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Innovations for Greenhouse Gas Reductions
- Life Cycle Analysis of Chemical Products in Japan and around the World -
carbon-Life Cycle Analysis (cLCA)

Japan Chemical Industry Association

Life-Cycle Assessment Society of Japan

Innovations for Greenhouse Gas Reductions

-Life Cycle Analysis of Chemical Products in Japan and around the World-

carbon-Life Cycle Analysis (cLCA)

Third Edition - Summary

March 2014

Japan Chemical Industry Association
(general incorporated association)

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Introduction

The chemical industry provides products that are essential to our lives and, at the same time, contributes to humankind by creating new markets through the development of new materials and processes. In addition, the industry plays an important role as a "solution provider" (a provider of a method of settlement) that provides the products and technologies required for preventive measures against global warming that are centered on a reduction in greenhouse gas (GHG) emissions.

In 2009, the International Council of Chemical Associations (ICCA) carried out logical and demonstrative analysis called carbon Life Cycle Analysis (cLCA) in which the avoided CO_2 emissions were calculated based on the difference between CO_2 emissions of final products that use chemical products and CO_2 emissions of products for comparison, over the entire life cycle from the procurement of raw materials, through manufacture and usage, to disposal/recycling. The analysis showed that chemical products made a great contribution to the reduction in CO_2 emissions in the world.

ICCA engages in various activities concerning preventive measures against global warming in the "Energy and Climate Leadership Group." On this subject, Japan is the chair country and the Japan Chemical Industry Association (JCIA) serves as the secretariat, thereby playing a leading role in carrying out preventive measures against global warming in the world.

In February 2012, JCIA published "Guidelines for Calculating the Avoided CO_2 Emissions", which clarified the rules for calculating the avoided CO_2 emissions and highlighted the practical matters to be noted. Through this publication, JCIA sought to improve the transparency and reliability of cLCA.

In the meantime, in October 2013, ICCA and the Chemical Sector of the World Business Council of Sustainable Development (WBCSD) issued "Addressing the Avoided GHG Emissions Challenge," Global Guidelines on the basis of the Guidelines of JCIA, based on the ISO standards for Life Cycle Assessment (LCA), and additionally consistent with the GHG Protocol as well as advanced standards and specifications for the carbon footprint.

Furthermore, in July 2011, JCIA issued the first edition of its "Life Cycle Analysis of Chemical Products in Japan (JCIA Report)", in which examples of cLCA were presented by providing a bird's eye view of the entire life cycle of chemical products, from the procurement of raw materials, through manufacture and usage, to disposal/recycling, and in December 2012, it issued the second edition that contained ten examples of contributions in Japan and four examples of contributions from around the world.

JCIA is now ready to issue the third edition of the JCIA Report that contains 15 examples of contributions in Japan and four examples from around the world. These examples include new examples in addition to the examples included in the second edition of the report that have been re-evaluated according to the Global Guidelines.

It is our hope that this report and the range of JCIA initiatives concerning the problem of global warming will lead to a renewed understanding that the chemical industry is a "solution provider" that contributes to society through the reduction in CO_2 emissions and that it is important to strive for a real reduction in CO_2 emissions as a preventive measure against global warming by understanding the state of CO_2 emissions through a product's life cycle.

March 2014
Kyohei Takahashi, Chairperson, Japan Chemical Industry Association

Executive summary

1. Overview and conclusions

The Japan Chemical Industry Association has been soliciting parties engaged in discussions related to GHG[1] emissions from products and technologies to understand the importance of evaluating GHG emissions in the life cycle of chemical products.

This report is the third edition following "Life Cycle Analysis of Chemical Products in Japan - carbon Life Cycle Analysis (cLCA)" issued in 2011 and "Life Cycle Analysis of Chemical Products in Japan and around the World - carbon Life Cycle Analysis (cLCA)" issued in 2012, and addresses reduction in GHG emissions. Sections 1.1, 1.2, 1.3 and 1.4 describe the main points of the products of the chemical industry that were published before, while Section 1.5 outlines newly issued products, and 1.6 outlines the revisions made. The remainder of the report summarizes the conclusions.

1.1 ICCA Report (July 2009)

The chemical industry (which includes plastic and rubber, but does not include metal, glass or cement)[2] contributes to the reduction of GHG emissions in other industries and throughout society as a whole through the use of products. From this viewpoint, ICCA (International Council of Chemical Association) prepared a cLCA report by investigating the GHG emissions from chemical products in the world in their life cycle, with a perspective that provides a bird's eye view of the entire life cycle from the procurement of raw materials, through manufacture and usage, to disposal. The report makes comparisons of the GHG emissions from chemical products in specific applications with those produced through the second-best alternative measures that are employed in industries other than the chemical industry.

Fig. 1. ICCA Report

1.2 Japan Chemical Industry Association (JCIA) Report (July 2011)

The first edition issued by JCIA in July 2011 evaluated the avoided CO_2 emissions when the products that were expected to be manufactured during the one year under assessment would have been used until the end of their life. The year 2020 was taken as the year under assessment. Nine examples were

Fig. 2. JCIA Report

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1 Greenhouse Gases: Six types of gases, i.e. carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O = dinitrogen monoxide), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6).

2 Website of the Ministry of Economy, Trade and Industry, "Statistical Investigation of Industries, Material Related to Classification, Industrial Classification Code File"
http://www.meti.go.jp/statistics/tyo/kougyo/result-4.html#menu08 In the Subsection of Industrial Classification (2 digits), 16, 18 and 19 are being considered.

analyzed quantitatively in the fields of renewable energy and energy saving, concerning the avoided CO_2 emissions throughout society resulting from the use of specific chemical products in Japan. The report compares the emissions of finished products that incorporate chemical products over their life cycle with the emissions of finished products that incorporate the products for comparison over their life cycle. As a result of these analyses, it has been made clear that the chemical products described in the report are key materials that contribute to the reduction of CO_2 emissions by about 110 million tons on a finished-product basis.

Note that, as stated in the "Guidelines for Calculating the Avoided CO_2 emissions" issued by JCIA (described later), no allocation was made for the degree of contribution to the emission abatement. The details of the description are given below.

“If a certain product being evaluated achieved a reduction in CO_2 emissions, it is rare that the effect is solely due to the individual product. In almost all cases, multiple constituent elements contribute to the effect. In such cases, if the degree of contribution according to that for each constituent element can be obtained, then it can be expected that the effect of solicitation will be increased as the avoided CO_2 emissions by chemical products and technologies. However, no technique for the objective and reasonable calculation of the degree of contribution has been established and it is difficult to obtain the degree of contribution. For these reasons, no technique for calculating the degree of contribution has been defined.”

Fig. 3. JCIA Guidelines

1.3 JCIA Guidelines (February 2012)

After the issuance of the first edition, JCIA devised the "Guidelines for Calculating the Avoided CO_2 Emissions" to ensure transparency and reliability of cLCA. The guidelines were issued as a booklet in February 2012.

The guidelines were prepared with a view to [1] presenting consistent criteria for the method of calculating the avoided CO_2 emissions by the chemical industry by means of the cLCA technique, thereby identifying and organizing the practical matters to be noted; and [2] preventing any irregularities in the results as caused by differences in technique or the method of calculation, thereby increasing the transparency and reliability of cLCA.

1.4 Second edition of the JCIA Report (October 2012)

Based on the guidelines devised in February 2012, it was recently decided that the second edition would be issued, in which more examples are presented by conducting assessments on ten examples of contribution to the reduction in greenhouse gases in Japan and four examples from around the world by [1] revising the

Fig. 4. JCIA Report Second Edition

results of assessment using cLCA for the examples given in the first edition and [2] by including new examples.

(Details of the revisions)

[1] Review of numerical values for calculation by means of continued investigation for sources

As a result of continued investigations for the sources, the numerical values for motor efficiency and the service lives of the products have been reviewed and re-evaluated with regard to the examples of Hall effect devices and Hall effect ICs.

[2] Addition of new examples

Japan: Materials for fuel-efficient tires; materials for high-durability apartments

World: Automotive materials (carbon fiber); materials for aircraft (carbon fiber); materials for air conditioners (Hall effect devices; Hall effect ICs)

1.5 JCIA Guidelines (October 2013)

ICCA and the Chemical Sector of the World Business Council for Sustainable Development (WBCSD) devised "Main title: Addressing the Avoided GHG Emissions Challenge; Subtitle: Guidelines from the chemical industry for accounting for and reporting greenhouse gas (GHG) emissions avoided along the value chain based on comparative studies," Global Guidelines prepared on the basis of the "Guidelines for Calculating the Avoided CO_2 Emissions" devised by JCIA, and issued the guidelines in October 2013. The guidelines are the first international guidelines for calculating avoided GHG emissions enabled by chemical products.

Fig. 5. Global Guidelines

The Global Guidelines provide guidelines for calculating avoided GHG emissions enabled by chemical products, by comparing two products with the same user benefit. The guidelines also give guidance on how to communicate the results.

◆ Relationship to existing standards and guidelines

The Global Guidelines build on internationally accepted requirements and guidelines (found in the ISO 14040 (1) and ISO 14044 (2) related to LCA) and are inspired by the "Guideline for Calculating the Avoided CO_2 Emission (2012)" devised by JCIA. In addition, the guidelines aim to be consistent with leading standards and specifications for the product carbon footprint (including the GHG Protocol "Product Life Cycle Accounting and Reporting Standard (2011)," "PAS2050 (2011)," and ISO/TS 14067 (2013). The guidelines provide a step-by-step procedure to estimate the differences in GHG emissions between products. They focus on common challenges of LCA practitioners (people and organizations carrying out studies) in the chemical industry. In particular, they take into account the upstream position of chemical products in the value chain and provide a way to reliably quantify the effect a chemical product can have on environmental impacts of downstream activities. Accordingly, the guidelines go beyond existing standards. Table 1 gives an overview of the extra guidelines provided in the guidelines compared to ISO 14040/44.

The guidelines have been devised for all chemical companies worldwide and for their stakeholders. Companies that seek to measure, manage and communicate the avoided GHG emissions of their chemical products are encouraged to use this guidance document. Widespread use of these guidelines will increase consistent calculation and communication of avoided emissions and make companies' findings more credible.

Table 1. Extra guidelines provided in the Global Guidelines on accounting and reporting avoided emissions compared to ISO 14040/44

ISO 14040/44	Guidelines in this document
Goal and Scope definition	Purpose of study (Section 3.1) Selecting the level in the value chain (Section 3.1)) Solution to compare (Section 3.2) Functional unit (Section 3.3) Boundary setting (Section 3.4.1)
Life Cycle Inventory (LCI)	Methods/formulas used (Section 3.4.2) Simplified calculation methodology (Section 3.4.3)
Life Cycle Impact Assessment (LCIA)	Methods/formulas used (Section 3.4.2)
Interpretation	Key parameters (Section 3.4.4) Integrating uncertainties and scenarios of future developments (Section 3.4.5)
-	Assignment of the Avoided CO2 Emissions with Value chain partners (Chapter 4)
Report	Report Guidelines (Chapter 5)

(Note) Excerpts from the Global Guidelines

◆ Overview of the Guidelines (Japanese edition)

Overview of "Addressing the Avoided GHG Emissions Challenge" (Japanese edition)

Issued by: The Japan Chemical Industry Association (general incorporated association)
Edited by: ICCA & WBCSD Chemical Sector
Format: A4, 44 pages
Contents

- Executive summary
- 1 Introduction
  - Purpose of the guidelines/ How the guidelines were developed/ Who should use the guidelines/ Relationship to existing standards and guidelines/ Limitations of the guidelines in this document
- 2 Principles
- 3 Guidelines on accounting avoided GHG emissions
- 4 Attribution of avoided GHG emissions to value chain partner
- 5 Reporting guidelines
- 6 Annexes
  - Report template /Glossary /References
- 7 Attachment
  - Matters to be noted on the Japanese translation of the Guidelines /Examples of guidelines

1.6 Third edition of the JCIA Report (March 2014)

This report is the third edition that contains 15 examples of contributions in Japan and four examples from around the world, by revising the contents of the existing examples and adding six new examples with a view to seeking consistency with the Global Guidelines issued in October 2013. Table 2 shows the major matters of revision that have been revised in line with the Global Guidelines.

Table 2. Items added in line with the Global Guidelines

Constituent Steps of LCA	Item
1. Definition of Goal and Scope of Study	(1) Description of the supervisor and practitioner of study (2) Selecting the level in the value chain
2. Life Cycle Inventory Analysis	(3) Life cycle flowchart
3. Life Cycle Interpretation	(4) Key parameters that affect GHG emissions
4. Others	(5) Integrating uncertainties and scenarios of future developments (6) Degree of contribution of a chemical product (7) Study Limitations and Future Recommendations

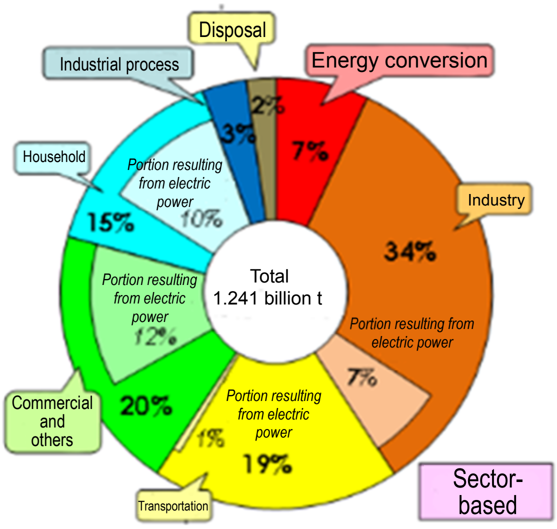
1.7 Conclusion

◆ In the first edition through the third edition of the JCIA Report, we have presented specific examples of chemical products that contribute to reduction in GHG emissions in the entire life cycle. In order to promote the global problem of reducing CO_2 emissions, it is important that measures be taken from the perspective of pursuing total optimization through a full understanding of the life cycle of products instead of taking measures from the perspective of partial optimization such as the reduction in CO_2 emissions during manufacture. From now, the chemical industry is determined to promote the reduction in CO_2 emissions throughout society, aiming at contributing to reducing greenhouse gases, not only by reducing emissions during manufacture, but also by utilizing chemical technologies and products in the entire life cycle.

◆ With a view to increasing the transparency and reliability of the calculation of avoided GHG emissions, the JCIA Guidelines and Global Guidelines were devised. We expect that these guidelines will not only provide more consistent guidelines for the chemical industry, but will also become tools for improving social sustainability in cooperation with all the stakeholders in the value chain.

2. The chemical industry in Japan

The chemical industry is a high energy-consuming industry that uses fossil fuels, mainly petroleum, as fuels and raw materials. Nevertheless, after the oil crisis, the chemical industry in Japan has taken active measures to conserve energy and has achieved the highest level of energy efficiency in the world. Consequently, CO_2 emissions from energy sources during the manufacture of chemical products in Japan in Fiscal Year 2011 were about 53 million tons, accounting for about 4% of the emissions in Japan as a whole (about 1.24 billion tons), which were the second greatest emissions after steel in the industrial sector.



Source: Ministry of the Environment Greenhouse gas emissions in Japan (Fiscal Year 2011)

Fig. 6. CO_2 Emissions in Japan

3. Concept of cLCA (extracted from the ICCA Report)

The chemical industry is a basic industry that supports other industries by providing its products to user enterprises in sectors that include automotive, electric machinery, electronics, etc. The method of assessment using cLCA focuses on GHGs that are emitted when the products are used in other industries and by consumers. The assessment compares the emissions of finished products that incorporate chemical products over their life cycle with the emissions of finished products that incorporate the products for comparison over their life cycle, and the difference between them is considered to be emissions that increase when there are no such chemical products, and is calculated as the net avoided emissions.

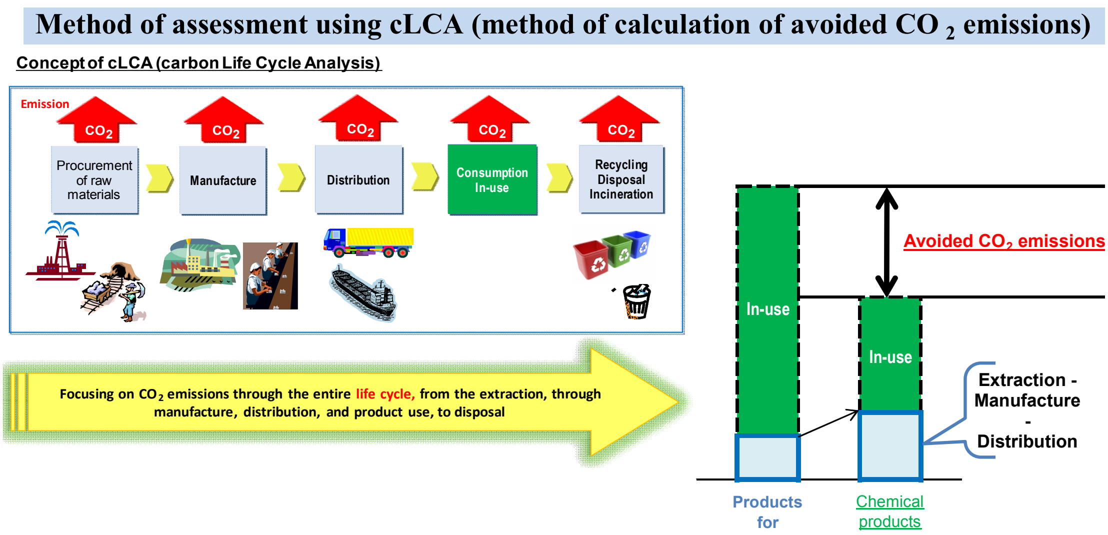


Fig. 7. Method of assessment using cLCA

4. Summary of the examples of assessment of products to be manufactured in Japan in 2020

[Period under assessment]
Taking 2020 as the year under assessment, the avoided CO_{2e} emissions when the products expected to be manufactured during the one year under assessment would have been used until the end of their life.
[Range of products under assessment contributing to the abatement effect]
Chemical products contribute to CO_{2e} emissions reduction in cooperation with all the partners in the value chain such as the energy sector, transportation sector, consumer and household sector, etc.

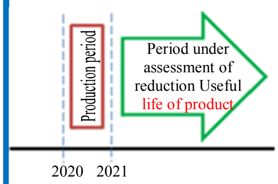
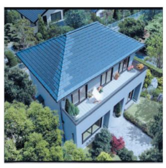
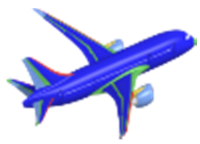


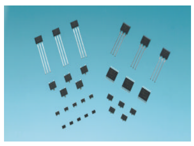
Table 3. Summary of Assessed Examples

	Renewable energy	Energy-saving		
	Materials for solar power generation	Automotive materials	Materials for aircraft	Materials for fuel-efficient tires
Concept				
Functions/ advantages	Solar energy is converted directly into electricity by using the principle of semiconductors.	Carbon fiber composite materials are used to reduce weight while maintaining the same levels of performance and safety.	Same as description on the left	Fitted to an automobile to reduce rolling resistance on the road surface during driving.
Products under assessment (finished products that incorporate chemical products)	Electric power produced by solar power generation	Automobiles that use plastics reinforced with carbon fiber	Aircraft that use plastics reinforced with carbon fiber	Automobile fitted with fuel-efficient tires ・For passenger vehicles (PCR) ・For trucks/buses (TBR)
Products for comparison	Utility power	Conventional automobiles	Conventional aircraft	Automobile fitted with non-fuel-efficient tires
Abatement effect	No CO_2 is emitted because fossil fuels are not used.	Weight reduction improves fuel consumption and reduces fuel consumption.	Same as description on the left	Improved automotive fuel consumption by reducing rolling resistance
Life of finished products	20 years	10 years	10 years	PCR 30,000 km TBR 120,000 km
Production volume	1,760,000 kW	15,000 units	45 units	PCR 73 million units. TBR 5 million units.

Finished products: Emissions from raw materials, manufacture, and disposal (tons)	-	Automobiles 93,000	Aircraft 176,000	
Chemical products: Emissions from raw materials, manufacture, and disposal (tons)	Si, etc. (1.29 million)	-	-	Synthetic rubber, etc. (1.74 million)
Avoided CO_2 emissions (tons)	-8.98 million	-75 thousand	-1.22 million	-6.36 million

Avoided CO_2 emissions when products that are expected to be manufactured in 2020 would have been used until the end of their life (calculated by specifying a certain set of conditions): Total for the examples in Japan -120 million tons

Avoided CO_2 Emissions
The results of assessing the fifteen examples here clearly show that chemical products are key materials that contribute to about 120 million tons in reduced emissions[1)] until the end of their life. Any of these examples leads us to understand that chemical products or finished products that incorporate chemical products contribute to reducing CO_{2e} emissions that exceed the CO_{2e} emissions of such chemical products or finished products themselves during manufacture.

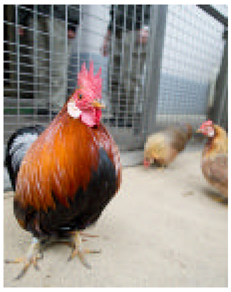
Energy-saving				
LED-related materials	Thermal insulation materials for housing	Aluminum-plastics composite window/ Thermal insulation materials	Hall effect device, Hall effect ICs	Piping materials
				
A semiconductor that emits light when a current passes through it; it has high light-emitting efficiency and long service life.	Increases the air-tightness and thermal insulation performance of housing.	Increases airtightness and thermal insulation performance by using aluminum-plastics composite windows	An inverter fitted with a commutator-less DC motor increases the motor efficiency.	Has the same performance as that of pipes made of cast iron, and is widely used in waterworks and sewage.
LED light bulbs	Housing that meets the Fiscal Year 1999 energy-saving standard (using thermal insulation materials)	Detached housing that meets the Fiscal Year 1999 energy-saving standard (using aluminum-plastics composite windows and thermal insulation materials)	Inverter air conditioner (using Hall effect devices/Hall effect ICs as their parts)	PVC resin pipes
Incandescent light bulbs	Housing before the energy-saving standard of 1980 (not using thermal insulation materials)	Detached housing before the 1980 energy-saving standard was enforced (not using thermal insulation materials)	Non-inverter air conditioners	Ductile cast iron piping
Long service life and low power consumption.	Reduces power consumption for cooling and heating by improving thermal insulation performance.	Reduces power consumption for cooling and heating by improving thermal insulation performance.	Reduction of power consumption by increasing motor efficiency.	Low energy consumption because high temperatures are not used during manufacture.

10 years	Detached houses: 30 years Apartments: 60 years	Detached houses: 30 years	14.8 years	50 years
28 million units	Detached houses: 367,000 units Apartments: 633,000 units	Detached houses: 25,000 units	7,460 units (Number of air conditioners)	493,092 tons
LED light bulb: 92,000	-	-	-	-
-	Thermal insulation materials (2.35 million)	Aluminum-plastic composite window/Thermal insulation materials (107 thousand)	-	PVC pipe (740,000)
-7.45 million	-75.8 million	Number of examples included in those on the left (-46 thousand)	-16.4 million	-3.3 million

1) Reference: CO_2 emissions in Japan in Fiscal Year 2009 1.15 billion tons (Fig. 6)
2) Preconditions for calculation are clearly stated in the explanatory sentences for each of the examples.

	Energy-saving		Resource-saving	
	Concentrated liquid detergent for cleaning clothes	Low-temperature steel plate detergent	Materials for high-durability apartments	High durability paint
Concept				
Functions/advantages	Makes containers more compact and reduces the number of times of rinsing by concentration	Reduces the cleaning temperature for steel plates from 70ºC to 50ºC.	Increases the strength and durability of reinforced concrete.	Reduction of the number of coatings by using high durability paint
Products under assessment (finished products that incorporate chemical products)	Concentrated liquid detergent for cleaning clothes	Low-temperature steel plate detergent	High-durability apartments	Paint composition: Silicone resin paint, fluororesin paint
Products for comparison (Products for comparison)	Conventional liquid detergent for cleaning clothes	Conventional steel plate detergent	Ordinary apartment house	Paint composition: Acrylic resin paint, urethane resin paint
Abatement effect	CO_2 emissions reduction by making containers more compact and electric power reduction by reducing the number of times of rinsing	Reduction of the amount of steam as required for heating	Improves durability by suppressing cracking when the concrete is drying.	Reduction of the amount of paint used by reducing the number of coatings
Life of finished products	24 times of cleaning		100 years	50 years
Production volume	148 thousand tons	8.75 million tons of steel plates	61,000 units	61,000 units

Finished products: Emissions from raw materials, manufacture, and disposal (tons) Chemical products: Emissions from raw materials, manufacture, and disposal (tons)	1.09 million Detergent for cleaning clothes (32 thousand)	3 thousand Steel plate detergent (3 thousand)	Apartments: 16.55 million Drying and shrinkage agent, etc. (240 thousand)	 Paint (12 thousand)
Avoided CO_2 emissions (tons)	-290 thousand	-44 thousand	-2.24 million	-11 thousand

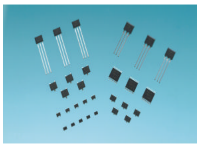
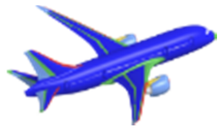
	Recyclable resource	Suppression of N_2O emission
	Shampoo container	Feed additives
Concept	 	
Functions/ advantages	Manufacturing of polyethylene by using sugar cane that is a renewable bio resource as a raw material	Adjustment of essential amino acids balance by adding methionine
Products under assessment (finished products that incorporate chemical products)	Biopolyethylene container	Assorted feed containing DL-methionine as an additive
Products for comparison (Products for comparison)	Fossil resource polyethylene container	Additive-free assorted feed
Abatement effect	Biomass is carbon-neutral	Reduction of the amount of nitrogen in broiler chicken feces
Life of finished products	Number of uses 100 times	Breeding period 48 days
Production volume	1 million containers	3.96 million tons
Finished products: emissions from raw materials, manufacture, and disposal (tons) "( )" shows emissions from chemical products*	300 (0.03)	1.09 million (850 thousand)
Avoided CO_2 emissions (tons)	-100	-160 thousand

5. Summary of the examples of assessment in the world concerning products that are expected to be manufactured in 2020

The global CO_{2e} emissions avoided (potential) was calculated resulting from the use of chemical products that are expected to be manufactured by Japanese businesses in Japan or overseas in 2020.

Effect of emissions reduction

It can be seen that, based on the result of the assessments of the four examples conducted here, chemical products are key materials that contribute to about 390 million tons in reduced emissions until the end of their life.

	Energy-saving			
	Desalination plants	Air conditioners	In the stage of automobile usage	Aircraft
Concept				
Function	Using semipermeable membranes, desalinates seawater based on the principle of reverse osmosis.	An inverter fitted with a commutator-less DC motor increases the motor efficiency.	Carbon fiber composite materials are used to reduce weight while maintaining the same levels of performance and safety.	Same as description on the left
Products under assessment (finished products that incorporate chemical products)	Desalination plant by means of the RO membrane process	Inverter air conditioner	Automobiles that use plastics reinforced with carbon fiber	Aircraft that use plastics reinforced with carbon fiber
Products for comparison (products for comparison)	Evaporation process	For non-inverter air conditioners	Conventional automobiles	Conventional aircraft
Abatement effect	Low energy consumption because no heating is required.	Reduction of power consumption by increasing motor efficiency	Weight reduction improves fuel consumption and reduces fuel consumption.	Same as description on the left
Life of finished products	5 years	14.8 years	10 years	10 years
Production volume	RO membrane 610,000 units	47,311,000 units (Number of air conditioners)	300,000 units	900 units
Finished products: Emissions from raw materials, manufacture, and disposal (tons) "( )" shows emissions from chemical products*	Seawater desalination plant: 1.5 million -	- -	Automobiles: 1.86 million -	Aircraft: 3.51 million -
Avoided CO_2 emissions (tons)	-172.57 million	-189.94 million	-1.5 million	-24.3 million
Total	**Avoided CO_2 emissions when products that are expected to be manufactured in 2020 would have been used until the end of their life (calculated by specifying a certain set of conditions [Note]): -390 million tons globally**			

Note: Preconditions for calculation are clearly stated in the explanatory notes for each of the examples.

1. About the chemical industry

1.1 Features of the chemical industry

The chemical industry plays an important role in people's lives by providing many industries, such as the automotive, electric machinery/electronics, pharmaceutical and cosmetics industries, with raw materials and materials for processing.

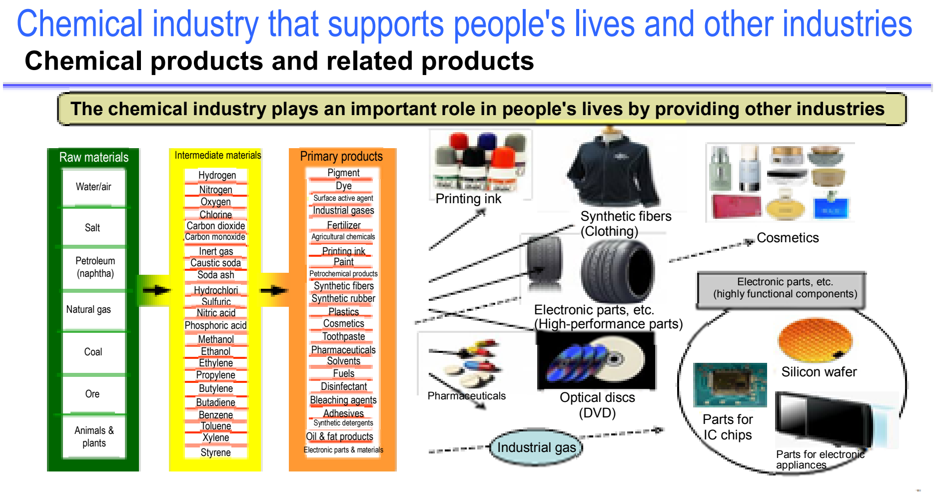


Fig. 8. Chemical industry that supports everyday life and industries

1.2 Features of the chemical industry in Japan (overview as of 2011)

[1] The first industry in added value ranking, of all manufacturing industries in Japan

[2] Employs 860,000 people

[3] It is a basic industry that supports the competitiveness of industries in Japan by providing products to user enterprises in sectors such as the automotive and electric machinery/electronics sectors through the supply of high-grade parts.

[4] A high energy-consuming industry that uses fossil fuels as raw materials and fuel

[5] An industry that faces international competition from Europe, America, Asia and elsewhere

Table 4. Amount shipped, added value and number of employees for each industry

	Amount shipped	Amount of added value	Number of employees	Amount of added value per capita
	Trillion yen	Trillion yen	10,000 persons	10,000 yen
Total for manufacturing industries	285.0	91.6	747.2	1,226
Entire chemical industry (ratio to total for manufacturing industries)	40.4 (14%)	15.6 (17%)	85.8 (11%)	1,818
Entire electric/information/electronics	40.4	13.4	111.3	1,204
Transportation machinery & equipment manufacturing industry	50.6	14.0	94.7	1,478
General machinery& equipment manufacturing industry	32.2	12.2	106.5	1,146

Sources: Ministry of Economy, Trade and Industry "Industrial Statistics Table," Ministry of Internal Affairs and Communications "Science and Technology Research Survey" and Ministry of Finance "Statistical Survey on Corporations"

1.3 Approach taken by the chemical industry in Japan concerning the prevention of global warming

(1) Current situation of CO_2 emissions

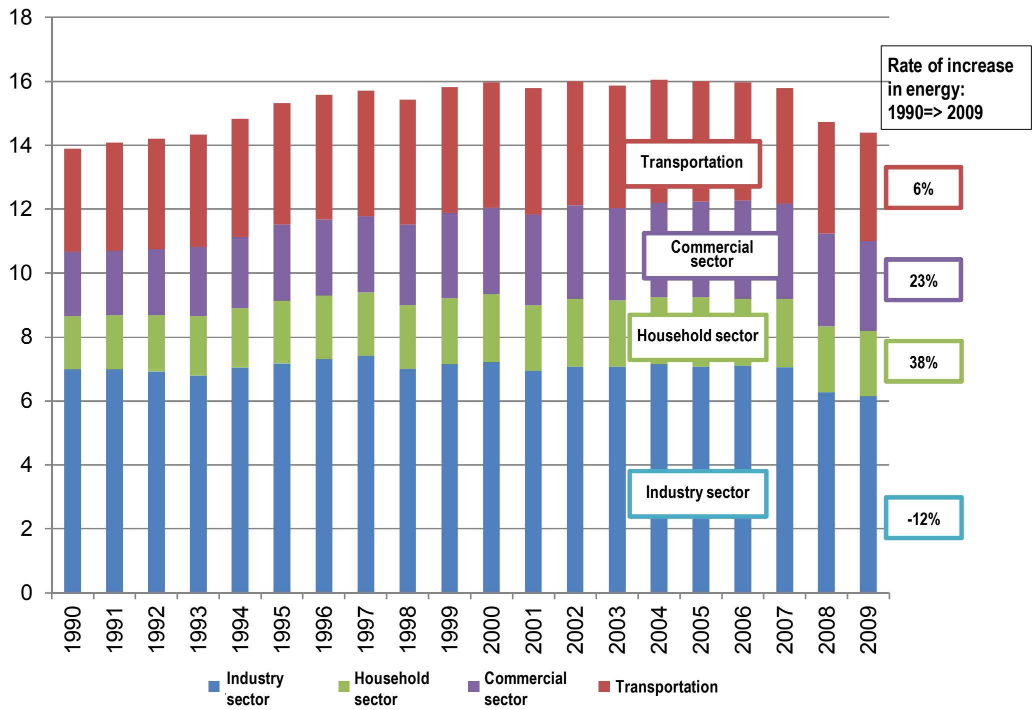
Proportion of CO_2 emissions in each sector

CO_2 emissions in the industrial field account for 34% of the total emissions in Japan, with the remaining 66% being emitted by the commercial, transportation, household sectors, etc. The emissions resulting from chemical products were the second greatest after steel in the industrial sector, accounting for 4% of the emissions in Japan as a whole.

(2) Approach taken by the chemical industry in Japan concerning energy saving activities

Change in the amount of energy used in each sector

The energy consumption of the industrial sector to which the chemical industry belongs has decreased compared with that in 1990. In recent years, however, the amount of energy used in the commercial and household sectors has been increasing, and it has become a problem to be addressed in the reduction in CO_2 emissions in Japan as a whole.



Source: Energy Economic White Paper 2011

Fig. 9. Changes in the amount of energy used in each sector

Overall change in energy-saving activities

The chemical industry uses many fossil fuels, and it uses them as raw materials for various types of products as well. To ensure security both in terms of fuel and raw materials after the oil shocks of the 1970s, a proactive approach to energy saving was adopted and substantial energy saving was pursued until the latter half of the 1980s.

Concerning changes in the consumption of ethylene etc., as a raw material for petrochemical products, the consumption as converted into energy shows an increasing trend as a result of an increase in the amount of production. However, the amount used as energy (fuel, etc.) remains flat, and it can be seen that continuing efforts are being made to reduce energy usage.

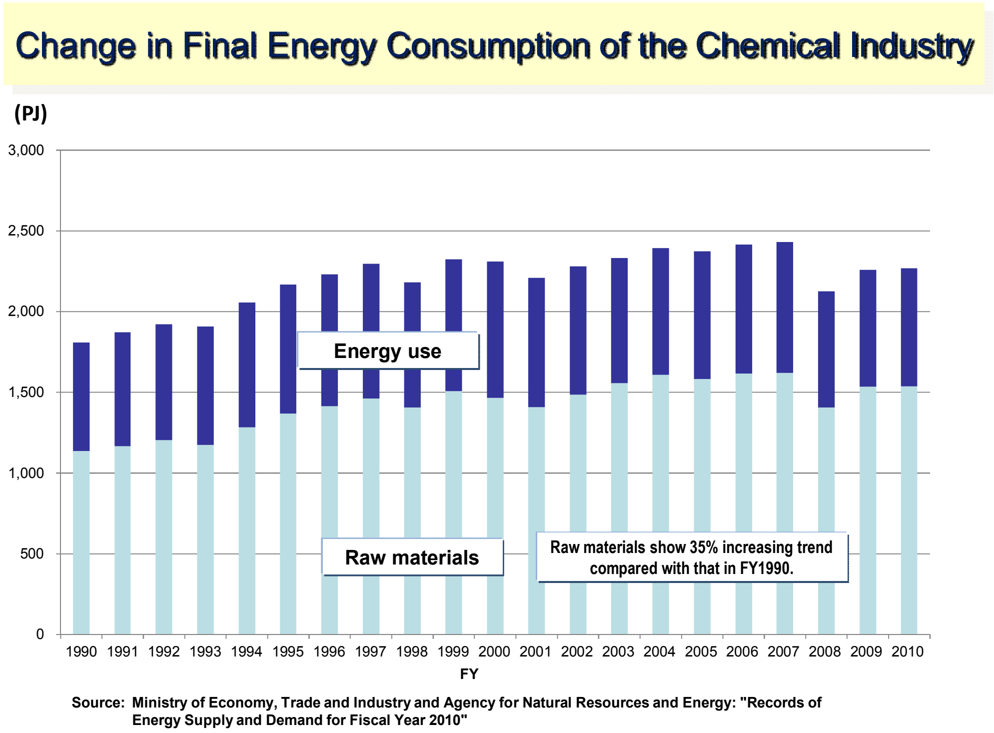


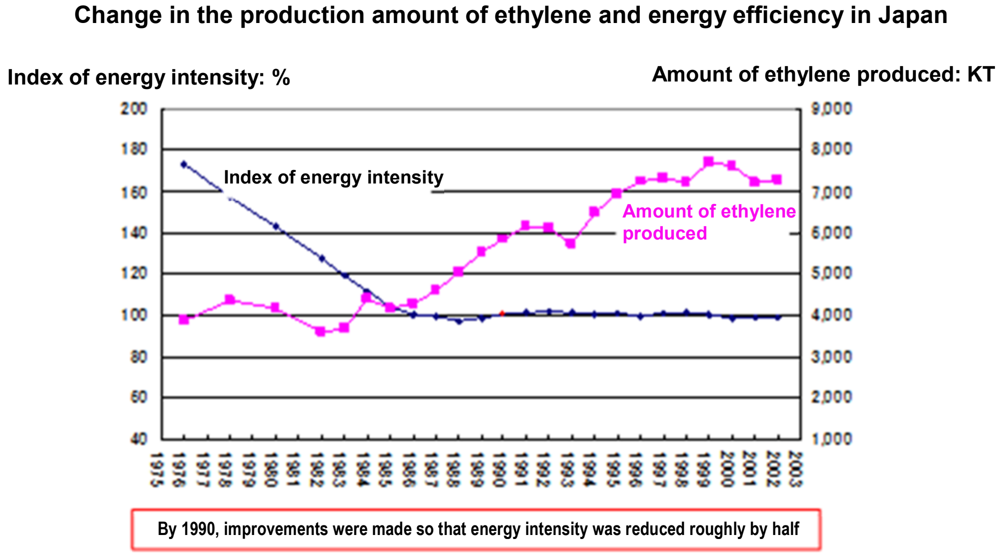
Fig. 10. Change in final energy consumption in Japan[3]

Change in energy-saving activities for each product

When each product is analyzed, the energy efficiency in the production of ethylene was reduced to about half by 1990. The intensity for electricity for caustic soda showed an improvement of about 30%.

[3] Ministry of Economy, Trade and Industry and Agency for Natural Resources and Energy: "Records of Energy Supply and Demand for Fiscal Year 2010"
http://www.enecho.meti.go.jp/info/statistics/jukyu/result-1.htm

Record of achievement by energy-saving activities [1]



Source: NEDO's Investigational Material for 2003

Record of achievement by energy-saving activities [2]

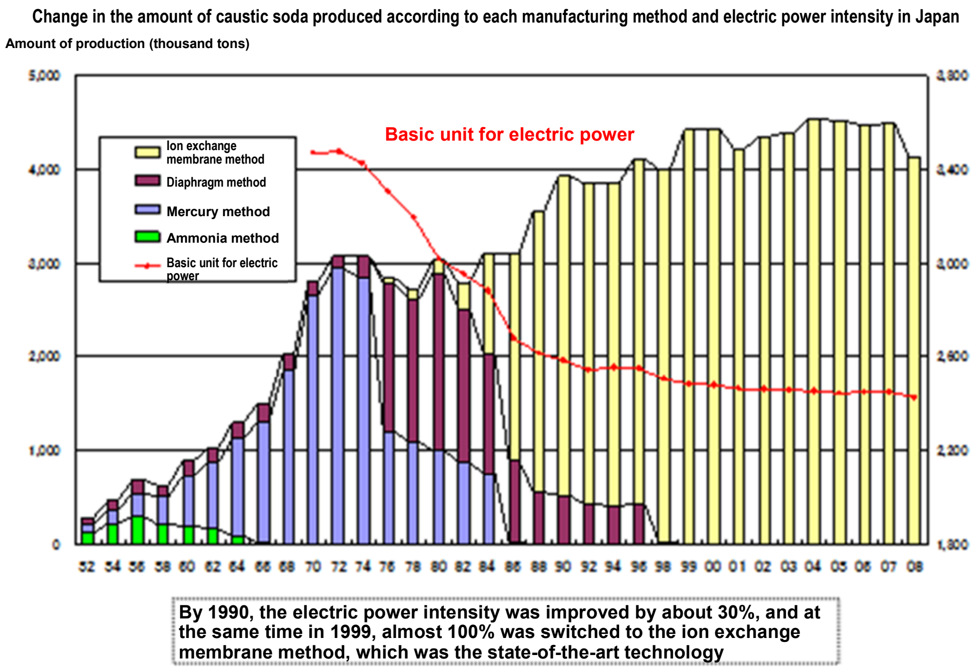


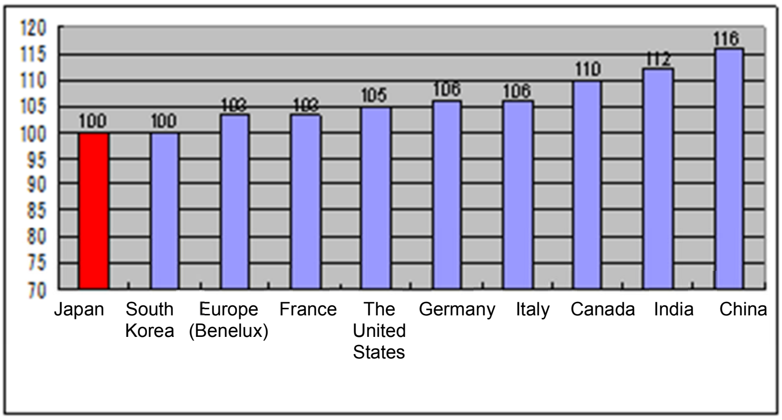
Fig. 11. Changes in energy intensity in the manufacturing processes of ethylene and caustic soda in Japan

(3) International comparison of energy efficiency of the chemical industry

International comparison of overall energy efficiency

The chemical industry has proactively promoted energy-saving activities since the oil shocks of the1970s. These initiatives include: [1] Switching the manufacturing method, process development, [2] improving facility/equipment efficiency, [3] improving the method of operation, [4] collecting discharged energy, and [5] streamlining the processes, etc. As a result of these energy-saving efforts, the chemical/petrochemical industries overall have achieved the highest level of energy efficiency in the world.

International comparison of energy efficiency (Entire chemical and petrochemical industries)

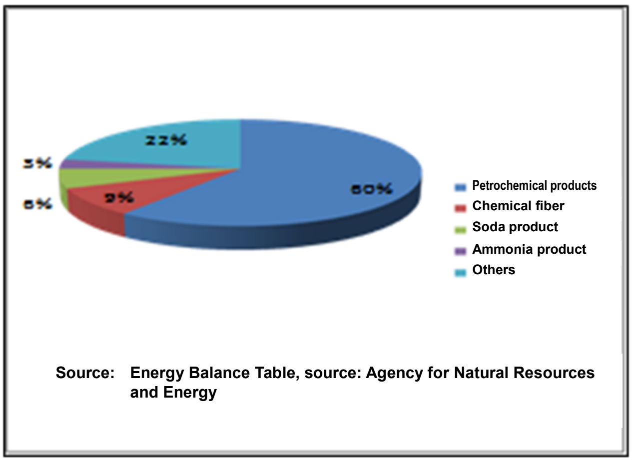


IEA Energy Efficiency Potential of the Chemical & Petrochemical sector by application of Best Practice Technology Bottom up Approach -2006 including both process energy and feedstock use-

Fig. 12. International comparison of energy efficiency in the chemical industry

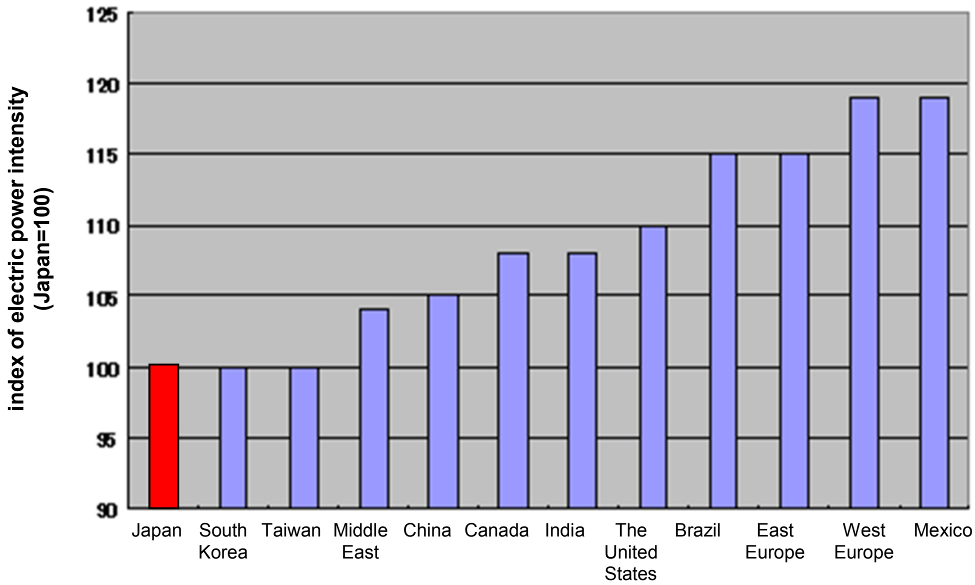
International comparison of the energy efficiency of each product

Based on its business model, energy consumption in the chemical industry is classified into petrochemical products, chemical fibers, soda products, ammonia products, and others. Of these, ethylene plants and soda products employ manufacturing processes that have achieved the highest level of energy efficiency in the world.



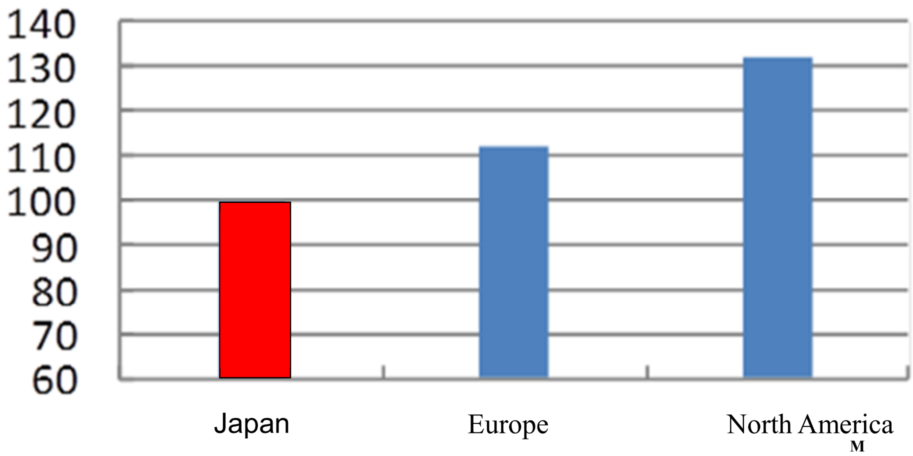
Energy Statistics of the Chemical Industry (FY2010)

Fig. 13. Details of energy consumption in the chemical industry in each sector (FY2010)



(Source: Estimated from iSRI Chemical Economic Handbook, August 2005 and Soda Handbook)

Fig. 14. Comparison of energy efficiency for caustic soda among various countries (electric power intensity for electrolysis, FY2004)



Source: Chemical and Petrochemical Sector 2009 (International Energy Agency (an international agency within OECD))

Fig. 15. Comparison of energy efficiency for ethylene plants among various countries (energy intensity)

The chemical industry will continue with its energy-saving activities while supporting energy saving and reduction in CO_2 emissions by promoting measures such as: [1] Propagating state-of-the-art facilities when upgrading production facilities and BPT (Best Practice Technologies) that are at the highest level in the world (more specifically, building energy-saving process technologies for ethylene crackers, and the like), [2] achieving the best fuel mix, [3] making effective use of waste, [4] using renewable energy, such as biomass.

(4) Chemical industry - efforts to reduce greenhouse gas emissions through voluntary action

[1] Improvement in the index of energy efficiency

Since the establishment of its Global Environment Charter in 1991, the Japan Business Federation has been taking an autonomous and responsible approach toward solving the problem of global warming. In particular, in 1997, prior to the adoption of the Kyoto Protocol, it devised the Voluntary Action Plan on the Environment (FY1997 - FY2012), and has been making efforts to reduce CO_2 emissions in Japan, focusing on the industry and energy sectors. The chemical industry also participated in the "Keidanren Voluntary Action Plan on the Environment" from the beginning of FY1997, *engaging in work to* improve the index of basic units for energy, and achieved an improvement of 15% in the index of basic units, with the results from FY2008 through FY2012 being 85% on average.

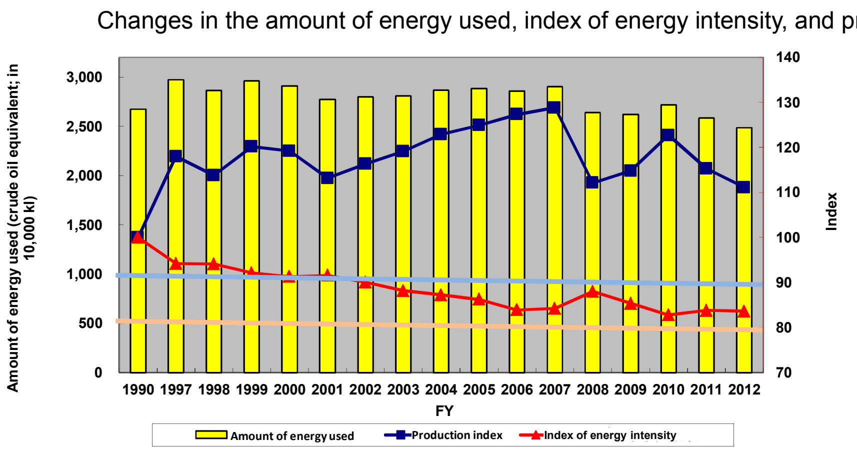


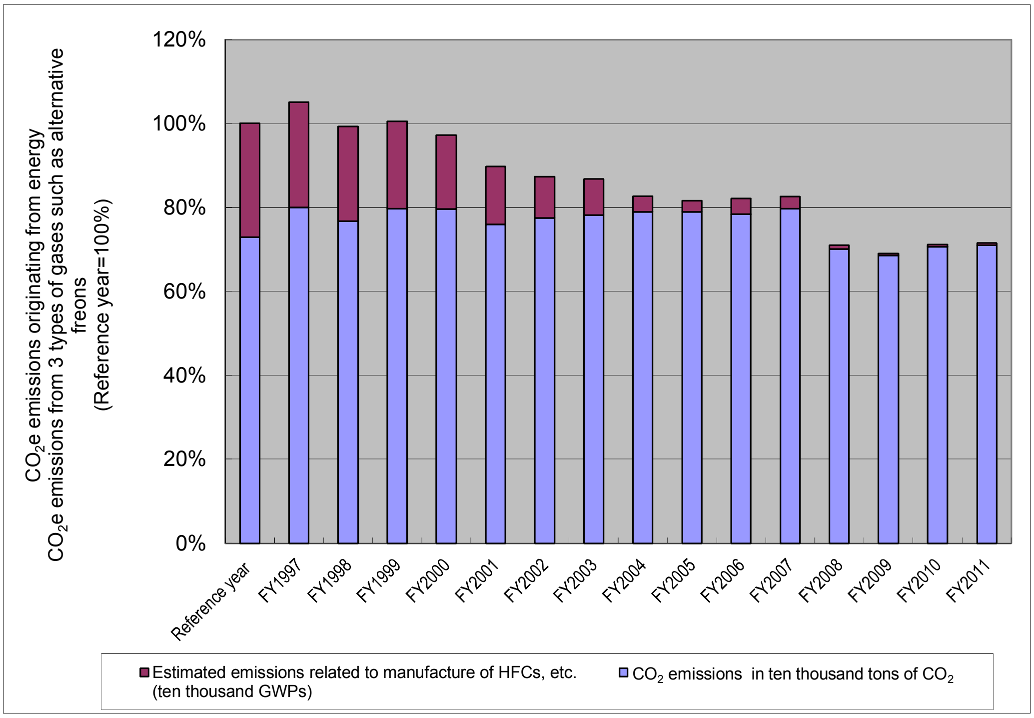
Fig. 16. Change in the indexes of energy efficiency in the chemical industry

[2] Reduction in GHG emissions

As a result of implementing measures to reduce GHG emissions, a reduction of 29% was achieved in 2011 compared with that in the reference year (FY1990 for CO_2 and the calendar year of 1995 for three alternatives to freon, etc.[4]). In particular, regarding the three alternatives to freon, etc., efforts have been made to reduce emissions. These efforts include reviewing the work processes, strengthening daily inspections, and systematically upgrading facilities. In addition, facilities to remove toxins through the combustion of diluted exhaust gases have been installed by utilizing subsidies from the national government. These initiatives have resulted in a substantial reduction in emissions.

4 HFCs (hydrofluorocarbons), PFCs (perfluorocarbons) and SF_6 (sulfur hexafluoride).

CO_2 emissions originating from energy & emissions of three types of gasses including alternatives to freon



Reference year: Three types of gasses including alternatives to freon 1995, CO_2 FY1990

Fig. 17. Change in GHG emissions in the chemical industry

2. Concerning cLCA (carbon Life Cycle Analysis)

2.1 Concept of cLCA (carbon Life Cycle Analysis)

The method of assessment using cLCA is a technique that focuses on CO_2 emitted during use in other industries or by consumers. The assessment compares the emissions of finished products that incorporate chemical products over their life cycle with the emissions of finished products that incorporate the products for comparison over their life cycle, and the difference between them is considered to be emissions that increase when there are no such chemical products, and is calculated as the net avoided emissions.

CO_2 emissions in a life cycle become the total of emissions from the procurement of raw materials, through manufacture, distribution and usage, to recycling/disposal.

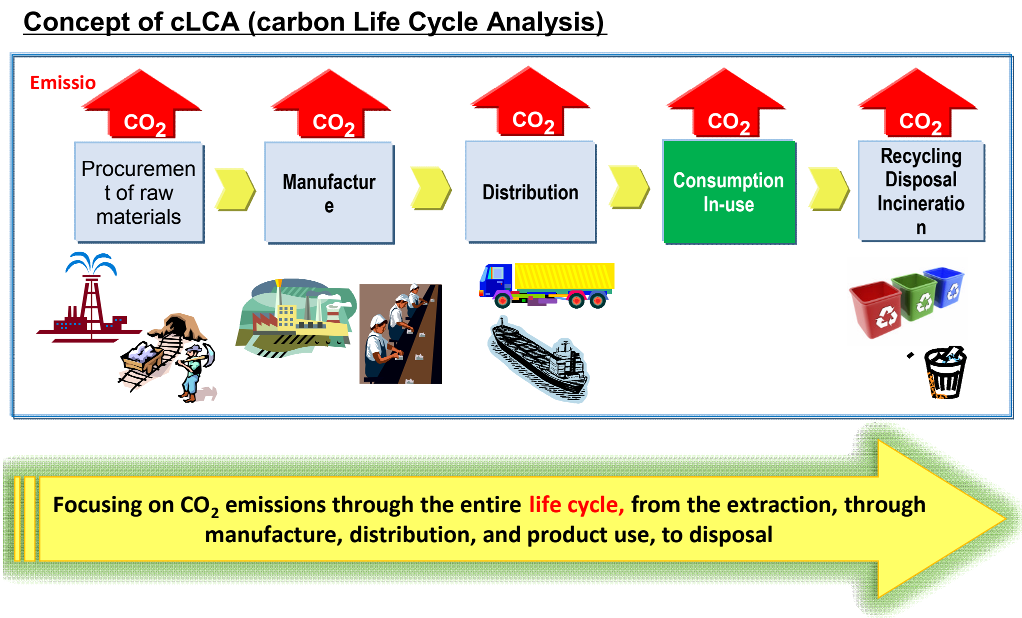


Fig. 18. Concept of cLCA

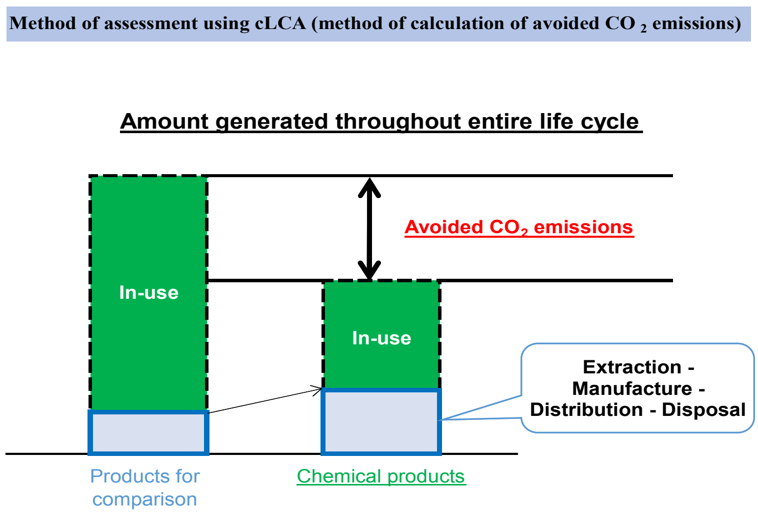


Fig. 19. Method of assessment using cLCA

2.2 cLCA Report of ICCA

(1) Purpose and overview

When striving to reduce GHG emissions globally, it is no longer sufficient to save energy and reduce GHG emissions during manufacture, which have been the focus up to this point. It has become important to strive to avoid GHG emissions in society as a whole through the development and propagation of products that lead to a reduction in GHG emissions in the consumer sector, commercial sector and other sectors.

In a context such as this, ICCA published a cLCA report entitled "Innovations for Greenhouse Gas Reductions" in July 2009 as a means of highlighting the situation and calling for action to help reduce GHG emissions from a new perspective that provides a bird's eye view of the entire life cycle, from the procurement of raw materials, through manufacture, distribution and consumption, to recycling/disposal.

The cLCA herein means a comparison of the GHG emissions, namely the CO_2e emissions (where e stands for equivalent; carbon dioxide equivalent to greenhouse gases) of chemical products in specific applications throughout the world. The scope encompasses the stages of procurement of raw materials, manufacture, distribution, usage, and disposal with the CO_2e emissions of alternative products that are the second-best products other than those produced by the chemical industry. As part of the scope, "CO_2e life cycle analysis" is carried out on more than 100 examples of use of chemical products in order to evaluate the influence of chemical products on the carbon balance in society as a whole.

Note that, to ensure objectivity and transparency, the cLCA of ICCA adopted the method proposed by McKinsey & Company, and all the quantified data for each field through numerical analysis were verified by the Öko-Institut, a German third-party organization.

cLCA Report

"Innovations for Greenhouse Gas Reductions"

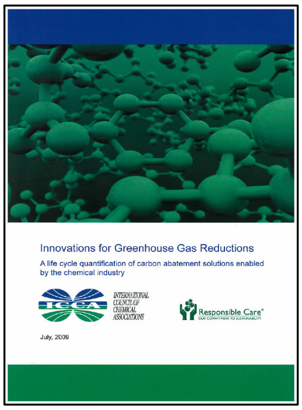


Fig. 20. ICCA Report

(2) Result of assessment for 2005

Global CO_{2e} emissions in the chemical industry

As a result of cLCA, global GHG emissions related to the chemical industry in 2005 were 3.3 billion tons. Of this volume, 2.1 billion tons, more than half of the figure, were produced as a result of purchasing raw materials and manufacturing chemical products by the chemical industry. Also, the figure includes 400 million tons of three alternatives to freon, which has a strong greenhouse effect.

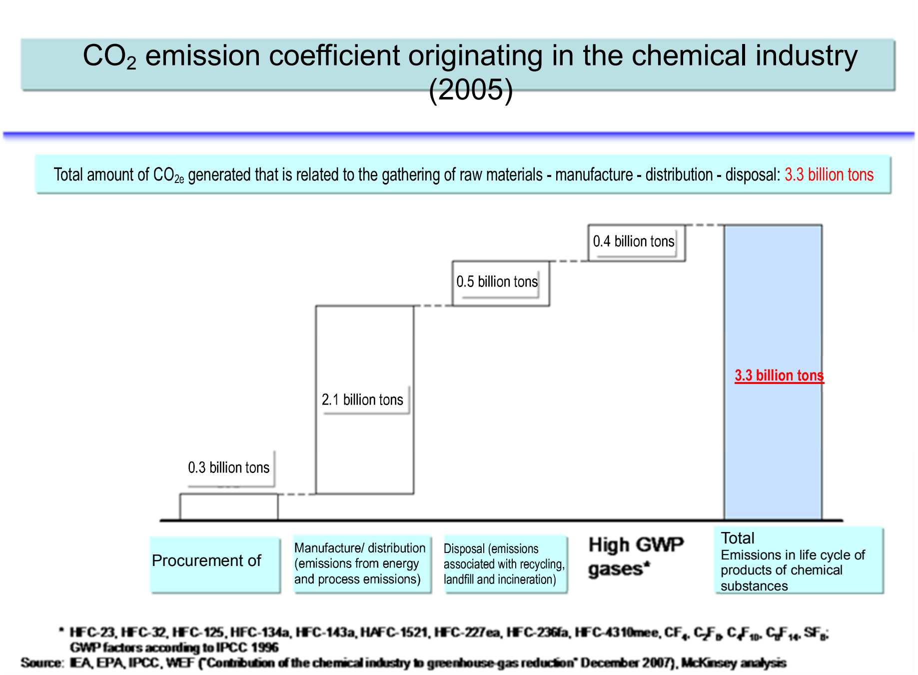


Fig. 21. CO_2 emissions originating from the chemical industry in 2005 (global)

"Net emission abatement"

Based on the result of assessment using cLCA, net emission abatement in the chemical industry in 2005 came to 3.6 billion tons, which surpassed the 3.3 billion tons emitted in the life cycle, excluding usage. Of these, the top two examples where the amount of reduction was greatest were thermal insulation materials and lighting.

Figures for the field of agriculture were excluded from the total as there were great variations in agricultural technology according to the country or region, and it could be considered that it was difficult to obtain a common understanding of the effect of reduced CO_2 emissions in agricultural materials (agricultural chemicals, fertilizers, etc.).

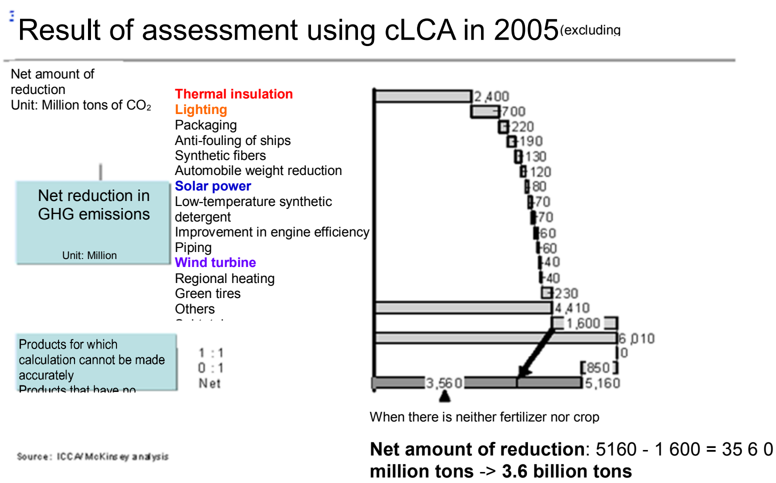


Fig. 22. Net emission abatement in 2005

(3) Result of assessment for 2030

Expected global CO_{2e} emissions in the chemical industry

Emissions in the BAU case (business-as-usual: a case in which the present regulations and lifestyle remain unchanged and efforts to reduce energy consumption remain at the current level) for 2030 originating from the chemical industry and emissions on a best-effort basis incorporating the use of innovative technologies that are expected to emerge and possible regulations in 2030 are shown below. In the BAU case for 2030, with the year 2005 being used as the starting point, the portion of improvements in production efficiency was excluded from the portion of increased production based on BAU, and the portion of increase in emissions associated with moving production bases was added. As a result, it is expected that emissions will nearly double to 6.5 billion tons.

In the case of the best-effort basis, calculation was made by taking account of the effect of reducing CO_2 emissions through measures such as the proactive adoption of functional products as compared to the BAU case and emissions that will increase as a result of producing such functional materials themselves. As a result, it is expected that a nearly twofold increase in emissions (from 3.3 to 6.5 billion tons) will be able to be controlled to 1.5 times (from 3.3 to 5 billion tons).

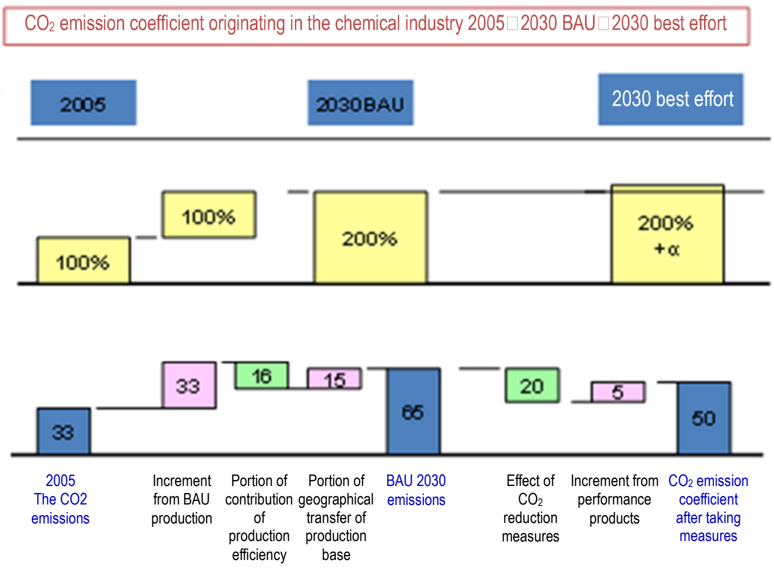


Fig. 23. CO_2e emissions originating from the chemical industry in 2030

Net emission abatement

Net emission abatement in 2030 on a best-effort basis is estimated to be 16 billion tons in total, excluding CO_2 emissions from agricultural materials. Among them, the greatest emissions are from thermal insulation materials (6.8 billion tons), followed by lighting apparatus (4.1 billion tons) and solar power generation (2 billion tons).

Global anthropogenic GHG emissions in 2005 are estimated to have been around 46 billion tons (WEF 2007[6]), and a net reduction of 16 billion tons translates into about 1/3 of such emissions.

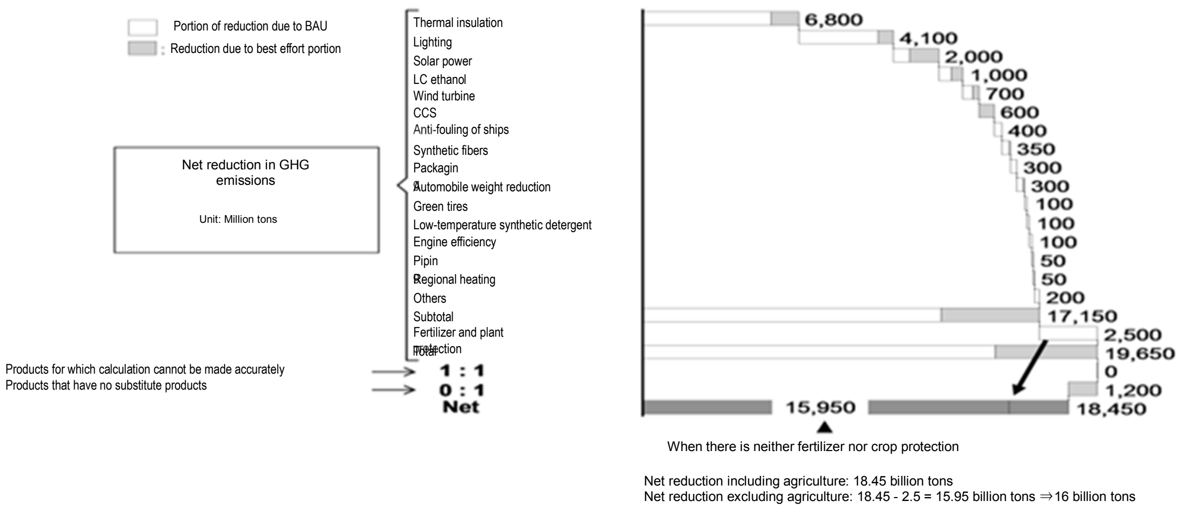


Fig. 24. Net emission abatement in 2030 (on a best-effort basis)

"Summary"

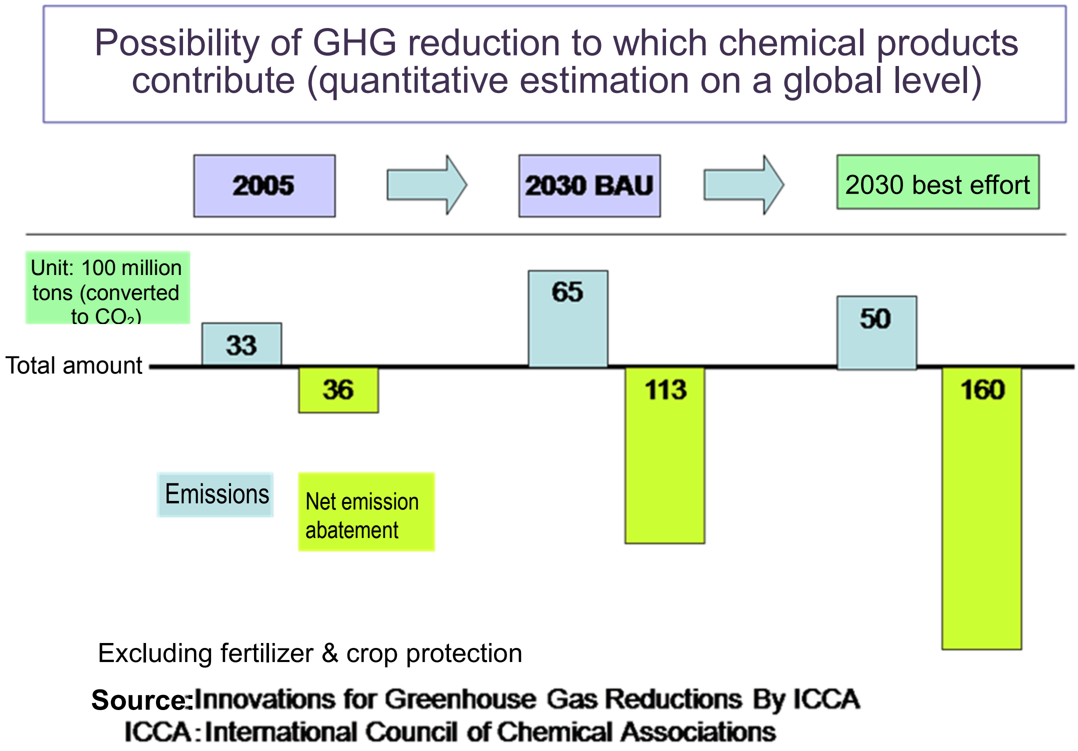


Fig. 25. Summary of emissions and net emission abatement originating from the chemical industry in 2030

3. On assessment using cLCA in Japan and around the world

3.1 Background and objectives

In the timetable in the New Growth Strategy that the Ministry of Economy, Trade and Industry published in August 2010 as a mid-term target for preventive measures against global warming, the year 2020 is set as the target year. Under these circumstances, the chemical industry is striving to help reduce CO_2 emissions at the usage stage of final products that use chemical products and to contribute to the reduction in CO_2 emissions in society as a whole through cooperation between different types of businesses. These objectives are in addition to efforts to reduce energy consumption and to reduce CO_2 emissions at the stage of manufacture, as described above.

The ICCA report calculated global emission abatement in 2005 and 2030 in the chemical industry throughout the world. Whereas, this booklet is intended to evaluate specific examples of chemical products in Japan and to show the situation of CO_2 emissions by taking account of the timetable of the "New Growth Strategy" of the Ministry of Economy, Trade and Industry.

1. Paying attention to the timetable of the New Growth Strategy of the Ministry of Economy, Trade and Industry, **the year 2020**, which is the period considered in the timetable, has been adopted as the target fiscal year.
2. Net avoided CO_2 emissions by the use of specific chemical products **in Japan and around the world** in 2020 have been quantified.

The first edition dealt with eight examples in Japan and one example from around the world, for which LCI[7] data were published and of which data sources were clear. In the third edition, the number of examples has been increased to include 15 examples in Japan and four examples from around the world. We are determined to continue to contribute to industry as a whole hereafter as well, in order to realize a low-carbon society through the provision of chemical products and technologies, thereby providing information proactively for the policies on emissions reduction.

3.2 Selecting the level in the value chain

The objectives of studies on avoided emissions in the chemical industry can be grouped into the following two categories, according to the level in the value chain (see Fig. 26).

1. Chemical product level: Make a comparison between the emissions of a certain product with those of a (chemical) product for comparison or the industry average value concerning how small the former is as compared to the latter. Commonly reported reasons for making such a calculation include in-house purposes (for instance, product benchmarking) and product differentiation, and the like.
2. End-use level: Assess the contribution of a chemical product to emissions avoided by the use of a specific low-carbon technology that makes use of the chemical product in place of the currently implemented product (product composition). Commonly reported reasons for making such a calculation include in-house purposes (for instance, portfolio planning), exchanges with partners in the value chain, and communications with stakeholders

[7] Life Cycle Inventory：Environmental load from manufacture to disposal

(investors, policy planners, general citizens, etc.) on the roles of the chemical industry, and the like.

Each of the levels is exemplified below.

● **Chemical product level:**

If the study is carried out at the chemical product level, the definition of the functional unit takes into account the performance of the chemical product and the alternative product. In this case the avoided emissions calculation is equal to the comparative assertion according to ISO 14040/44, except that the avoided emissions calculation focuses on greenhouse gas emissions only.

Examples of functional units specified in studies that place emphasis on chemical product level

- *Production and disposal of 1,000 intake manifolds having thermal resistance of yxz*
- *Production, use and disposal of a resin hardening agent for hardening resin XYZ that is used when manufacturing 10 wind turbine rotating blades in 30 - 60 seconds*

● **End-use level:**

Chemical products are often intermediate products integrated in technologies that are manufactured downstream in the value chain. Chemical products may influence the performance of technologies in such a way that emissions are avoided compared to a specific reference case. To assess how a chemical product influences an end-user technology, the functional unit of the study is chosen based on the end-use technology and taking into account the function of the chemical product in the technology.

Examples for definition of functional unit in studies that focus on the end-use level:

- *Running a medium-sized gasoline automobile for 200,000 kilometers with fuel-efficient tires using special chemicals vs. regular tires.*
- *Living in an existing single-family detached house in Germany (building year: 1964) with an average temperature of 19°C for 50 years, with polystyrene insulation and without.*

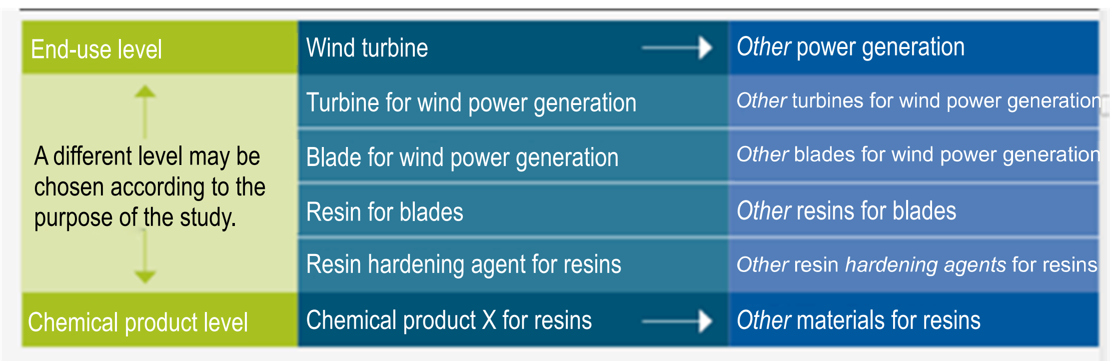


Fig. 26 Examples of wind power generation: Various levels in the value chain and an alternative product that can meet the purpose of the same customer at each of the levels

In the case of the examples of wind power generation in Fig. 26, each of the levels is described as follows.

- **Chemical product level: Resin hardening agent for wind power turbine blades**
- **End-use level: Electric power**

3.3 Object of assessment products to be assessed shall be based on the products/technologies that are being put into the markets at the point in time that is described in each of the examples, and not based on products that are expected to be in widespread use in 2020 as a result of the progress of technological development.

In addition, the products to be compared shall be the products that deliver the same function to the user, and avoided emissions are calculated, based on this, by being multiplied by the quantity expected to be manufactured in 2020.

Note that avoided emissions include not only those of chemical products but those in the entire value chain as well, but at the present point in time no technique is available that quantitatively sorts out avoided emissions resulting from chemical products and those from non-chemical products, and therefore no attribution of avoided emissions has been performed.

Fig. 27 and Table 5 show chemical products for which the avoided CO_2 emissions have been calculated on a trial basis this time and the finished products and products for comparison that have become the object of assessment using cLCA.

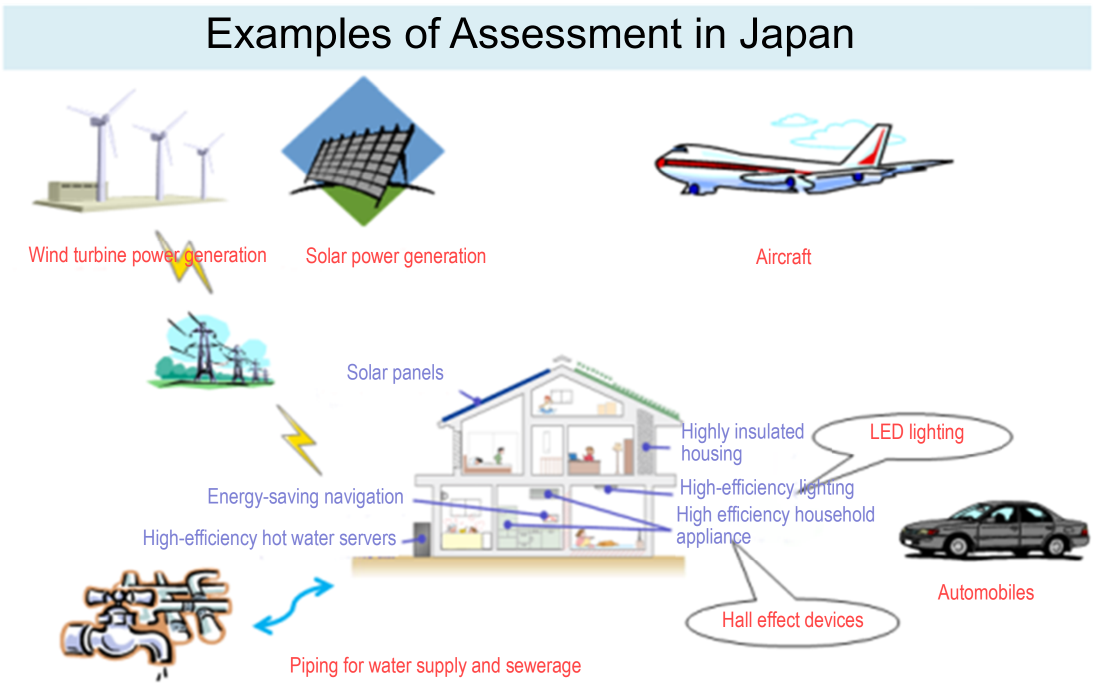


Fig. 27. Diagrams of the products to be assessed

Table 5. List of products to be assessed

◆ **Japan**

Classification	Chemical product	Products to be assessed	Products for comparison
Renewable energy	Materials for solar power generation	Electric power produced by solar power generation	Utility power
Energy-saving	Automotive materials	Automobiles that use carbon fiber reinforced plastic composite materials (CFRPs)	Conventional automobiles
	Materials for aircraft	Aircraft that uses carbon fiber reinforced plastic composite materials (CFRPs)	Conventional aircraft
	Materials for fuel-efficient tires	Automobile fitted with fuel-efficient tires	Automobile fitted with non-fuel-efficient tires
	LED-related materials	LED light bulbs	Incandescent light bulbs
	Thermal insulation materials for housing	Housing that meets the Fiscal Year 1999 energy-saving standard (using thermal insulation materials)	Housing before the energy-saving standard of 1980 (not using thermal insulation materials)
	Aluminum-resin composite windows and thermal insulation materials	Detached housing that meets the Fiscal Year 1999 energy-saving standard (using aluminum-plastics composite windows and thermal insulation materials)	Housing before the energy-saving standard of 1980 (not using thermal insulation materials)
	Hall effect device, Hall effect ICs	Inverter air conditioner	Non-inverter air conditioners
	Piping materials	PVC resin pipes	Ductile cast iron pipes
	Concentrated liquid detergent for cleaning clothes	Concentrated liquid detergent for cleaning clothes	Conventional liquid detergent for cleaning clothes
	Low-temperature steel plate detergent	Low-temperature steel plate detergent	Conventional steel plate detergent
Resource-saving	Materials for high-durability apartments	High-durability apartments	Ordinary apartment house
	High durability paint	Silicone resin based paint and fluororesin based paint	Acrylic resin based paint and urethane resin based paint
Recyclable resource	Shampoo container	Biopolyethylene container	Fossil resource polyethylene container
Suppression of N_2O emission	Feed additives	Assorted feed containing DL-methionine as an additive	Additive-free assorted feed

◆**Global**

Classification	Chemical product	Products to be assessed	Products for comparison
Energy-saving	Materials for desalination plants	Desalination technology by means of RO membranes	Desalination technology by means of the evaporation process
	Hall effect device, Hall effect ICs	Inverter air conditioner	Non-inverter air conditioners
	Automotive materials	Automobiles that use carbon fiber reinforced plastic composite materials (CFRPs)	Conventional automobiles
	Materials for aircraft	Aircraft that uses carbon fiber reinforced plastic composite materials (CFRPs)	Conventional aircraft

3.4 Ways of thinking about the period under assessment

1. **Evaluate avoided CO_2 emissions when the products expected to be manufactured in the year under assessment would have been used until the end of their life.**
2. Evaluate the avoided CO_2 emissions as a result of operation, for the year under assessment, of the total number of product units that will be in widespread use and put into operation until the year under assessment.

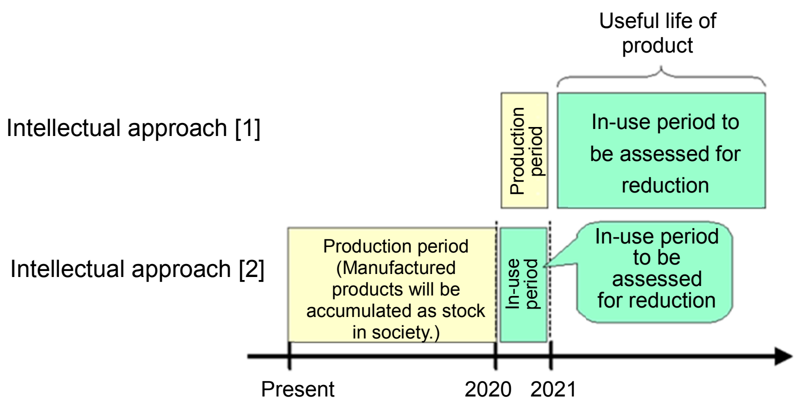


Fig. 28. Two ways of thinking about the period under assessment

Since the assessment using cLCA is intended to identify the potential of chemical products for reducing emissions, in the assessment here, it has been determined that the thinking [1] should be adopted and **the products to be manufactured during the year 2020**, which is the reference year, should be considered.

3.5 Calculation of emission abatement

(1) CO_2 emission factor

Since it is difficult to predict the level of technological sophistication for conventional products in 2020, **previous data that are known at present for the CO_2 emissions of alternative products that become the object of comparison** have been used (except the CO_2 emission factor for utility power).

(2) Geographical conditions

Regarding emission abatement for CO_2 emissions resulting from the use of products under assessment, evaluation has been made based on the degree of use **in Japan and throughout the world**.

(3) Method of calculation

Using cases where conventional products are manufactured as the baseline, the avoided CO_2 emissions have been calculated by multiplying the difference when the conventional product (product for comparison) has been replaced with the product under assessment by the quantity manufactured during the year under assessment.

Step 1: Calculate the avoided CO_2 emissions per unit quantity (e.g. kg, piece) of the product under assessment.

CO_2 emissions over the life cycle per unit quantity of the product for comparison

- CO_2 emissions over the life cycle per unit quantity of the product being assessed = A

Step 2: Calculate the avoided CO_2 emissions by multiplying A by the quantity of the products under assessment that are expected to be manufactured in 2020.

Emission abatement of A × Quantity of the products under assessment that are expected to be manufactured in 2020 (one year)

3.6 Qualitative assessment of the degree of contribution of chemical products to the avoided emissions in the value chain

Life cycle avoided emissions almost always result from efforts of multiple partners along the value chain. This is particularly the case for a study at the end-use level. Since the avoided emissions are the sum of changes made by all the partners in the value chain (raw material suppliers, materials manufacturers (chemical product companies, materials processing services suppliers, components assembly services suppliers), technology users, etc.), the avoided emissions cannot be attributed to one partner. **For this reason, the avoided emissions calculated at the end-use level must always be attributed to the entire value chain.**

It often occurs that partners in the value chain desire communications of the avoided emissions in the entire value chain. In order to increase the credibility of such an assertion, the reporting company needs to clarify the role in the value chain, and at the same time if value chain avoided emissions are too small to communicate, the company needs to refrain from reporting the avoided emissions. The reporting company must describe the degree of contribution as shown in Table 6 in order to clarify the degree of contribution of its products to the value chain avoided emissions. In this scheme, the degree of contribution is classified based on the relations between chemical products and final products.

Table 6: The significance of the contribution of chemical products to value chain avoided emissions

Significance of contribution	**Relationship between chemical products and final products**
Fundamental	The chemical product is the key component that enables the GHG emission avoiding effect by using the final product.
Extensive	The chemical product is part of key component and its properties and functions are essential for enabling the GHG emission avoiding effect by using the final product.
Substantial	The chemical product does not contribute directly to the avoided GHG emissions, but it cannot be substituted easily without affecting the avoided emissions by using the final product.
Minor	The chemical product does not contribute directly to the avoided GHG emissions, but it is used in the manufacturing process of a fundamentally or essentially contributing product.
Too small to communicate	The chemical product can be substituted without changing the avoided GHG emissions by using the final product.

3.7 Name and description of the organization(s) commissioning the study and that performing it ("the practitioner")

- Organization commissioning the study for 19 assessed examples: Japan Chemical Industry Association (general incorporated association)
- Practitioner: Japan Chemical Industry Association (general incorporated association)

4. Conclusions and proposals

4.1 Summary of assessed examples

Table 7. Summary of Assessed Examples

◆Examples in Japan Products under assessme	Finished products: CO_2 emissions from raw materials -manufacture - disposal (10,000 tons) ( ) shows CO_2 emissions at the stage of manufacture of chemical products	Production volume (FY 2020)	The avoided CO_{2e} emissions (thousand tons)	Life of finished product (years)	Products for comparison
Electric power produced by solar power generation	(129)	1,760,000 kW	-898	20	Utility power
Automobiles that use plastics reinforced with carbon fiber	9.3	15,000 units	-7.5	10	Conventional automobiles
Aircraft that use plastics reinforced with carbon fiber	17.6	45 units	-122	10	Conventional aircraft
Automobile fitted with non-fuel-efficient tires (Note 1)	(174)	PCR73,000,000 units TBR5,000,000 units	-636	PCR 30,000 km TBR120,000 km	Automobile fitted with non-fuel-efficient tires
LED light bulbs	9.2	28 million units	-745	10	Incandescent light bulbs
Housing that meets the Fiscal Year 1999 energy-saving standard: Thermal insulation materials (Detached house) (Apartment)	(129) (106)	367,000 houses 633,000 apartments	-953 -6,628	30 60	Housing before the energy-saving standard of 1980 (not using thermal insulation materials)

Housing that meets the Fiscal Year 1999 energy-saving standard: Aluminum-plastics composite windows/ Thermal insulation materials (Detached house)	(10.7)	25,000	Number of thermal insulation materials for housing included	30	Housing before the energy-saving standard of 1980 (not using thermal insulation materials)
Inverter air conditioner	—	7,460 thousand units	-1,640	14.8	Non-inverter air conditioners
PVC resin pipes	(74)	493,092 tons	-330	50	Ductile cast iron piping
Concentrated liquid detergent for cleaning clothes	109 (32)	148 thousand tons	-29	24 times of cleaning	Conventional liquid detergent for cleaning clothes
Low-temperature steel plate detergent	0.3 (0.3)	Steel plates of 8.75 million tons	-4.4	—	Conventional steel plate detergent
High-durability apartments	1,655 (24)	61,000 units	-224	100	Ordinary apartment house
Silicone resin paint and fluoro resin based high-durability paint	(1.2)	61,000 units	-1.1	50	Acrylic resin based and urethane resin based paint
Biopolyethylene container	0.03 (0.03)	1,000,000 pieces	-0.01		Fossil resource polyethylene container
Assorted feed containing DL-methionine as additive	109 (85)	3.96 million tons	-16	Breeding period 48 days	Additive-free assorted feed
Total			-12,200		

Note 1: Those for passenger vehicles are indicated as PCR, and those for trucks/buses as TBR.

Note 1: Difference between emissions during the procurement of raw materials through to manufacture and disposal, instead of the difference in use

◆ **Global examples**

Products under assessment	Finished products: CO_2 emissions from raw materials -manufacture - disposal (10,000 tons)	Production volume (FY 2020)	The avoided CO_{2e} emissions (thousand tons)	Life of finished product (years)	Products for comparison
Desalination technology by means of RO membranes	150	610,000 units	-17,257	5	Desalination technology by means of the evaporation process
CFRP automobile	186	300,000 units	-150	10	Conventional automobiles
CFRP aircraft	351	900 units	-2,430	10	Conventional aircraft
Inverter air conditioner	—	47,311 thousand units	-18,994	14.8	Non-inverter air conditioners
Total			-38,831		

4.2 Conclusions and proposals

It can be seen from the total for the examples, chemical products are a key material in reducing CO_{2e} emissions by about 120 million tons in Japan and by about 390 million tons globally. Note that the avoided CO_{2e} emissions include not only those from chemical products but those from other products related to raw materials and parts as well. Life cycle avoided emissions almost always result from efforts of multiple partners along the value chain, and therefore no attribution of avoided emissions to each constituent product has been performed.

Also, it can be inferred from the examples that chemical products contribute to the reduction in GHG emissions for finished products in various fields, such as the energy sector (solar power generation), consumer and home sector (LED light bulbs, housing, air conditioners, piping, automobiles, detergents, shampoos), transportation sector (automobiles, aircraft), etc., in cooperation with products that are related to other materials for processing and parts.

5. Plans to be pursued by the chemical industry hereafter

In the "Keidanren’s Commitment to a Low Carbon Society," **"Contribution to reduction through the spreading of low-carbon products," "Promotion of international contributions" and "Development of innovative technologies"** were regarded as principal areas of activities, in addition to the efforts for the reduction in CO_2 emissions produced during the manufacture of chemical products, and the activities were started in Fiscal Year 2013.

5.1 Contribution to reduction through the spreading of low-carbon products: Increasing the number of examples of assessment using cLCA in Japan and around the world

In order to promote CO_2 emissions reduction, it is important that measures be taken from the perspective of pursuing total optimization that provides a bird's eye view of the entire life cycle, from the procurement of raw materials, through manufacture, distribution and consumption, to recycling/disposal, rather than from the perspective of partial optimization such as the reduction in CO_2 emissions in the manufacturing sector.

<u>The role of the chemical industry is to contribute to CO_2 emissions reduction in society as a whole through the supply chain by the development and spreading of chemical products and technologies.</u>

It can be said that the implementation of cLCA here, as shown in the fifteen examples in Japan and four international examples, is very significant in view of the magnitude of the avoided CO_2 emissions that has been shown will be achieved by the contribution of the chemical industry in Japan. However, final products that are low in carbon, with which chemical products help to reduce CO_2 emissions, are not limited to those in the 19 examples here. There are plans to expand that examples of cLCA to include those of materials for the next generation of automobiles (materials for weight reduction, materials for secondary batteries, materials for fuel cells, etc.), thermal insulation members for high-efficiency architecture, materials for wind turbine power generation, etc.

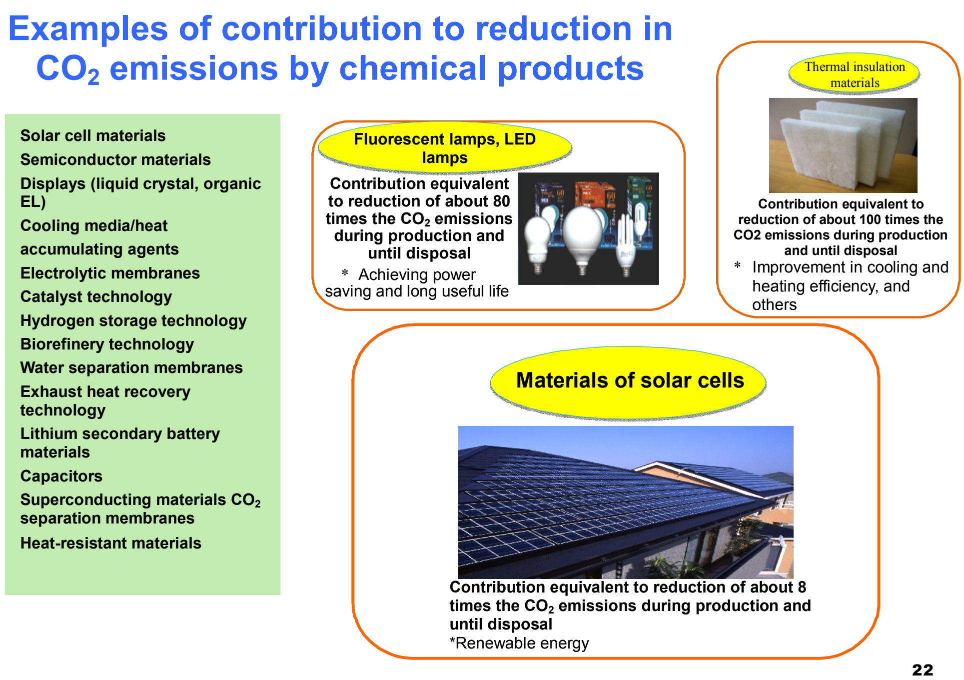


Fig 29. Examples of the avoided CO_2 emissions by chemical products

5.2 Promotion of international contributions by means of energy-saving technologies and low-carbon products

The chemical industry is determined to proactively contribute to the reduction in GHGs on a global scale, based on the principle of "responsible care" in which the environment, safety and health are secured voluntarily, and improvements in reliability represented by society and communications are promoted in all processes, from the development of products through to manufacture, use, and disposal/recycling, by continually engaging hereafter in the propagation and deployment overseas of chemical processes, energy-saving technologies and low-carbon products of the world’s highest standard.

Table 8 exemplifies the fact that the use of Japanese products/technologies will have a great avoided GHG emissions potential of about 400 million tons in the world in 2020, although just six examples are given herein.

Thus it is thought that chemical products will be able to make a great contribution to the reduction in GHG emissions in the world by spreading technologies.

Table 8 Contribution to the reduction in GHG emissions in the world

Contribution (potential) to the reduction in GHG emissions in the world by means of Japanese products/technologies

Field	Example	Abatement effect	Abatement potential ten thousand tons-CO_2/year
Manufacturing technologies	Caustic soda manufacturing technology using the ion exchange membrane process	Improvement in power consumption intensity	650
Materials for processing/ products	Desalination technology using reverse osmosis membranes*	Energy saving using substitution for the evaporation process	17,000
	Automotive materials (carbon fiber)*	Improvement in fuel efficiency by weight reduction	150
	Materials for aircraft (carbon fiber)*	Improvement in fuel efficiency by weight reduction	2,430
	DC motor control device for use in air conditioners*	Increase in motor efficiency	19,000
Making alternatives to Freon, etc. harmless	Reduction of emissions of three alternatives to Freon, etc. by means of exhaust gas combustion technology	Reduction of GHG emissions	2,000
			About 40,000

*Source: Calculated based on JCIA's "Life Cycle Analysis of Chemical Products in Japan" and "Guidelines for Calculating the Avoided CO_2 Emissions"
As for the examples of technology, those for which the share of Japanese businesses is 70% or more are described.

Shown below are specific examples of avoided emissions overseas including the examples described in Table 8 and technologies for which deployment overseas are expected hereafter.

Examples of contribution by the transfer of energy-saving and low-carbon technologies overseas

Manufacturing technologies: Provision of chemical processes and energy-saving technologies at the world's highest standard

- Manufacturing technology for polycarbonate using CO_2 as a raw material in countries in the Middle East and Asia
- State-of-the-art manufacturing equipment for terephthalic acid in India and China
- Manufacturing technology for acrylamide that uses biotechnology in South Korea
- Caustic soda manufacturing equipment that reduces power consumption during electrolysis by using the ion exchange membrane process in the Middle East, Asia, Europe and America
- Ethylene plant in Singapore having the highest level of energy efficiency in the world

Unprocessed materials/products: During the usage stage, CO2 can be substantially reduced as compared with conventional unprocessed materials and methods.

- Desalination technology using reverse osmosis membranes
- Drainage treatment system by means of multistage aeration tanks
- Control devices for DC motors for inverter air conditioners

Treatment for making three alternatives to Freon harmless:

- Reduction in the emissions of three alternatives to Freon by the installation of exhaust gas combustion equipment

  For the results in 2012, achieved substantial reduction in PFCs to 92% and in SF6 to 95%, using the basic unit for emissions relative to that in the reference year. From now on, reduction in greenhouse gas emissions through transfer of technologies overseas will be promoted in cooperation with the national government as well, through the use of production technologies for reducing the emissions of alternatives to Freon and through the use of exhaust gas combustion equipment that is possessed by businesses.

5.3 Development of innovative technologies

The chemical industry uses fossil fuel both as fuel and as raw materials, and the development of innovative technologies both in terms of raw materials and fuel is an important problem to be addressed on a mid to long-term basis.

For this reason, considering the situation in 2020 and thereafter, we will promote development by sharing the roadmap and cooperating with the national government regarding the technical problems and barriers to be overcome in development. It is also important that information concerning the contribution to such environmental aspects be transmitted by implementing quantitative assessments, such as that carried out by using cLCA with regard to such technical development.

Major mid and long-term technical development in the chemical industry is shown below.

[1] Innovative process development

- Development of innovative processes that reduce waste and byproducts
- Development of innovative processes for naphtha decomposition

- Development of distillation and separation technology by means of precision separation membranes
- Development of high-efficiency separation and refining processes for byproduct gases by means of high-performance porous materials

[2] Development of chemical product manufacturing processes that do not use fossil fuels

- Development of chemical product manufacturing processes that use CO_2 as raw materials
- Development of processes for manufacturing propylene from cellulose-based biomass ethanol

[3] Development of the next generation of high-performance materials that contribute to reduction in GHG emissions in terms of LCA

- Thermal insulation materials for high efficiency construction
- Solar cell materials (high efficiency compound semiconductors, organic based solar cells, etc.)
- Next-generation automobiles
- Materials for weight reduction (engineering plastics, etc.)
- Parts for secondary batteries (positive electrode materials, negative electrode materials, electrolytic fluids, separators, etc.)
- Parts for fuel cells (catalysts, solid electrolytes)
- Next-generation high-efficiency lighting (high efficiency LEDs, organic EL, etc.)
- Materials for flat panel displays (organic EL, etc.)
- Materials for high-efficiency heat pumps (cooling medium, heat accumulating agent)
- CO_2 separation membranes, hydrogen manufacturing, and storage technologies, etc.

[4] Development of chemical technologies and creation of new parts, materials and products in line with the "Cool Earth Innovative Energy Technology Plan"

6. Review for cLCA Report (Third Edition)

6.1 Overview of the review

During the period from December 2013 through January 2014, the "cLCA Report - Third Edition" was presented to a panel of experts and their opinions were solicited. Four people expressed their opinions: Masahiko Hirao (committee chairperson, Professor, Department of Chemical System Engineering, School of Engineering, the University of Tokyo), Atsushi Inaba (Professor, Department of Environmental and Energy Chemistry, Kogakuin University), Yasunari Matsuno (Associate Professor, Department of Materials Engineering, School of Engineering, the University of Tokyo), and Yuki Hondo (Professor, Graduate School of Environment and Information Sciences, Yokohama National University).

Note that the four people in charge of the review were not concerned with obtaining the data used in the investigation, and did not directly verify the completeness, representativeness, accuracy, etc. of the data given in the report. Hence, the data used for calculation and the values themselves obtained as the result of calculation are outside the scope of the review.

The matters pointed out are described below by itemizing them as the "Overview of the result of review."

6.2 Opinions and response of the panel of experts on the cLCA Report (third edition)

(1) Opinions of the experts

1) Levels in the value chain

- It is felt that regarding the selection of levels in the value chain, all the examples given are those at the end-use level. Assuming that the stage of chemical products being used (the stage after cleaning in the case of a steel plate detergent; the stage after coating in the case of a paint) is the end-use level, it can also be said that both the steel plate detergent and the paint are not at the chemical product level, but are at the end-use level. Also, if a consumer is given the status of being at the end-use level, such examples can also be regarded as being at the chemical product level, and in this respect it is difficult to make a judgment on the status of the value chain level. Concerning the terms to be used, classification of the terms such as the unprocessed material level, final product level, and process level might also be necessary.
- Explanations based on the chemical product level and end-use level only are not easy to understand. The grouping of levels into unprocessed material level, part level, and process level could also be required.
- All the examples given appear to be those at the end-use level. The explanations given in page 15 of the Global Guidelines ("Addressing the Avoided GHG Emissions Challenge") based on the chemical product level and the end-use level are not easy to understand. In addition, in the case of the chemical product level, it is thought that the comparison may also be equal to comparative assertion if the provisions of ISO 14040/44 are to be followed, and so measures for addressing such a comparison will be required.
- In the example of a shampoo container, it appears to be at the end-use level if the study is focused on the shampoo container.

- If it is said that the study focuses on the chemical product level, perhaps the name should be changed to a resin for shampoo containers.
- Regarding the value chain level and system boundary, methods of representation vary between those at the end-use level and those at the chemical product level for the topic of the entire value chain and for the system boundary part. In particular, differences in representation at the chemical product level between those for the topic of the entire value chain and those for the system boundary part might be perplexing.
- It is better to clearly indicate the selected level in the diagram of the value chain.

2) Degree of contribution

[1] About Table 2 in the Global Guidelines

- In the case of the chemical product level, if "Fundamental" is selected as the degree of contribution, a mismatch may occur with the specific contents of description of the degree of contribution ("The chemical product is the key component that enables the GHG emission avoiding effect by using the final product."), which might cause misunderstanding.
- Also, the translation into Japanese "Kansetsu Koken" (which means "indirect contribution" in Japanese) of the term "minor" may be regarded as indirect contribution that is used for an effect obtained by recycling, and the like. Also, in the English language as well, a term corresponding to indirect contribution exists ("Indirect") aside from "minor," and the Japanese translation may also be regarded as the term corresponding to it, which might result in misunderstanding that "indirect contribution" is small.
- The Japanese translation should elaborate on expressions. For example, the term "Hitsuyo Fukaketsu" (which means indispensable in Japanese) may also be construed as having the meaning of fundamental or essential. Another possible way of thinking might be that the portions indicating the degree of contribution shall not be translated, but shall be represented by numbers or the alphabet, thereby giving an indication that shows the order of priority to some extent.
- The term "Contribution" has two different meanings: (1) Contribution to reduction in CO_2 emissions; (2) Contribution for realizing the product to be assessed that enables reduction in CO_2 emissions (essential product/technology), and therefore it is thought that ways of using expressions that prevent confusion between them are important.

[2] About the judgment criteria for the degree of contribution

- The degree of contribution involves factors such that the portion to be marked with "○" may vary with the perspective. It becomes a problem if a different judgment is reached by each perspective.
- How about representing the evaluation of the degree of contribution of products by using two axes? Specifically, how about depicting the intermediate product through final product on the horizontal axis and describing the degree of contribution to emissions reduction on the vertical axis?

  Also, how about depicting contribution enabled by processes separately?

3) Others

[1] The Global Guidelines state in 3.3.4 that the typical duration of a reference period is one year. Perhaps the calculation of avoided emissions for each of the examples should be made on a per-year basis.

[2] About assessed examples overseas

Not only in the chemical industry, Japanese technologies and products play a very large role overseas, and therefore it is desirable that assessment should not be limited to that in Japan only, and more examples of chemical products that are in widespread use overseas/in the world as well as of Japanese chemical technologies should be described.

4) Individual matters

[1] Materials for solar power generation

- There is no diagram for the system boundary for utility power which is the product for comparison, and it is not clear whether an evaluation of equipment required for power generation has been made. In addition, in all the other examples the system boundary for products for comparison is stated clearly, and it needs to be stated clearly for solar power generation as well.
- In solar power generation, it is appropriate to assess the equipment required for the manufacture of electric power as well. This is also true of power generation such as thermal power generation, hydropower generation, nuclear power generation, etc. While on the other hand, in general, manufacturing equipment (plant and equipment for producing products) is not included in the object of assessment in LCA, although it may depend on the product to be assessed, or its assessment is often omitted. Actually in the other examples included in this report, manufacturing equipment is not included in the object of assessment. Hence, it is desirable that power generation should be regarded as a special case and this point should be clearly stated.
- In the sentence in 3. Product comparison, the following description is necessary, but it is appropriate that the description should not be included in 3., but should be included in some other place. "If the rate of electric power production by solar power generation increases, which is a mode of power generation that is likely to be affected by weather conditions, there may be a possibility that preparatory equipment and facilities will additionally be required in order to realize stable electric power supply. At the present stage, there are no examples of assessment of CO_2 emissions which was carried out bearing in mind such a mode of electric power supply in the future, and therefore in this example the comparison has been restricted to that of CO_2 emissions in the life cycles of solar power generation and utility power."

[2] Aluminum-resin composite window and thermal insulation materials

In the preceding chapter 1.6 for thermal insulation materials for housing, cLCA of housing that uses thermal insulation materials was carried out. Perhaps relations with this report should be described.

Regarding the examples of thermal insulation materials only and the examples of composite window & thermal insulation materials, partly because their chapters are provided successively, confusion may occur as to whether the effect of the window has been added to the effect of thermal insulation materials or whether evaluations were made independently from each other, and therefore it is better to avoid any possibility of misunderstanding.

For example, differences such as those given below, need to be described.

- Difference in boundary between the two (Tokyo and the entire Japan)
- Whether the effect of thermal insulation materials is incorporated into the calculation in the cLCA for the window frame (explanations should be made in an easy-to-understand way).

[3] Concentrated liquid detergent for cleaning clothes

- In order to realize contribution to reduction, cooperation from consumers is necessary, such as ensuring that the setting of "rinsing with water once" will be put into practice. Perhaps this point should also be described as a factor of uncertainty.
- Regarding the matters related to the stage of disposal of containers, calculation is made by referring to the PCR of the CFP system. Although it may depend on the unprocessed materials of containers, the ratio of incineration has increased in the PCR, and this is also a method of calculation in which the effect given by the recycling of container packages is not sufficiently reflected. Fundamentally, when carrying out life cycle assessment, the effect given by recycling should also be reflected.
  However, in this example, there is no problem because the result gives conservative values and transparency of the data is also ensured.

[4] Low-temperature steel plate detergent

"Fundamental" is selected as 6. Degree of contribution. On the other hand, in the column for the "Relations between chemical products and final products" in the table, the words "that enables the GHG emission avoiding effect by using the final product" are stated, but what is the final product?

[5] Shampoo container

Perhaps the calculation boundary for the amount of consumption of water resources in 11. should be different from the calculation boundary for GHG emissions.

How about describing the amount of water consumption at the container level by also creating a new item, if possible?

For example, it is better to include the item in Appendix, thereby stating clearly that such an item is evaluated separately from the evaluation of the calculation of GMG emissions.

(2) Response to the opinions

1) Level in the value chain

The level in the value chain was described in the 16 examples and presented to the experts. On the basis of the opinions given by reviewers, it has been decided to examine the following points as the problems to be addressed hereafter, and not to clearly state the level this time.

- Examination will be implemented so that reasonable explanations can be made on a wide range of examples, not only using the concept of the chemical product level and end-use level, but also giving explanations, etc. in the classification into unprocessed materials, parts, and processes.
- When the selection criteria for the level in the value chain have been clarified, the selected level will be clearly indicated in the value chain diagram.

2) Degree of contribution

The degree of contribution was described by using 16 examples and presented to the experts. On the basis of the opinions given by reviewers, it has been decided to examine the following points as the problems to be addressed hereafter, and not to clearly state the degree of contribution this time.

[1] Portion of the Japanese translation in Table 2 of the Global Guidelines

Expressions that match the contents of the "Degree of contribution of chemical products to value chain avoided emissions" will be reexamined.

[2] Judgment criteria for the degree of contribution

Judgment criteria will be clarified including the examination of the methods of indication of the degree of contribution in products and processes, and explanations will also be elaborated on so that the judgment criteria are easy to understand.

3) Others

[1] In the examples, avoided CO_2 emissions when the products expected to be manufactured in the year (2020) under assessment would have been used until the end of their life are evaluated. A description is given to that effect in 4.4 "Temporal and geographical standards" in each of the examples.

[2] From now on, efforts will be made to expand the examples that have already been published. The chemical industry has participated in the "Keidanren's Commitment to a Low-Carbon Society" that started in Fiscal Year 2013, and is engaging in work for the "Promotion of international contributions" as one of the four principal areas of activities. It is planned that examples of reduction in GHG emissions in the world by using Japanese products and technologies will also be reported in the " Commitment to a Low-Carbon Society."

4) Individual matters

[1] Materials for solar power generation

- Whether or not evaluation has been carried out concerning the equipment required for power generation has been stated clearly.
- The following has been described in the item of "10. Problems to be addressed."

  "If the rate of electric power production by solar power generation increases, which is a mode of power generation that is likely to be affected by weather conditions, there may be a possibility that preparatory equipment and facilities will additionally be required in order to realize stable electric power supply. At the present stage, there are no examples of assessment of CO_2 emissions which was carried out bearing in mind such a mode of electric power supply in the future, and therefore in this example the comparison has been restricted to that of CO_2 emissions in the life cycles of solar power generation and utility power."

[2] Aluminum-plastics composite window and thermal insulation materials
1.7Added sentences that describe the relations with 1.6 "thermal insulation materials for housing" as 10. in 1.7 "Aluminum-resin composite window and thermal insulation materials."

[3] Concentrated liquid detergent for cleaning clothes
In "9. Study Limitations and Future Recommendations," sentences concerning cooperation to be given by consumers have been added.

[4] Low-temperature steel plate detergent
Steel plate is assumed to be the final product. Note that with regard to the term "final product," "solution" is used in the original English text, and the "final product" has been used when translating the text into Japanese.

[5] Shampoo container
The calculation of the amount of consumption of water resources in the life cycle of shampoos has been described in Appendix.

6-3. Pending problems since the issuance of the first and second editions

(Opinions of the experts)

◆Concerning the avoided CO_2 emissions in 2020

The calculation of the avoided CO_2 emissions in 2020 was made on condition that the products under assessment were excluded. This method may be good for product comparison, but with regard to emission abatement as of 2020, it is thought that the present scenario is insufficient. How about examining a new scenario as a problem to be addressed hereafter?

(Response to the opinions)

Considering this issue as the problem to be addressed hereafter in JCIA's LCA WG, work will be performed while soliciting guidance from the experts as well.

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