIME2 (Life cycle Impact assessment Method based on Endpoint modeling 2) was used to assess the following three steps: characterization, damage assessment, and weighting. Table 5.1-1 shows the areas of impact subject to the assessment in each step.

Table 5.1-1 Subject areas of environmental impact and assessment steps

	Characterization	Damage assessment	Weighting
Resource consumption (energy)	○	○	○
Resource consumption (mineral)	○	○	○
Global warming	○	○	○
Urban air pollution	-	○	○
Ozone depletion			
Acidification	○	○	○
Eutrophication	○	○	○
Photochemical oxidant			
Human toxicity			
Ecotoxicity			
Indoor air quality	-		
Noise	-		
Waste	○	○	○
Land use			○

5.2 Impact Assessment Result

5.2.1 Characterization

Figures 5.2-1 and 5.2-2 show the characterization of 1 day of the traditional toiletry assistance and one day of Humany-based toiletry assistance in terms of the environmental impact on global warming and waste disposal. Since the previous LIME2 calculation indicated a large environmental impact on global warming, we prepared an additional scenario in which all waste was subject to landfill instead of incineration. The overall result was that the Humany-based toiletry assistance had a lower environmental impact than the traditional toiletry assistance.

With regard to the environmental impact on global warming, since used paper diapers are in general incinerated, the environmental impact of the traditional toiletry assistance is high, simply due to the amount of waste incinerated. The negative environmental impact on global warming could be reduced using landfills instead of incinerating the waste; however, the environmental impact caused by Humany-based toiletry assistance was still lower than the traditional toiletry assistance even after incineration was replaced by use of landfills. This was due to the amount of energy used in manufacturing of materials and also due to the fact that Humany required less material for manufacturing.

In terms of the environmental impact on waste disposal, the environmental impact caused by landfills was three-digits higher than incineration. Although use of landfills could reduce the environmental impact in terms of global warming, incineration could result in dramatic reduction of the waste volume.

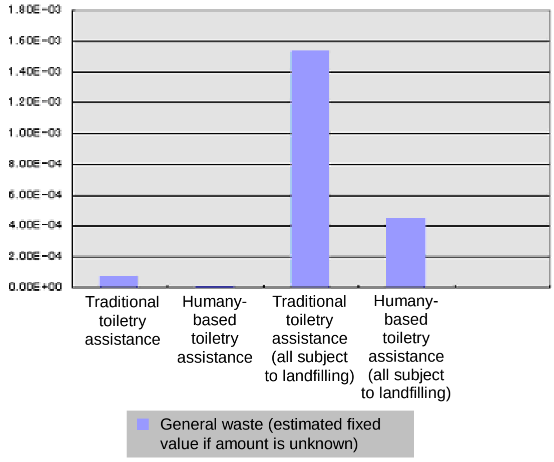

Figure 5.2-1 Characterization (waste)

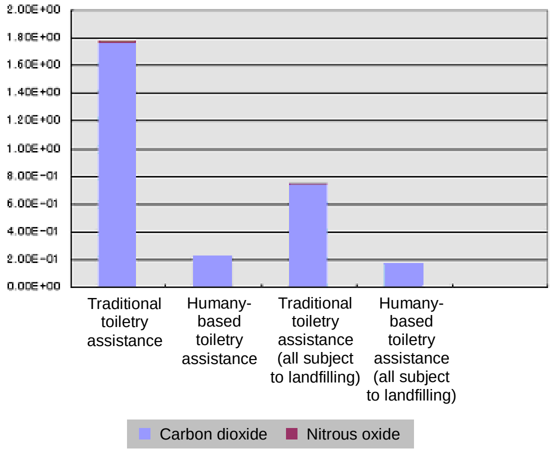

Figure 5.2-2 Characterization (global warming)

5.2.2 Damage Assessment

Figures 5.2-3 through 5.2-6 show the results of damage assessment in the four areas to be protected (by substance). The overall result was that the Humany-based toiletry assistance had a lower environmental impact than the traditional toiletry assistance. Note, however, incineration of waste products caused greater damage to human health than landfills did. In the remaining areas, however, landfilling had a larger impact than incineration. We believe that the damage to the human health was high because of air pollutants such as CO_2 and SO_2 generated during waste incineration or during combustion of fossil fuels used as energy. In other areas, waste landfills had a large environmental impact in all scenarios.

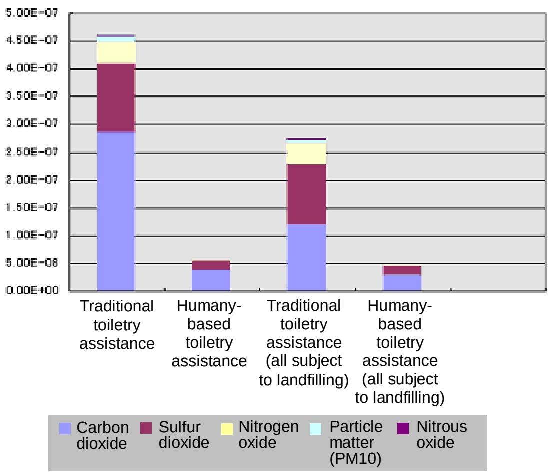

Figure 5.2-3 Damage assessment (human health) [DALY]

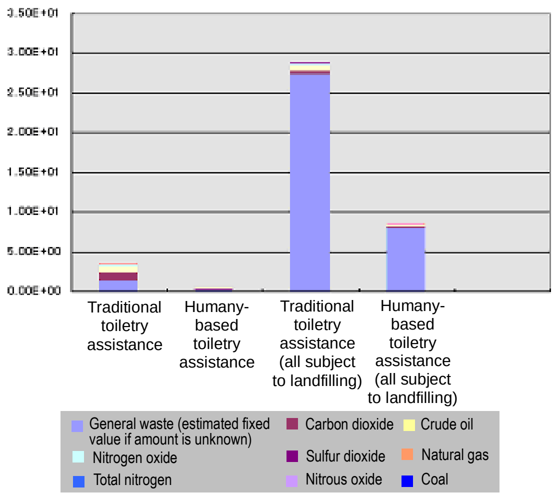

Figure 5.2-4 Damage assessment (social assets) [yen]

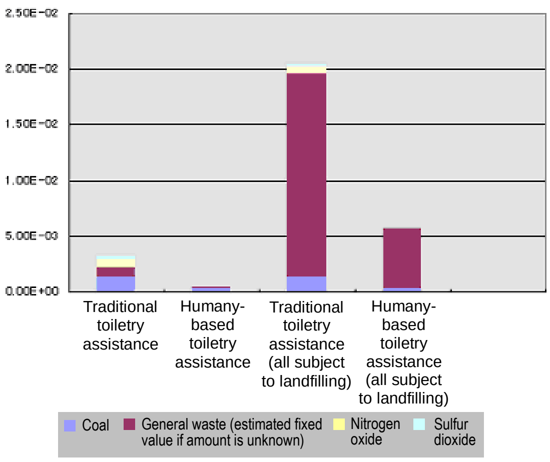

Figure 5.2-5 Damage assessment (primary production) [kg]

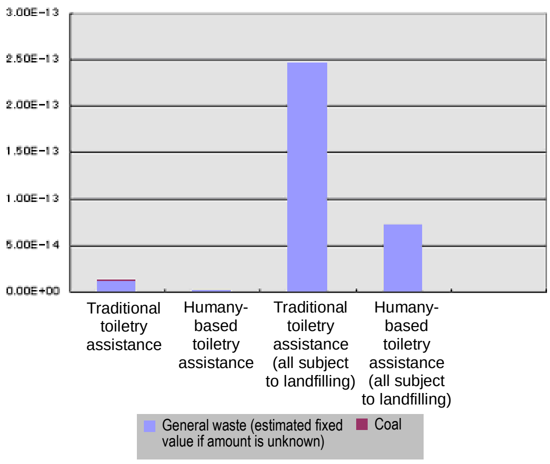

Figure 5.2-6 Damage assessment (biodiversity) [EINES]

5.2.3 Weighting

Figure 5.2-7 shows the weighting result (by substance). Overall, the environmental impact was dramatically reduced when the traditional toiletry assistance was replaced with Humany-based toiletry assistance, and the reduction ratio was approximately 87%. Under this condition, the environmental impact became lower throughout the life cycle.

When the environmental impact of waste disposal was compared between incineration and landfilling, landfilling indicated a higher environmental impact. As shown in the weighting result by process in Figure 5.2-8, the disposal process accounted for more than 75% of the entire impact in the scenario in which the waste product was subject to landfilling. Therefore, although the overall environmental impact was largely attributed to CO_2 causing the global warming, replacement of incineration with landfilling would have a higher environmental impact.

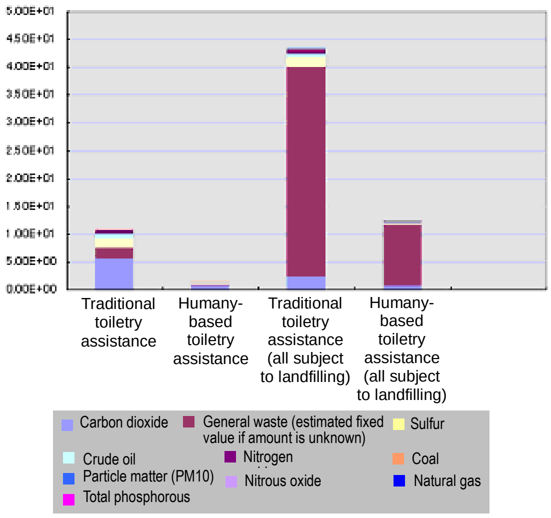

Figure 5.2-7 Weighting result (by substance) [yen]

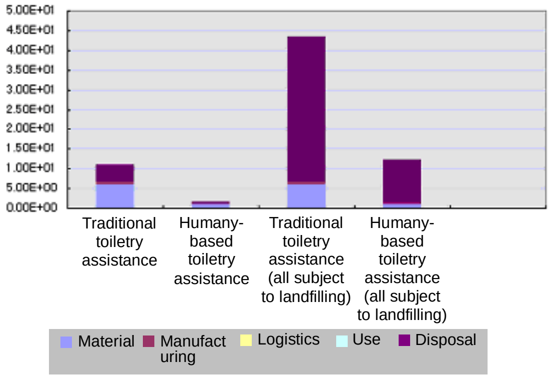

Figure 5.2-8 Weighting result (by process) [yen]

Figure 5.2-9 shows the breakdown of the weighting result by the area of impact, Figure 5.2-10 shows the percentage-based presentation of the same weighting result. Figure 5.2-9 suggests that the environmental impact was high in the areas of global warming, urban air pollution, and disposal. Among them, the global warming in particular accounted for approximately 50% of the entire impact. Although the environmental impact on global warming decreased in the scenarios in which waste products were subject to landfilling instead of incineration, the environmental impact on waste disposal became more significant, accounting for more than 90% of the entire impact.

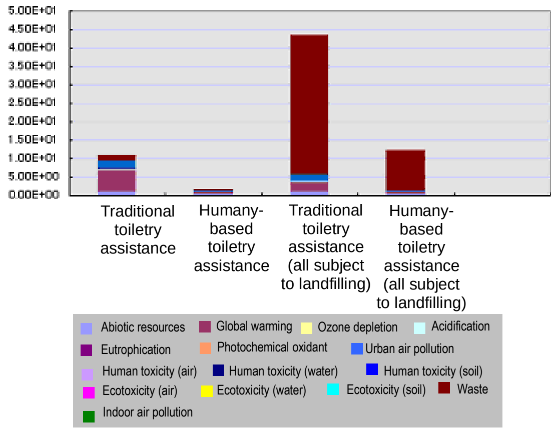

Figure 5.2-9 Weighting result (by area of impact ①) [yen]

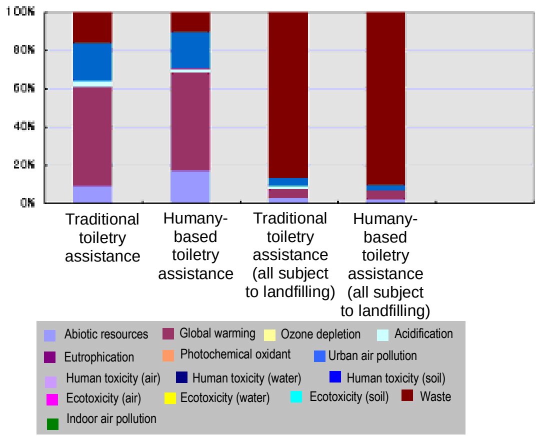

Figure 5.2-10 Weighting result (by area of impact ②) [yen]

The raw material of the pulp that we use in manufacturing of paper diapers is obtained from thinning wood in managed forests. Wood used for other purposes is also cut in managed forests. Therefore, we created an additional scenario in which wood cut from unmanaged forests was used in the traditional toiletry assistance in order to examine the changes in weighting results.

Figures 5.2-11 and 5.2-12 show the weighting results by substance taking into account the environmental impact of forest management. The results show that the environmental impact was approximately 23 times higher when pulp made from wood of unmanaged forests was used than when pulp made from wood of managed forests was used. Compared to the scenario in which waste was subject to landfilling as well, this newly created scenario had a significantly higher environmental impact. We believe this is due to the environmental impact of land use, such as the cutting down of trees in unmanaged forests, on the biodiversity.

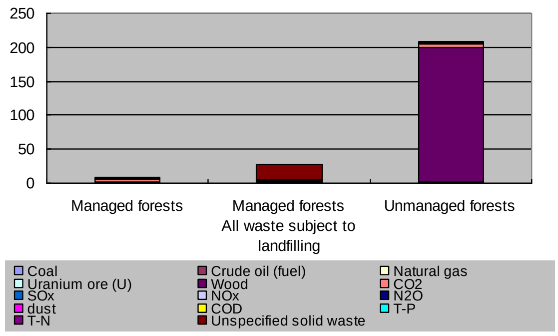

Figure 5.2-11 Weighting result (by substance for different forest management scenarios ①)

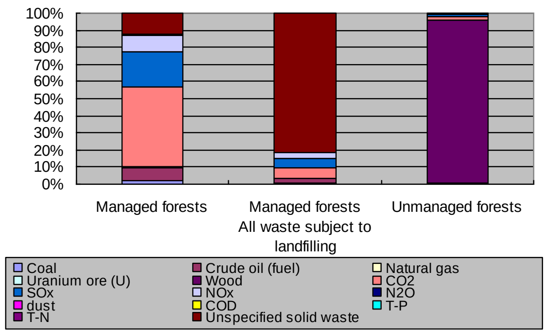

Figure 5.2-12 Weighting result (by substance for different forest management scenarios ②)

6 Conclusion

6.1 Summary of the Study Result

We assessed the environmental impact of the entire life cycle (material production, product manufacturing, product use (1 day), and disposal) of the functional unit, which was 1 day of toiletry assistance (1 day of the traditional toiletry assistance and Humany-based toiletry assistance). When the environmental impact was converted into social costs, the social costs of the traditional toiletry assistance were approximately 9 yen/day (3,250 yen/year), and the social costs of Humany-based toiletry assistance was approximately 1.1 yen/day (approximately 400 yen/year). The actual expenses of toiletry assistance such as purchase of paper diapers was approximately 450 yen/day for the traditional toiletry assistance and approximately 430 yen/day for Humany-based toiletry assistance (note that the initial cost of purchasing the Humany system is approximately 100,000 yen, and 90% of it would be refunded since it is covered by the nursing-care insurance). Therefore, the social costs were approximately 2% and approximately 0.3%, respectively, with respect to the type, or scenarios, of toiletry assistance.

In both scenarios, material production accounted for more than 50% of the entire environmental impact, followed by incineration. Material production and incineration combined accounted for more than 90% of the entire environmental impact. In particular, CO_2 emission and crude oil (resource) consumption were responsible for a large part of the impact, followed by CO_2 emission during incineration and landfilling after incineration. As a result, we found that the both material production and incineration had significant environmental impacts on global warming, urban air pollution, and waste disposal.

Meanwhile, when the method of waste disposal was replaced by landfilling to reduce the major contributing factors to global warming, the study showed that the environmental impact on global warming did decrease; however, the environmental impact on waste disposal significantly increased. According to the weighting result, incineration would cause less environmental impact than landfilling.

We also compared the scenario in which wood, a raw material of pulp to serve as a major product material, was obtained from managed forests and the scenario in which wood was obtained from unmanaged forests. When the environmental impact was converted into social costs, the social costs of the scenario in which wood obtained from managed forests was used in the traditional toiletry assistance product were approximately 9 yen/day (3,250 yen/year), and when the wood was obtained from unmanaged forests, the social costs were approximately 210 yen/day (approximately 76,000 yen/year). The study thus indicated the importance of forest management for protection of biodiversity.

6.2 Limitations of the Study and Future Tasks

In this study, we assessed the environmental impact of the material production, use, and disposal processes. Based on the previous paper diaper life cycle assessment result, the assessment covered the important processes that would be responsible for more than 90% of the environmental impact. Therefore, we believe that the validity of the assessment result can be guaranteed. Note, however, a Humany pad is manufactured in a very different way from a traditional paper diaper, and it is thus necessary in the future to conduct assessment again as new system production technologies are established. Also, we were unable to obtain data on manufacturing of the Humany system. Although we believe that this process does not have any significant impact, it is still necessary to reassess this as soon as the data becomes available such that more important data can be covered in the study.

Reference

1) Katsuhiko Muroyama, et al. Life Cycle Inventory Analysis for an Advanced Municipal Wastewater Treatment Plant. Kansai University Organization for Research and Development of Innovative Science and Technology Research Report, vol. 21, pp. 178-185. 2006.

Acknowledgments

For the participation in the LIME2 WG and creation of the report, we would like to express our gratitude to: Professor Itsubo of Tokyo City University and Mr. Motoshita of the National Institute of Advanced Industrial Science and Technology (AIST) for repeated advice and instructions; Mr. Yamagishi of the Japan Environmental Management Association for Industry for his administrative support; and all the representatives of the participating companies for providing a wide variety of comments and opinions during the working group activities.

Information

17th LCA Case Studies Symposium	
28 February - 1 March, 2011 Budapest, Hungary	SETAC Europe http://lcabudapest.setac.eu/?contentid=344
The 6th Meeting of The Institute of Life Cycle Assessment, Japan	
2-4, March, 2011 Sendai, Japan	ILCAJ http://ilcaj.sntt.or.jp/meeting/
The 18th CIRP Conference on Life Cycle Engineering	
2-4, May, 2011 Braunschweig, Germany	Technische Universität Braunschweig http://www.lce2011.de/en/home
SETAC Europe 21st Annual Meeting	
15-19, May, 2011 Milan, Italy	SETAC Europe http://milano.setac.eu/?contentid=291
ISIE 2011 conference	
7-10, June, 2011 Berkeley, USA	ISIE http://isie2011.berkeley.edu/
LCA XI	
4-6, October, 2011 Chicago	American Center for Life Cycle Assessment http://www.lcacenter.org/
Sustainable Innovation 11	
24-25, October, 2011 Farnham, UK	The Centre for Sustainable Design http://www.cfsd.org.uk/events/tspd16/index.html
SETAC North America 32nd Annual Meeting	
13-17, November, 2011 Boston, MA, USA	SETAC North America
3rd International Conference on Green and Sustainable Innovation	
December 2011 Thailand	
SETAC Europe 22nd Annual Meeting	
20-24, May 2012 Berlin, Germany	SETAC Europe http://berlin.setac.eu/?contentid=404
SETAC North America 33rd Annual Meeting	
11-15, November, 2012 Long Beach, CA, USA	SETAC North America
SETAC North America 34th Annual Meeting	
17-21, November, 2013 Gaylord Opryland, Nashville, TN,	SETAC North America
SETAC North America 35th Annual Meeting	
9-13, November, 2014 Vancouver, British Columbia	SETAC North America

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