Innovations for Greenhouse Gas Reductions

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

carbon Life Cycle Analysis (cLCA)

December 2012
Japan Chemical Industry Association (general incorporated association)

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Case Studies Employing Calculations Based on a Given Set of Conditions

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Introduction

This year marked the 20th anniversary of the 1992 Earth Summit. In June, the United Nations Conference on Sustainable Development (Rio+20) was held in Rio de Janeiro, Brazil, at the same venue that hosted the Earth Summit 20 years ago. The conference re-confirmed the importance of addressing climate change, and achieved a common understanding of the importance of an integrated approach that transcends the boundaries of regions, nations and industries in addressing climate change, in addition to the individual efforts in reduction that have been made so far.

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

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 the following roles with respect to measures to address climate change that are centered on a reduction in greenhouse gas emissions.

- The chemical industry has been reducing CO_2 emissions through improvements in energy efficiency, fuel switching, etc. despite the increase in production volume.
- The chemical industry contributes significantly to the reduction in CO_2 emissions in people's lives and other industries via the products and technologies it provides.
- The chemical industry is a "solution provider" (a provider of a method of settlement) that provides the products and technologies required to address climate change.

The Japan Chemical Industry Association (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. Also, 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.

Subsequent to these publications, JCIA is now ready to issue the second edition of the JCIA Report under the revised title of "Life Cycle Analysis of Chemical Products in Japan and around the World". The report contains ten examples of contributions made to the reduction in greenhouse gases in Japan and four examples from around the world. These examples include new examples and re-evaluated examples that were included in the first edition of the report that were re-evaluated according to the Guidelines for Calculating The Avoided CO_2 Emissions .

The scope of deployment for the guidelines prepared by JCIA is being expanded to include devising guidelines for global chemical sectors through ICCA as well as for the industrial fields around the world.

It is our hope that this report and the range of JCIA initiatives concerning the problem of global warming will lead to an 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 emission through a product's life cycle.

December 2012
Kyohei Takahashi, Chairperson, Japan Chemical Industry Association

高橋恭平

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 a revised edition of "Life Cycle Analysis of Chemical Products in Japan - carbon Life Cycle Analysis (cLCA)" issued in 2011, and addresses CO_2 emissions in GHG in the same manner as in the first edition. Sections 1-1, 1-2 and 1-3 describe the main points of the products of the chemical industry that have been published before, while Section 1-4 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 CO_2 emissions in other industries and in the entire society through the use of products. From this viewpoint, ICCA (International Council of Chemical Association) prepared a cLCA report by investigating the CO_2 emissions from chemical products in the world 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.

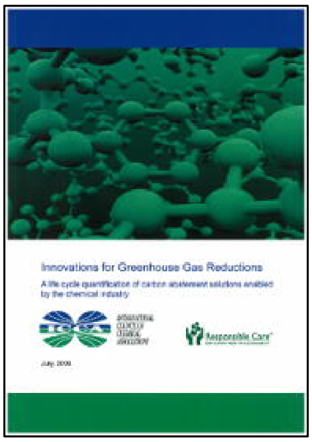

Fig. 1. ICCA Report

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 manufactured during the year under assessment were used until the end of their life. The year 2020 was taken as the year under assessment. To quantify the avoided CO_2 emissions in society resulting from the use of specific chemical products in Japan, nine examples for which data were available in Japan were analyzed based on the results of the evaluation in the first edition. The examples were in the fields of renewable energy and energy saving. Regarding the products evaluated, note that instead of making a comparison between the current products and the products expected to be in widespread use in 2020, a comparison was made with products that will have to be used when no chemical products are available.

As a result of these analyses, it was found that chemical products are key materials that contribute to the reduction of 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.

Fig. 2. JCIA Report

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.

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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.

1-3 JCIA Guidelines (February 2012)

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

The guidelines were prepared with a view to [1] presenting a 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.

Fig. 3. JCIA Guidelines

Overview of the Guidelines for Calculating the Reduction in CO_2 Emissions

◆ Purpose of and how to use the guidelines
◆ Definitions of terms
◆ Basic ways of thinking about assessment using cLCA (intermediate goods, final products)
◆ Method of calculating the reduction in CO_2 emissions (basic method, simplified method)
◆ Setting of various conditions for calculating the reduction in CO_2 emissions
  - Requirements for selecting the products for comparison (involving a different manufacturing method, involving a different alternative technology)
  - Specifying the scope of products that contribute to the reduction
  - Method of setting conditions, such as the market size, ratio of propagation, etc. of products under assessment (present, past, and future forecast)
  - Method of setting the year under assessment and the periods of production/use of products

◆ Transparency, reliability and validity of data
(Primary and secondary data, conditions for calculation concerning the stages of use of products, locality, typical data, and sources)
◆ Allocation of contribution
◆ Points to be noted when utilizing the reduction in CO_2 emissions and the degree of contribution to reduction
◆ Ensuring reliability of the results of calculation (confirmation of suitability)

1-4 Revised Edition of the JCIA Report (December 2012)

Based on the guidelines devised in February 2012, it was recently decided that a revised 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 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 into sources
As a result of continued investigations into 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] Inclusion of new examples
Japan: Materials for fuel efficient tyres; 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)

[3] Electric power emission factor as of FY2020 (at the power receiving end)

In the first edition, CO_2 emissions associated with the use of electricity were calculated by using as the electric power emission factor the target value of the Federation of Electric Power Companies of Japan, 0.33 kg-CO_2/kWh, as determined in the "Japan Business Federation - Action Plan for Achieving a Low-Carbon Society."

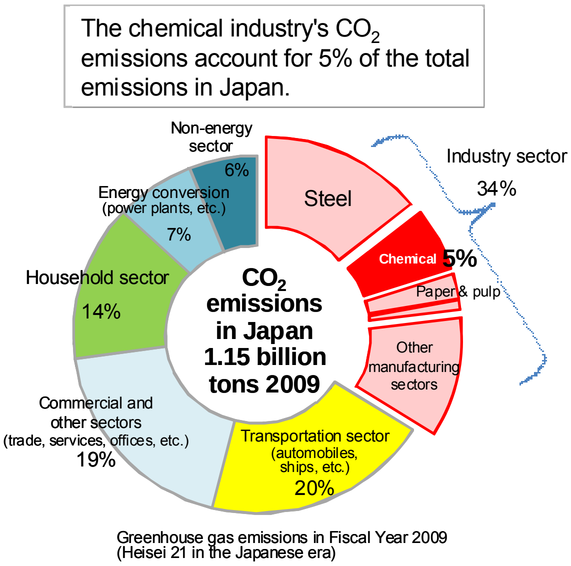
As an example, in the calculation of the avoided CO_2 emissions by the use of LED light bulbs, the CO_2 emissions in the usage stage of incandescent light bulbs, which are products for comparison, are obtained by multiplying the electric power used by the electric power emission factor. The result indicates that the contribution made by the electric power emission factor is substantial. Since this electric power emission factor is determined by the energy mix (electric power supplied by thermal power, nuclear power and renewable energy), the composition of power sources becomes important.

Since the first edition was issued, it is expected that the composition of power sources will change due to the Great East Japan Earthquake and associated accidents. It is believed, therefore, that a fundamental review of the target value of the electric power emission factor for Fiscal Year 2020 will be required. However, because the period for setting the target value to be reviewed is unknown and because, if the value of 0.33 kg-CO_2/kWh is used, the avoided CO_2 emissions is smaller than that obtained by using the value after a change in the composition of power sources when calculating the avoided CO_2 emissions, the said value has been used in the revised edition as well.

Through the first and second editions, it has been made clear that, 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 in society overall, aiming at contributing to reducing greenhouse gases, not only by reducing emissions during manufacture, but also by utilizing chemical technologies and products throughout the entire life cycle.

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 shocks, 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 caused during the manufacture of chemical products in Japan in 2009 were about 58 million tons, accounting for about 5% of the emissions in Japan overall (about 1.15 billion tons).



The chemical industry's CO_2 emissions account for 5% of the total emissions in Japan.

Greenhouse gas emissions in Fiscal Year 2009 (Heisei 21 in the Japanese era)

Fig. 4. CO_2 emissions by the chemical industry

3. The concept of cLCA (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. The differences are calculated as avoided CO_2 emissions by considering the differences as emissions that increase when assuming that the chemical products are not available.

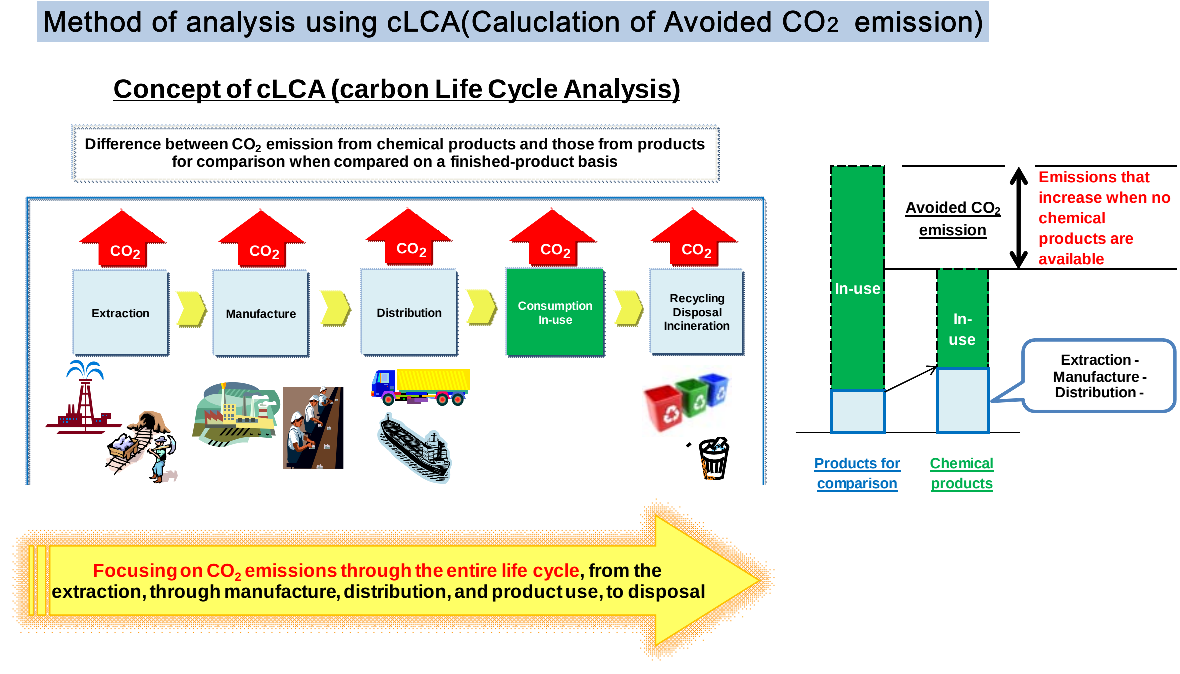


Fig. 5. Method of assessment using cLCA

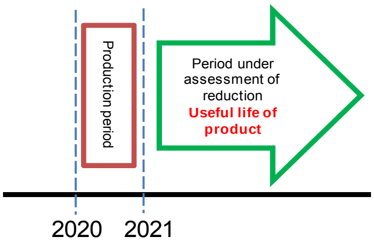
4. Summary of the examples of assessment of products to be manufactured in Japan in 2020

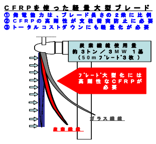
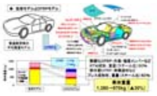
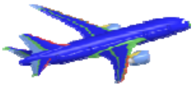
Period under assessment

Taking 2020 as the year under assessment, the avoided CO_2 emissions were evaluated when the products manufactured during the year under assessment were used until the end of their life.

Range of products under assessment contributing to the abatement effect

Chemical products contribute to the reduction in CO_2 emissions in finished products in various fields, such as the energy sector, transportation sector, consumer and household goods sectors, etc. in cooperation with other products related to raw materials and parts.



	Renewable energy		Energy-saving		
	Solar power	Wind turbine	Automobiles	Aircraft	Automotive tyres
Concept					
Functions/ advantages	Solar energy is converted directly into electricity by using the principle of semiconductors.	The generator is turned directly by the wind. Large high-rigidity blades made using carbon fiber.	Carbon fiber is used to reduce weight while maintaining the same levels of performance and safety.	Same as at left	Fitted to an automobile to reduce rolling resistance on the road surface
Products under assessment (finished products that incorporate chemical products)	Multicrystalline silicon solar cells	Wind turbines made from plastics reinforced with carbon fiber	Automobiles that use plastics reinforced with carbon fiber	Aircraft that use plastics reinforced with carbon fiber	Fuel efficient tyres • For passenger vehicles (PCR) • For trucks and buses (TBR)
Products for comparison (finished products using products for comparison)	Utility power	Utility power	Conventional automobiles	Conventional aircraft	Non fuel efficient tyres
Abatement effect	No CO_2 is emitted because fossil fuels are not used.	Same as at left	Weight reduction improves fuel consumption and reduces fuel consumption.	Same as at left	Improved automotive fuel consumption by reducing rolling resistance
Life of finished products	20 years	20 years	10 years	10 years	PCR 30,000 km TBR 120,000 km
Production volume	1,760,000 kW	150 units	15,000 units	45 units	PCR 73 million units. TBR 5 million units.
Finished products: emissions from raw materials, manufacture, and disposal (tons) "( )" shows emissions from chemical products *	–	–	Automobiles 93,000	Aircraft 176,000	Tyres 3.19 million
	Si, etc. (1.29 million)	Carbon fiber (9,000)	–	–	Synthetic rubber, etc. (1.74 million)
Avoided CO_2 emissions (tons)	▲8.98 million	▲8.54 million	▲75,000	▲1.22 million	▲6.36 million
Total	**The avoided CO_2 emissions when the products manufactured during 2020 are used until the end of their life**				

* CO_2 emissions during procurement of raw materials through manufacture to disposal (excluding the usage stage): 6.37 million tons as a total for six items

Avided CO_2 Emissions
The results of assessing the ten examples here clearly show that chemical products are key materials that contribute to about 130 million tons in reduced emissions[1] until the end of their life.
Each of these examples leads us to understand that chemical products or finished products that incorporate chemical products contribute to reducing CO_2 emissions that exceed the emissions of such chemical products or finished products themselves.

Energy-saving				Resource-saving
LED light bulbs	Thermal insulation materials for housing	Air conditioners	Piping materials	Apartments
				
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.	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.	Increases the strength and durability of reinforced concrete.
LED light bulbs	Foamed thermal insulation material, Polyurethane, Polystyrene	Inverter air conditioner (Hall effect devices as their parts)	PVC pipes	High-durability apartments to which agents have been added to reduce shrinkage during drying
Incandescent light bulbs	Housing before the energy-saving standard of 1980 (housing that does not use thermal insulation materials)	Non-inverter air conditioners	Ductile cast iron pipes	Ordinary apartment to which water-reducing agents have been added
Long service life and low power consumption.	Reduces power consumption for cooling and heating by improving thermal insulation performance.	Reduces power consumption by increasing energy efficiency.	Low energy consumption because high temperatures are not used during manufacture.	Improves durability by suppressing cracking when the concrete is drying.
10 years	Detached houses: 30 years Apartments: 60 years	14.8 years	50 years	100 years
28 million units	Detached houses: 367,000 units Apartments: 633,000 units	7,460 units (Number of air conditioners)	493,092 tons	61,000 units
LED light bulb: 92,000	–	–	–	Apartments: 16.55 million
–	Thermal insulation materials (2.35 million)	–	PVC pipe (740,000)	Drying and shrinkage agent, etc. (240,000)
▲7.45 million	▲76 million	▲16.4 million	▲3.3 million	▲2.24 million
The avoided CO_2 Emissions (calculated by specifying a certain set of conditions[2]): ▲130.57 million tons				

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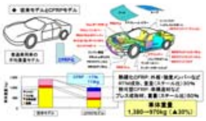
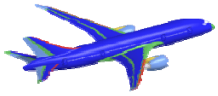
[1] Reference: CO_2 emissions in Japan in Fiscal Year 2009 1.15 billion tons (Fig. 4)
[2] Preconditions for calculation are clearly stated in the explanatory sentences for each of the examples.

5. Summary of the examples of assessment of products to be manufactured in the world in 2020

The global avoided CO_2 emissions (potential) was calculated resulting from the use of chemical products that are 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	Automobiles	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 is used to reduce weight while maintaining the same levels of performance and safety.	Same as at 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 (finished products that incorporate products for comparison)	Evaporation process	For non-inverter air conditioners	Conventional automobiles	Conventional aircraft
Abatement effect	Low energy consumption because no heating is required.	Reduces power consumption by increasing energy efficiency.	Weight reduction improves the fuel consumption and reduces fuel consumption.	Same as at 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 conditioning units)	300,000 units	900 units
Finished products: emissions from raw materials, manufacture, and disposal (tons) "( )" shows emissions from chemical products	Desalination plants: 1.5 million	–	Automobiles: 1.86 million	Aircraft: 3.51 million
	–	–	–	–
Avoided CO_2 emissions (tons)	▲170 million	▲189.95 million	▲1.5 million	▲24.3 million
Total	**The avoided CO_2 emissions when the products manufactured during the one year of 2020 are to be used until the end of their life (calculated by specifying a certain set of conditions[Note]): ▲3 85.75 million tons**			

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.

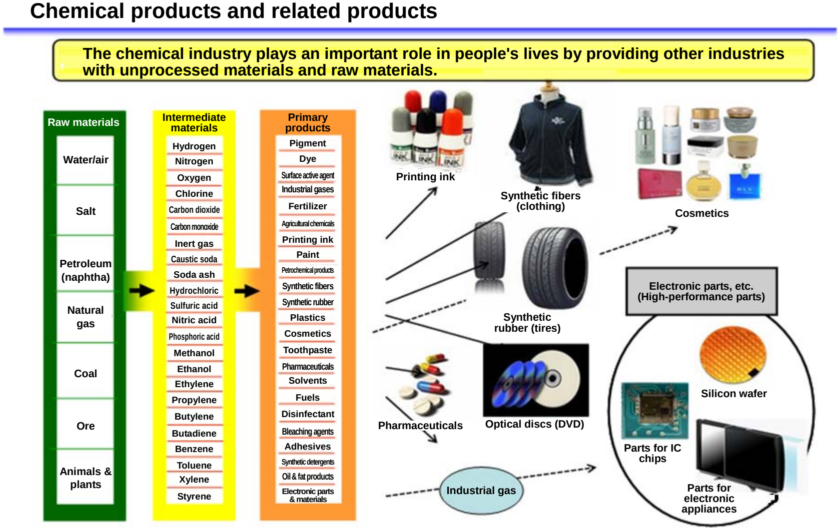


Fig. 6. The chemical industry that supports everyday life and industries

1.2 Features of the chemical industry in Japan (overview as of 2010)

[1] The first industry in added value ranking, of all manufacturing industries in Japan
[2] Employs 880,000 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 1. 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	289.1	90.7	766.4	1,183
Entire chemical industry (Ratio to total for manufacturing industries)	40.1 14%	15.4 17%	88.2 11%	1,741
Entire electric/information/electronics	44.3	14.3	114.9	1,243
Transportation machinery & equipment manufacturing industry	54.2	13.7	94.9	1,439
General machinery & equipment manufacturing industry	30.6	11.5	108	1,067

Source: "Industrial Statistics Tables" of the Ministry of Economy, Trade and Industry; "Investigative Research on Science and Technology" of the Ministry of Internal Affairs and Communications; "Financial Statements Statistics of Corporations by Industry" of the Ministry of Finance

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 areas of commercial, transportation, household, etc. The chemical industry's position in the industry sector is second after the steel industry, as shown in Fig. 4 above, with its emissions accounting for 5% of Japan's total emissions.

(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 industry 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.

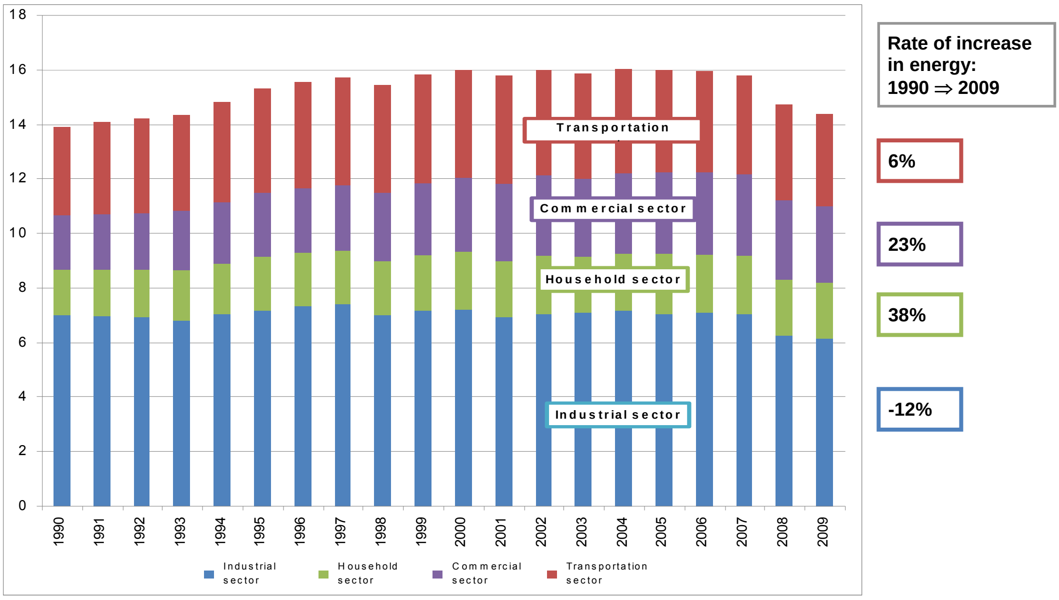


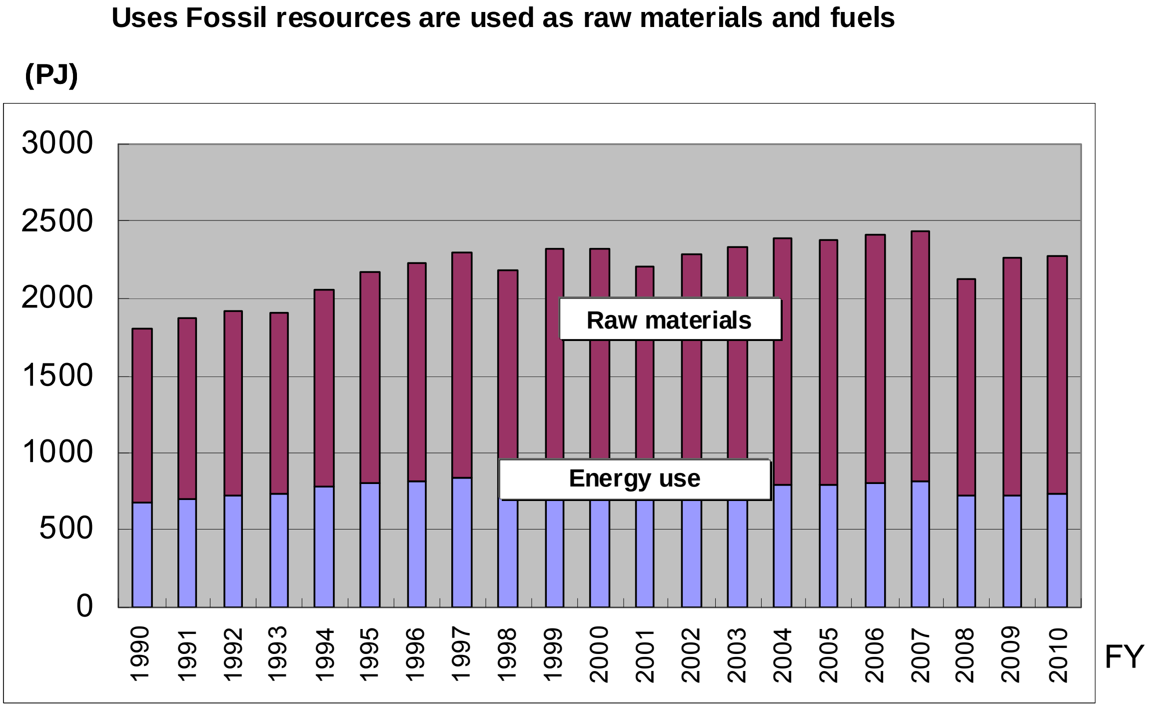
Fig. 7. Changes in the amount of energy used in each sector

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 such as ethylene 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.

Change in Final Energy Consumption of the Chemical Industry



Source: Ministry of Economy, Trade and Industry and Agency for Natural Resources and Energy: "Records of Energy Supply and Demand for Fiscal Year 2010"

Fig. 8. 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 reduced to about half by 1990. Theintensity for electricity for caustic soda showed an improvement of about 30%.

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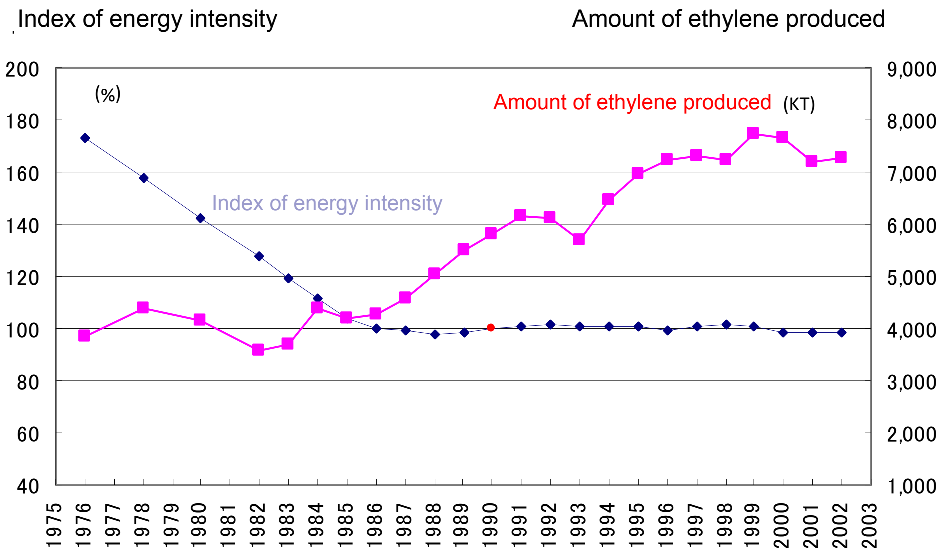
[3] Ministry of Economy, Trade and Industry and Agency for Natural Resources and Energy: "Records of Energy Supply and Demand for Fiscal Year 2010"
http://www.enecho.meti.go.jp/info/statistics/jukyu/result-1.htm

Record of achievement by energy-saving activities [1]

(Change in the production amount of ethylene and energy efficiency in Japan)

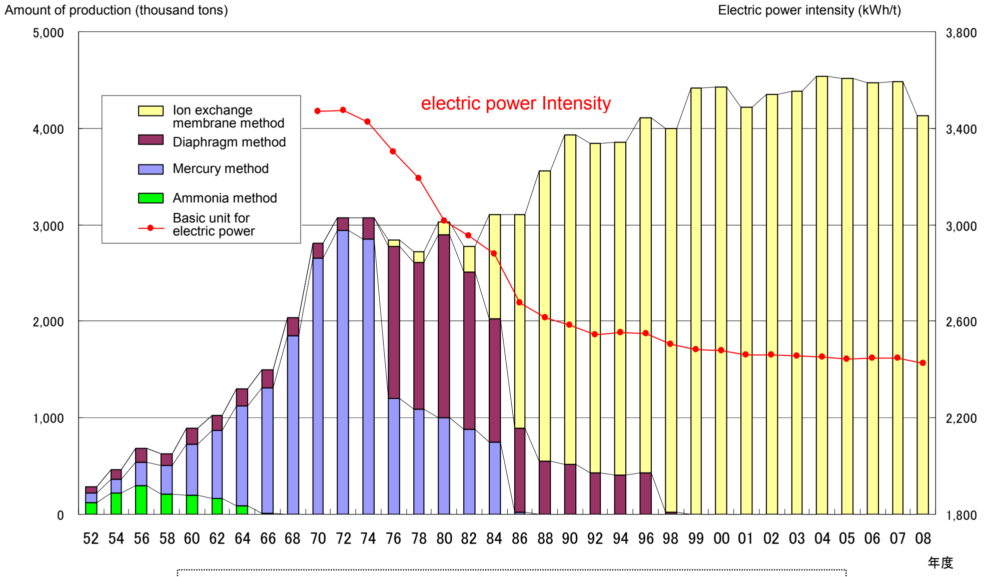


By 1990, achieved improvements in which energy intensity was reduced roughly by half

Source: NEDO’s Investigational Material for 2003

Record of achievement by energy-saving activities [2]

Change in the amount of caustic soda produced according to each manufacturing method and electric power intensity in Japan



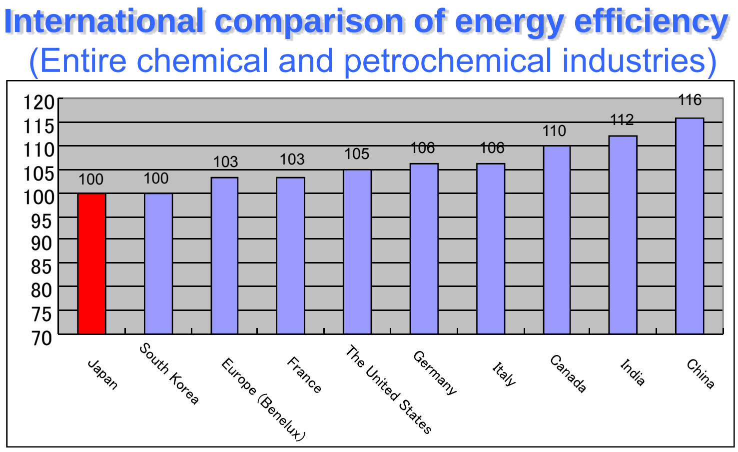
By 1990, the ielectric power intensity f was improved by about 30%, and at the same time in 1999, almost 100% was switched to the ion exchange membrane method, which was the state-of-the-art technology

Fig. 9. 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 the 1970s. 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.

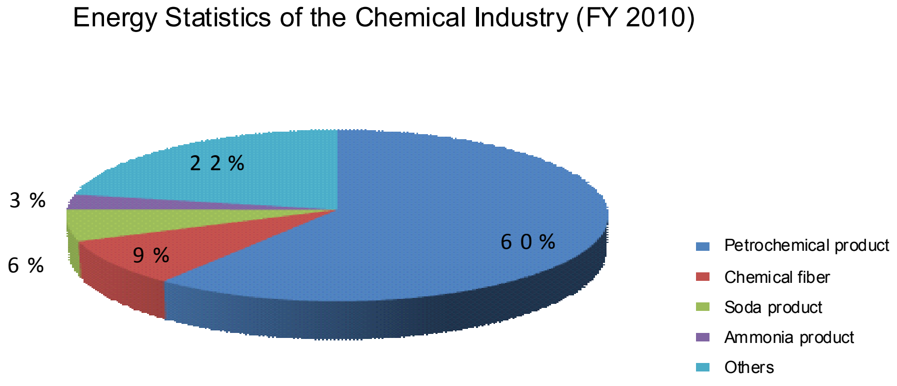


Source: IEA Energy Efficiency Potential of the Chemical & Petrochemical sector by application of Best Practice Technology Bottom up Approach -2006 including both process energy and feedstock use -

Fig. 10. International comparison of energy efficiency in the chemical industry

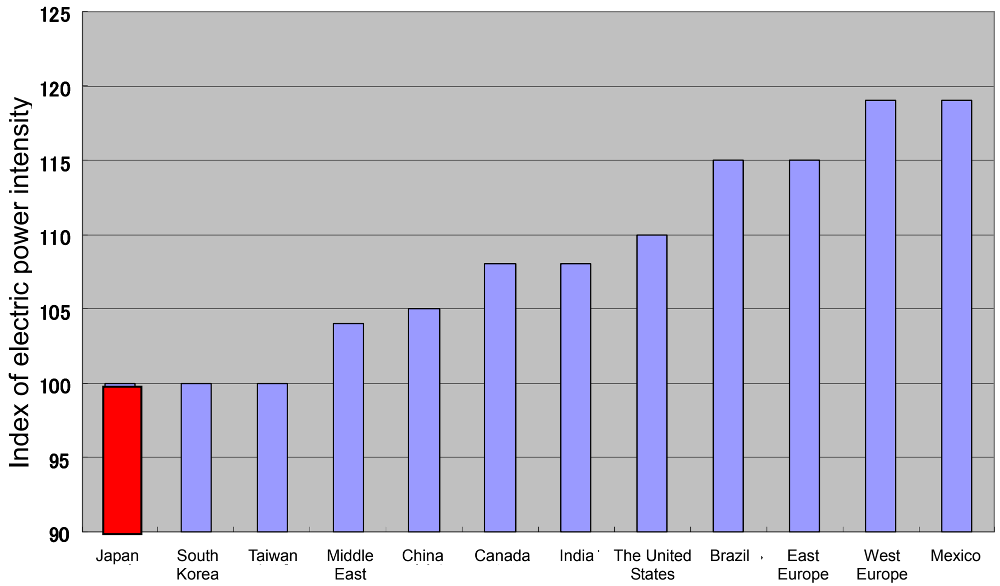
International comparison of the energy efficiency of each product

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.



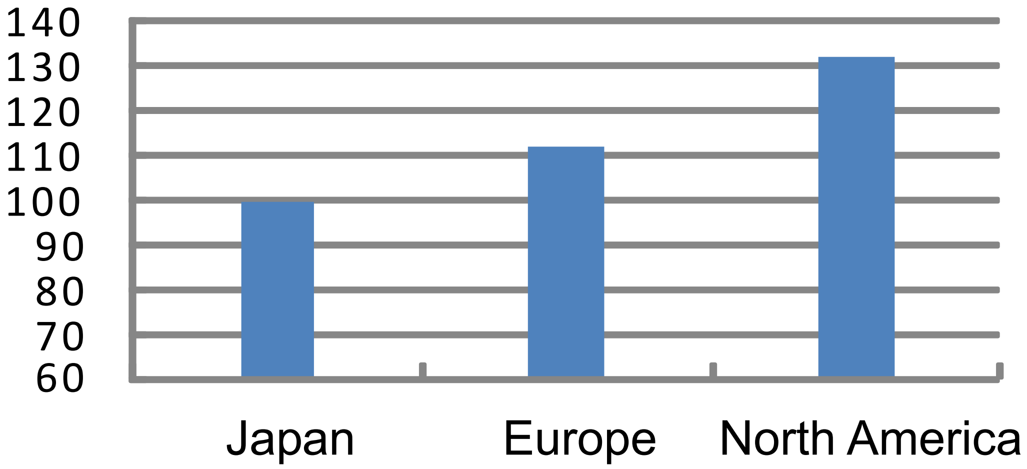
1) Energy Balance Table, source: Ministry of Economy, Trade and Industry, Agency for Natural Resources and Energy

Fig. 11. Details of energy consumption in the chemical industry in each sector (FY2010)



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

Fig. 12. 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 affiliation of the OECD))

Fig. 13. 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 attain the highest level in the world (more specifically, building energy-saving process technologies for ethylene crackers), [2] achieving the best fuel mix, [3] making effective use of waste, [4] using renewable energy, such as biomass

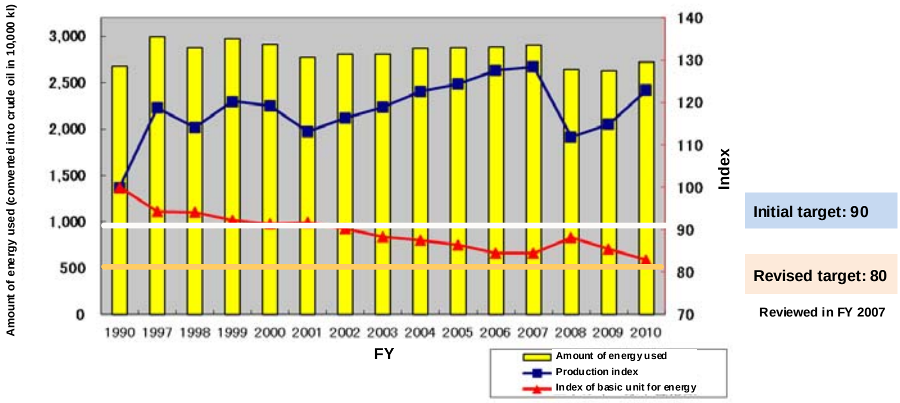
(4) Chemical industry - efforts to reduce greenhouse gas emissions through voluntary action

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 "Japan Business Federation - Voluntary Action Plan on the Environment" at the beginning of FY1997, engaging in work to improve the index of basic unit for energy, and achieved its initial target in FY2002. In FY2007, the non-binding target value was reviewed, and concerted efforts are still being made to achieve the target.

Record of Achievement by the Voluntary Action Plan on the Environment [1]

Changes in the amount of energy used, index of energy intensity, and production index



Initial target was attained ahead of schedule. Efforts are being made toward a further ambitious target.
Revised target: The target can become 87% if any factor of deterioration of the energy intensity has become apparent in future.

Fig. 14. 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 2010 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.

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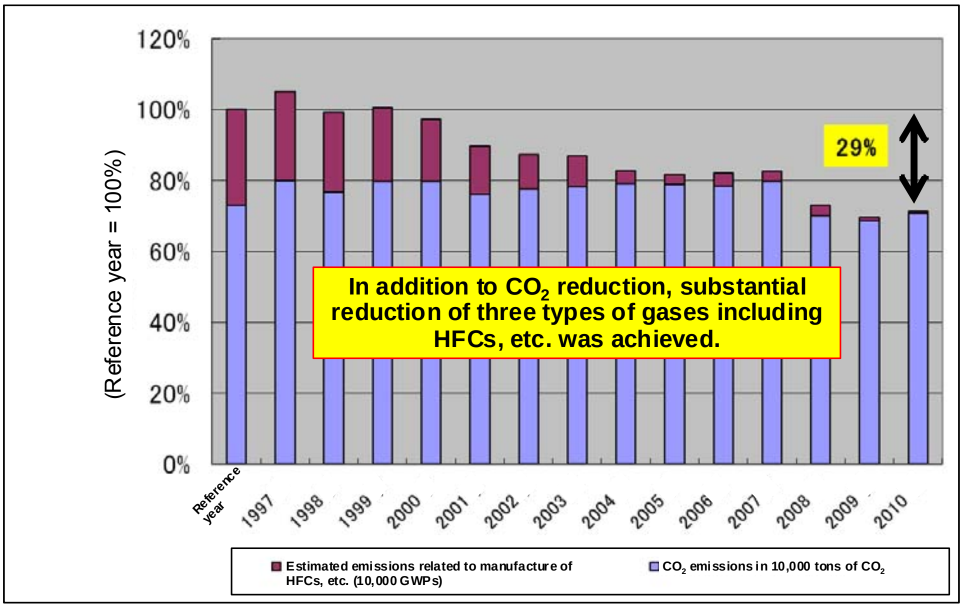
[4] HFCs (hydrofluorocarbons), PFCs (perfluorocarbons) and SF_6 (sulfur hexafluoride).

Track Record of Voluntary Action Plan on the Environment [2]

CO_2 emissions originating from energy & emissions of three types of gasses including HFCs, etc. as converted to GWP



In addition to CO_2 reduction, substantial reduction of three types of gases including HFCs, etc. was achieved.

Note) Reference year for emissions of HFCs, etc: 1995; Reference year for CO_2 emissions: 1990

Fig. 15. 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. It compares emissions over the life cycle of finished products that use chemical products with those of finished products that use products for comparison, and calculates the difference between them as avoided emissions by regarding the difference as emissions to be increased when assuming that the chemical products are not available.

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.

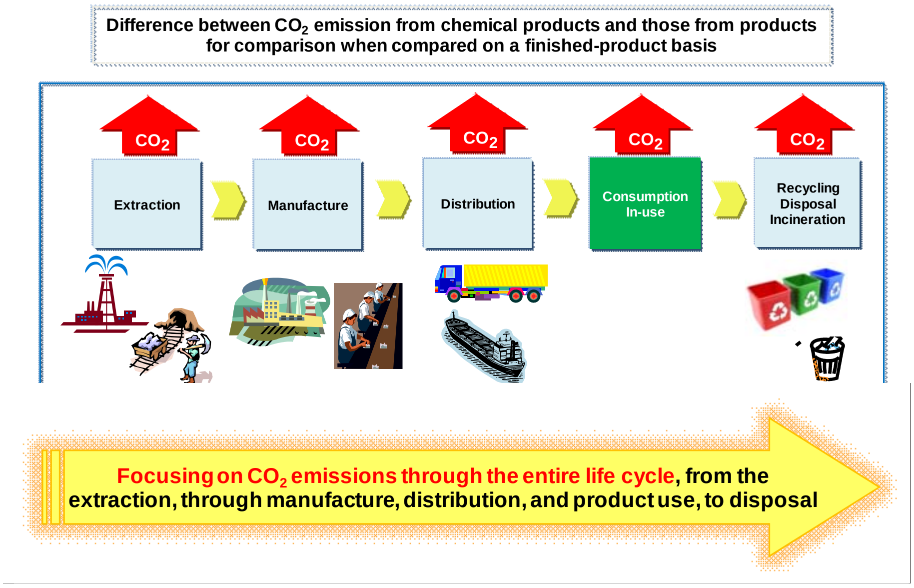


Fig. 16. Concept of cLCA

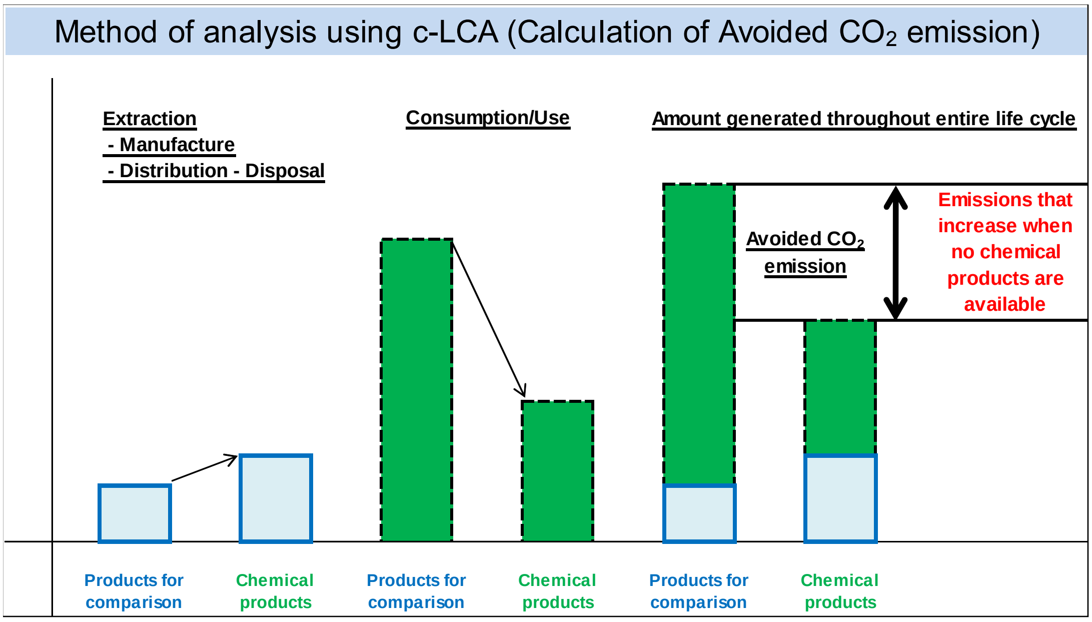


Fig. 17. Method of assessment using cLCA

2.2 cLCA Report of ICCA[5]

(1) Purpose and overview

When striving to reduce CO_2 emissions globally, it is no longer sufficient to save energy and reduce CO_2 emissions during manufacture, which have been the focus up to this point. It has become important to strive to avoid CO_2 emissions in society as a whole through the development and propagation of products that lead to a reduction in CO_2 emissions in the consumer sector, commercial sector and other sectors.

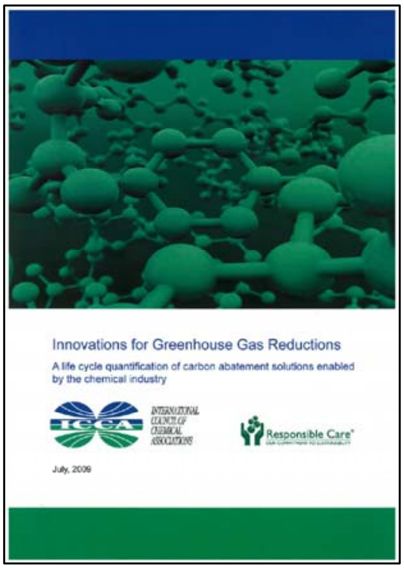
In a context such as this, ICCA published a cLCA report entitled "Innovations for Greenhouse Gas Reductions" in July 2009 as a means of highlighting the situation and calling for action to help reduce CO_2 emissions from a new perspective that provides a bird's eye view of the entire life cycle, from the procurement of raw materials, through manufacture, distribution and consumption, to recycling/disposal. The cLCA herein means a comparison of the GHG emission, 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

Title of the Report's Japanese translation: "New Perspective Toward Greenhouse Gas Reductions"



Innovations for Greenhouse Gas Reductions

A life cycle quantification of carbon abatement solutions enabled by the chemical industry

July, 2009

Fig. 18. **ICCA Report**

(2) Result of assessment for 2005

Global CO_2 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 exceeding the majority 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 have a strong greenhouse effect.

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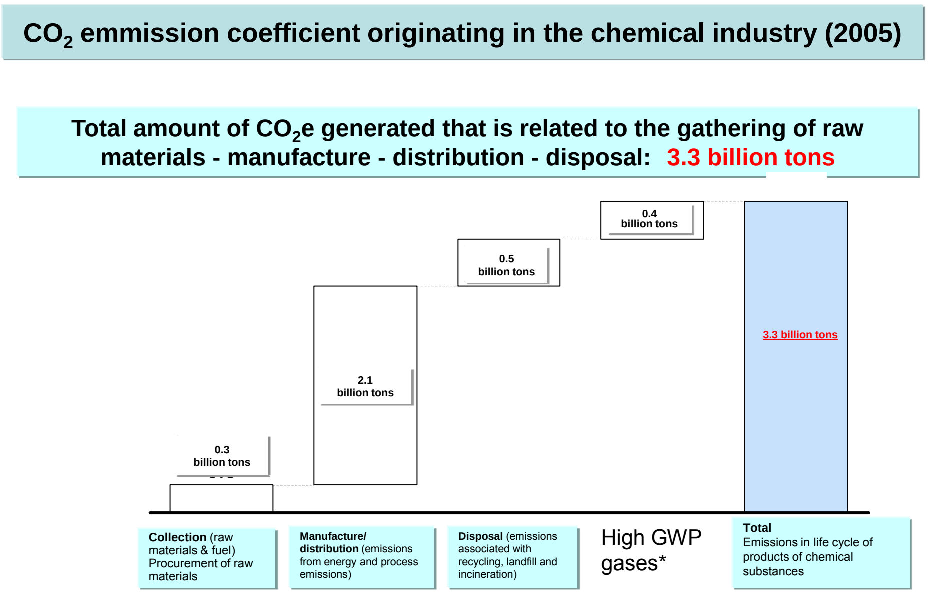
[5] International Council of Chemical Associations


CO$_2$ emmission coefficient originating in the chemical industry (2005)

Total amount of CO$_2$e generated that is related to the gathering of raw materials - manufacture - distribution - disposal: 3.3 billion tons

* HFC-23, HFC-32, HFC-125, HFC-134a, HFC-143a, HAFC-1521, HFC-227ea, HFC-236fa, HFC-4310mee, CF$_4$, C$_2$F$_6$, C$_4$F$_{10}$, C$_6$F$_{14}$, SF$_6$; GWP factors according to IPCC 1996

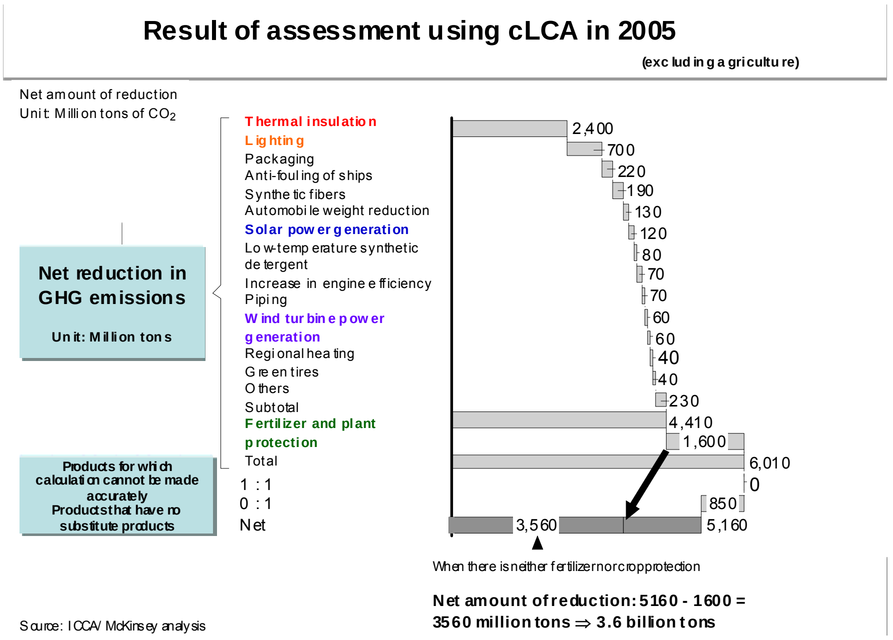
Source: IEA, EPA, IPCC, WEF ("Contribution of the chemical industry to greenhouse-gas reduction" December 2007), McKinsey analysis

Fig. 19. 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.).


Result of assessment using cLCA in 2005

(excluding agriculture)

Net amount of reduction: 5160 - 1600 = 3560 million tons ⇒ 3.6 billion tons

Source: ICCA/ McKinsey analysis

Fig. 20. Net emission abatement in 2005

(3) Result of evaluation for 2030

Expected global CO_2 emissions in the chemical industry

Emissions in the BAU case (business-as-usual: a case in which the present regulations and lifestyle remains 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).

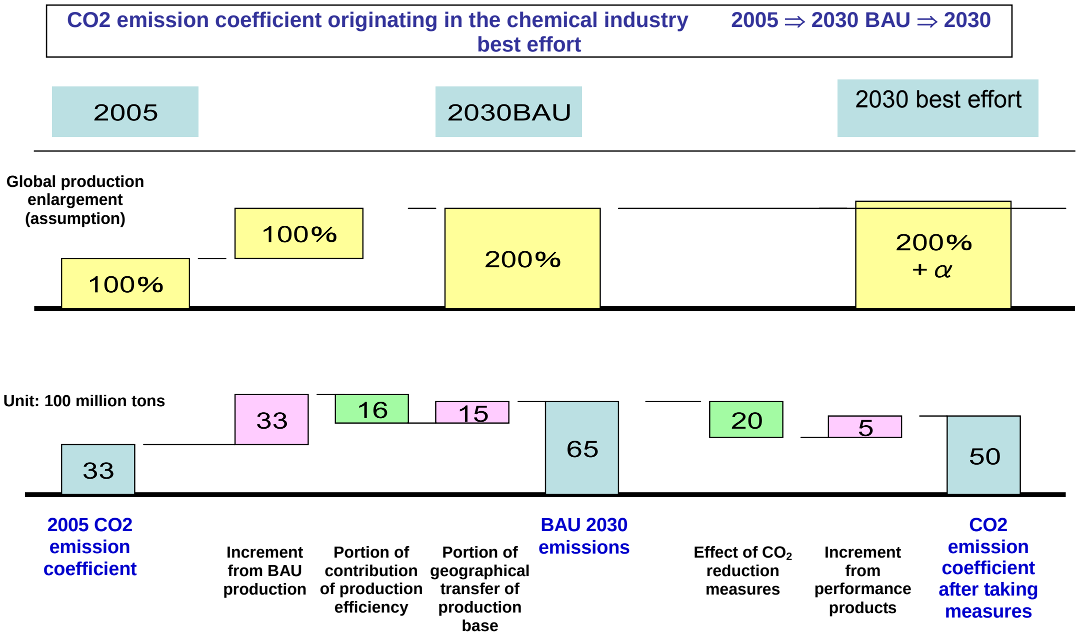
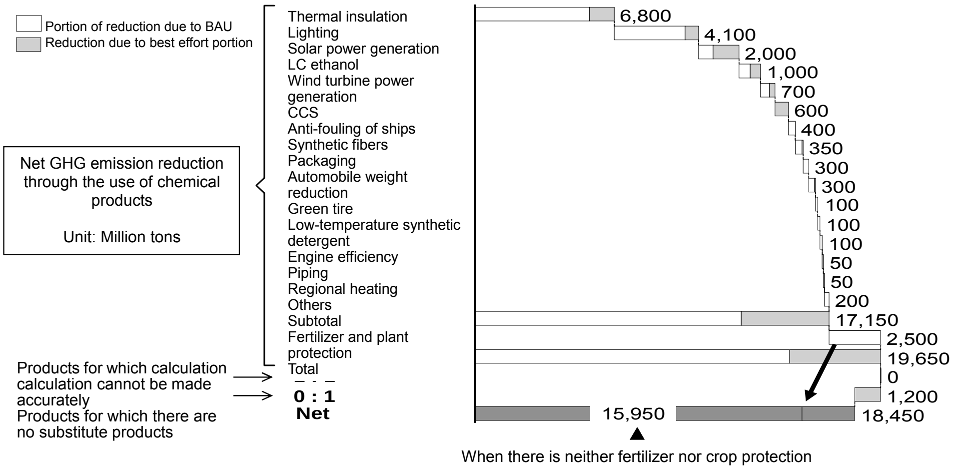


Fig. 21. CO_2e emissions originating from the chemical industry in 2030

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).

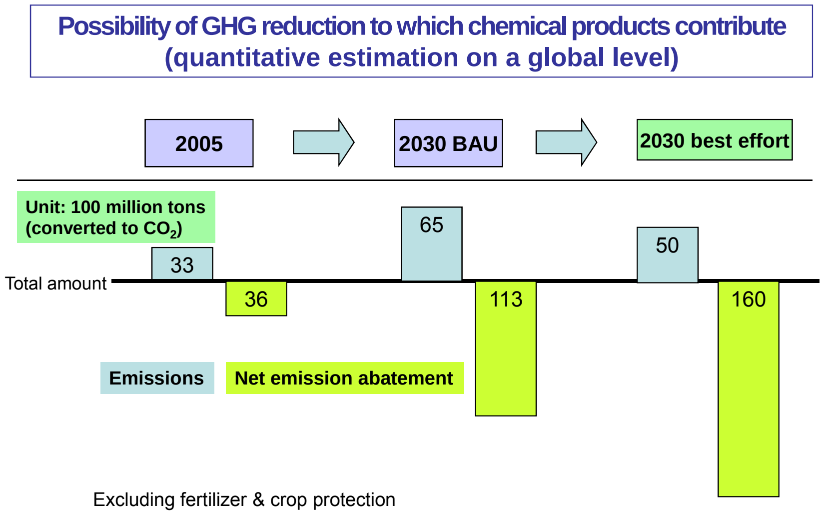
Global anthropogenic GHG emissions in 2005 are estimated to have been around 46 billion tons (WEF 2007[6]), and a net reduction of 16 billion tons translates into about 1/3 of such emissions.



Net reduction including agriculture: 18.45 billion tons
Net reduction excluding agriculture: 18.45 - 2.5 = 15.95 billion tons ⇒ 16 billion tons

Fig. 22. Net emission abatement in 2030 (on a best-effort basis)

"Summary"



Excluding fertilizer & crop protection

Source: Innovations for Greenhouse Gas Reductions By ICCA
ICCA: International Council of Chemical Associations

Fig. 23. Summary of emissions and net emission abatement originating from the chemical industry in 2030

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[6] World Economic Forum 2007 (commonly known as Davos Forum)

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. The present report 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** in 2020 have been quantified.

While the first edition dealt with eight examples in Japan and one example from overseas, for which LCI[7] data were published and for which supporting data were available, the revised edition has increased the number of examples to include ten examples in Japan and four examples from overseas. We will continue to contribute to all industries hereafter as well, in order to realize a low-carbon society through the provision of chemical products and technologies, thereby showing the direction for society as a whole with respect to the policies on the reduction in emissions.

3.2 Object of assessment

The following 14 examples have been adopted as objects of assessment using cLCA, as they meet the following two conditions: [1] LCI data are available and [2] they are believed to yield large avoided CO_2 emissions through the use of chemical products.

The products to be assessed are based on present products/technologies as of 2010. Products that are expected to be in widespread use by 2020 as the result of technical advancements are not considered as the object.

Also, the object of comparison is the products that have to be used if no chemical products are available. The emission abatement has been calculated by multiplying the value obtained based on this assumption by the expected volume manufactured as of 2020.

Note that the emission abatement includes both the portion of chemical products and the portion of products related to other raw materials and parts as well. However, no technique is currently available for making a quantitative distinction between the portion for chemical products and the portion for non-chemical products. Therefore, distribution of the emission abatement to each constituent product has not been done.

Fig. 19 and Table 2 show the 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.

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

Examples of Assessment in Japan

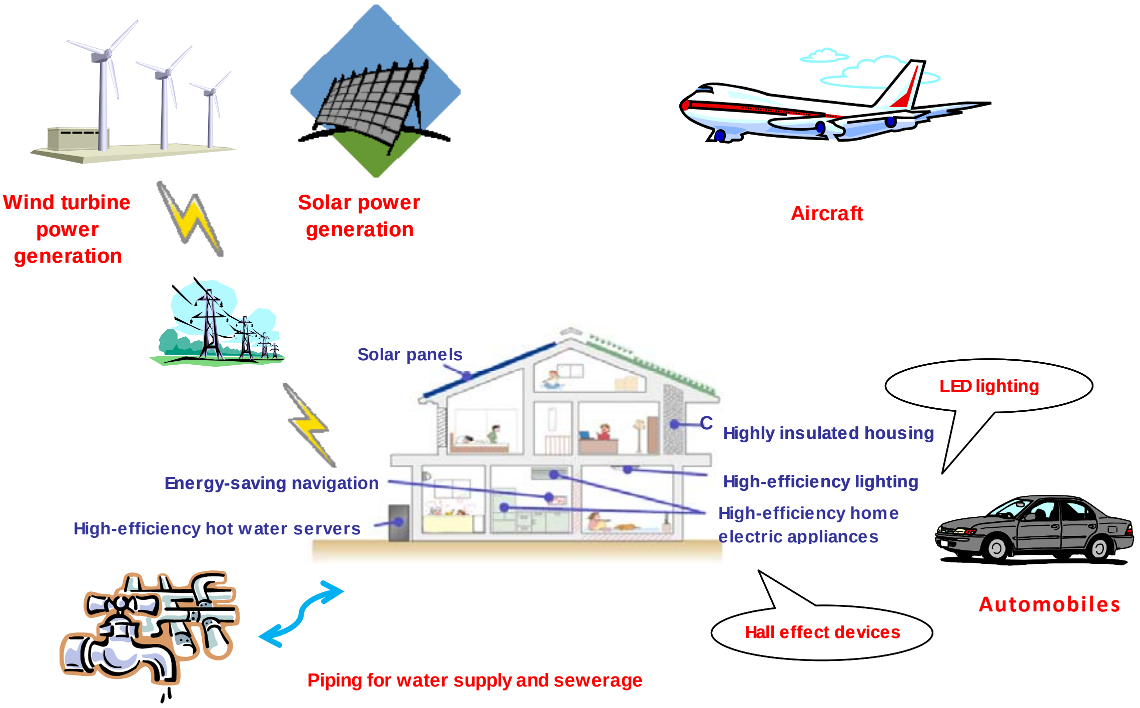

Fig. 24. Diagrams of the products to be assessed

Table 2. List of products to be assessed

◆ Japan

Classification	Chemical product	Product to be assessed	Product for comparison
Renewable energy	Materials for solar power generation	Equipment for solar power generation	Utility power
	Materials for wind turbines	Equipment for wind turbines	Utility power
Energy-saving	Automotive materials	Automobiles that uses carbon-fiber-reinforced plastics (CFRPs)	Conventional automobiles
	Materials for aircraft	Aircraft that use carbon-fiber-reinforced plastics (CFRPs)	Conventional aircraft
	Materialsfor fuel efficient tyres	Fuel efficient tyres	Non fuel efficient tyres
	LED-related materials	LED light bulbs	Incandescent light bulbs
	Thermal insulation materials for housing	Housing (that uses thermal insulation materials)	Housing before the energy-saving standard of 1980 (not using thermal insulation materials)
	Hall effect device, Hall effect ICs	Inverter air conditioners	Non-inverter air conditioners
	Piping materials	PVC pipes	Ductile cast iron pipes
Resource-saving	Materials for high-durability apartments	High-durability apartments	Ordinary apartments

◆ Global

Classification	Chemical product	Finished product	Product for comparison
Energy-saving	Materials for desalination plants	Desalination plants (RO membranes)	Desalination plants (evaporation process)
	Hall effect devices, Hall effect ICs	Inverter air conditioners	Non-inverter air conditioners
	Automotive materials	Automobile that uses carbon-fiber-reinforced plastics (CFRPs)	Conventional automobiles
	Materials for aircraft	Aircraft that uses carbon-fiber-reinforced plastics (CFRPs)	Conventional aircraft

3.3 Ways of thinking about the period under assessment

1. **Evaluate avoided CO_2 emissions when the products manufactured in the year under assessment 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, for the total number of product units that will be in widespread use and put into operation until the year under assessment.

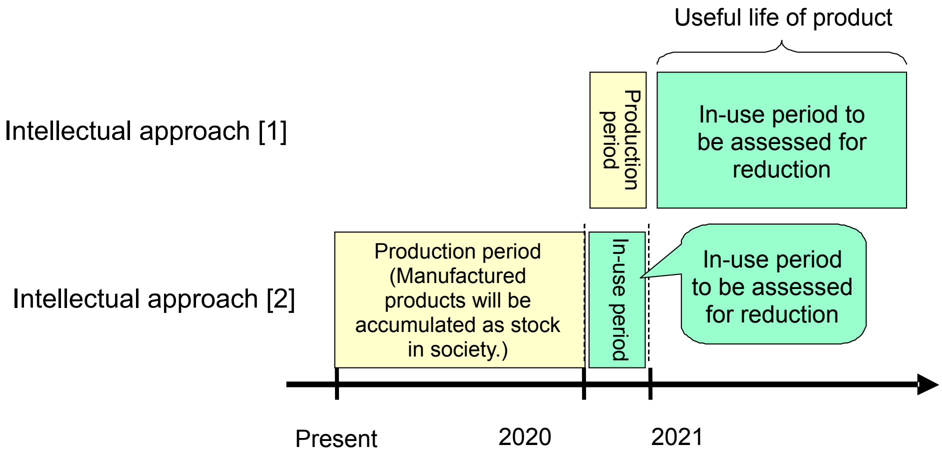

Fig.25. Two ways of thinking about the period under assessment

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.

3.4 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 is 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 being assessed – CO_2 emissions over the life cycle per unit quantity of the product for comparison = A

Step 2: Calculate the avoided CO_2 emissions by multiplying A by the quantity of the products under assessment 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)

4. Examples of assessment (The avoided CO_2 emissions calculated by specifying a certain set of conditions)

4.1 Renewable energy 1 – materials for solar power generation

(1) Overview of solar power generation

A solar cell is a device that directly converts the energy from the sun into electrical energy by utilizing the principle of a semiconductor. A solar power generation system consists of this solar cell and the power conditioner that converts electricity from direct current to alternating current, together with the platform for installing solar cells on the roof and others devices.

A solar power generation system can generate power in any location, and this attribute enables the size to be selected freely. It is also possible to install the system in an ordinary house, so more widespread use is expected. Environmental problems such as the depletion of fossil fuels and global warming are becoming apparent, and there are great expectations for solar power generation to become an important technology for solving these problems.

[1] The avoided CO_2 emissions

No CO_2 is emitted during power generation because no fossil fuels are used.

[2] Types and features of solar cells

- Crystalline silicon based: Mainstream at present. High conversion efficiency is achieved. The largest in distributed quantity.
- Silicon thin-film based: Low cost
- Compound semiconductor based: No silicon is used. Further cost reduction and improvement in conversion efficiency are expected.

[3] Power generation efficiency (efficiency of conversion from solar energy into electrical energy)

- Present: Efficiency of crystalline silicon based module: up to around 16%[8]
- Future: Target for 2025 - NEDO Technology Development Road map

Crystalline silicon based	25%
Compound based	40%

[4] Amount of solar energy delivered in Japan

- FY2009: About 1.7 million kW[9]
  Details According to destination: Overseas … about 1 million kW,
  Japan … about 0.7 million kW
  According to type: Total of multicrystalline and monocrystalline silicon …
  1.46 million kW (90% of the total amount delivered)
- Cumulative amount introduced until 2007: Global … 7,841 MW, Japan … 1,919 MW

[5] Examples of chemical products used in solar power generation systems

Of the materials that constitute the module of a solar cell, multicrystalline silicon, a back seat (resin) and a sealing material (resin) are the major chemical products, and these materials have been used as the object of calculation.

- Multicrystalline: Si, Si wafer, SiH_4 gas
- Sealing materials for solar cells (ethylene vinyl acetate copolymer, phenolic resin)
- Back seat for solar cells (polyvinyl fluoride, PET)
- Various types of chemicals (detergent, resist stripper)
- Diethylzinc, BCl_3, CVD materials
- Ceramic printed circuit boards and heat sinks for inverters

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[8] New Energy and Industrial Technology Development Organization (incorporated administrative agency): Report on the Review and Study Committee Concerning the "Solar Photovoltaic Generation Roadmap toward 2030 (PV2030)" (Solar Power Generation Roadmap PV2030+) (June 2009)

[9] Japan Photovoltaic Energy Association, Shipment volume of solar cells (May 2011) http://www.jpea.gr.jp/04doc01.html

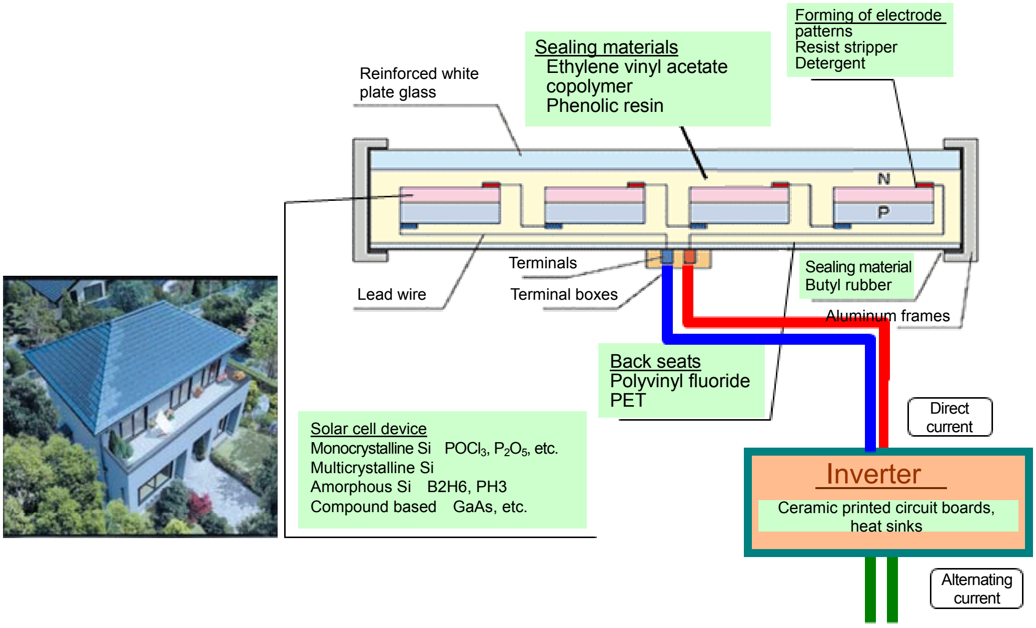

Fig. 26. Example of construction of a solar power generation system

(2) Conditions of assessment

[1] Object of assessment and object of comparison

Item	Contents
Chemical products/technologies that help reduce CO_2 emissions	Materials for solar power generation
Product under assessment	Multicrystalline silicon solar cell
Product for comparison	Utility power (power source mix with thermal power, nuclear power, hydropower, etc. Based on average composition in power generation plants in Japan)
Year under assessment / period under assessment	Year 2020 / period in which the products manufactured during the year under assessment will be used until the end of their life

[2] System boundary (scope of assessment that has been carried out)

With regard to solar power generation, all the emissions are included from raw materials, through manufacture, usage, and maintenance (replacement of parts) to disposal by using multicrystalline silicon solar cells. Regarding disposal, it has been assumed that from the dismantled/collected solar cell module, the aluminum frame and terminal box (including the cables for wiring) are to be removed and recycled by a recycling service provider. Other modules are to be treated as industrial waste. After intermediate treatment, those that can be recycled will be recycled, and those that cannot be recycled will be finally disposed of in landfill.

With regard to utility power, all the emissions are included from power generation systems using the power source mix and from raw materials, through manufacture, usage, and maintenance (replacement of parts) to disposal for fuel production, fuel transportation, and waste disposal.

[3] Functional unit

- Functions of a solar power generation system and utility power, each of which generate 1 kWh of power

[4] Preconditions for calculating emission abatement

- CO_2 emission factor (amount of CO_2 emitted per kWh of power generated)
  Solar power generation: 0.047 kg-CO_2/kWh[10]
  Utility power: 0.33 kg-CO_2/kWh[11]
- Conditions of the amount of solar radiation: Tokyo
- Number of years the solar power generation system will be used[12]: 20 years
- Annual reduction in CO_2 emissions per unit of adoption (rated output of solar power generation: 1 kW)
  Difference between CO_2 emissions from electric power utilities and those from solar power generation per kWh of power generated
  × Annual amount of power generation per kW of output

(3) Result of assessment

[1] Calculation of the avoided CO_2 emissions

Based on the annual amount of power generated under daylight conditions in Tokyo, the difference between the CO_2 emissions from solar power generation and those from electric power utilities has been used as emission abatement.

- Annual amount of power generated: 902 kWh/year/kW
  per kW of output from solar power generation when applying daylight conditions in Tokyo
- Annual reduction in CO_2 emissions: ▲Approx. 255 kg-CO_2/kW/year
  Difference from power generated as utility power when output of 1 kW has been adopted
- The avoided CO_2 emissions per kW from solar power generation: ▲5,105 kg-CO_2/kW (20 years)

Table 3. The avoided CO_2 emissions per kW of output from solar power generation

	Multicrystalline Si solar cell	Utility power
1) The avoided CO_2 emissions from solar power generation		
• CO_2 emissions during power generation (kg-CO_2/kWh) (a)	0.047	0.33
• Annual power generated per kW of solar power generated (kWh@Tokyo) (b)	902	902
• CO_2 emissions per kW of solar power generated annually (kg-CO_2/kW/year) (a) x (b)	(c) 42.39	(d) 297.66
• Difference in the avoided CO_2 emissions per kW of solar power generated annually (kg-CO_2/kW/year) (c) – (d)	▲255.27	–
2) The avoided CO_2 emissions in the lifetime of solar power generation (kg-CO_2/kW/20 years)	**▲5,105**	–

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[10] Report of Business Entrusted by NEDO Technical Development of Common Foundation Technologies for Solar Power Generation Systems
"Investigational Research on the Life Cycle Assessment of Solar Power Generation Systems" (March 2009)

[11] Action Plan for Low Carbon Society Target value of the Federation of Electric Power Companies of Japan
Target value for the year 2020 as of 2009

[12] The Industry's Self-imposed Rules on Indication (Fiscal Year 2010) Japan Photovoltaic Energy Association

[2] Effect of adoption throughout Japan

i) The avoided CO_2 emission over the life cycle

The avoided CO_2 emission relative to the level of adoption in Japan as a whole in 2020 has been calculated.

- Level of adoption for the year 2020: 1.76 million kW

  The avoided CO_2 emission greatly varies with the level of adoption. To prevent the evaluation from being erroneously excessive, the difference between the cumulative level of adoption for solar power generation systems[13] in 2005 and that in 2020 was calculated, and the average increment per year obtained by dividing the difference by 15 years has been regarded as the level of adoption.

- The avoided CO_2 emission in the lifetime of solar power to be generated in 2020: ▲8.98 million tons (20 years)

  5,105 kg-CO_2/kW/20 years×176 kW=8,984 kt-CO_2

Table 4. The avoided CO_2 emission achieved by solar power generation systems to be adopted in 2020

1) Level of adoption in 2020	
• Actual cumulative level of adoption in 2005 (10,000 kW)	140
• Predicted cumulative level of adoption in 2020 (10,000 kW)	2,780
Annual average increment until 2020 (10,000 kW) → Amount of production during the year 2020	176
2) CO_2 emissions per kW of solar power generated annually (kg-CO_2/kW/year)	42.39
3) The avoided CO_2 emission during the lifetime (in 2020; for the portion of use for 20 years) (10,000 t-CO_2)	▲898

ii) CO_2 emissions in the life cycle of solar power generation

- CO_2 emissions from solar power generation: 1.49 million tons

  42.39 kg-CO_2/kW/year ×20 years×1.76 million kW = 1,492 kt-CO_2

iii) CO_2 emissions in the procurement of raw materials for and in the manufacture of chemical products (except those during use)

- CO_2 emissions from chemical products (raw materials through manufacture): 735 kg-CO_2/kW (value included in emission abatement)
- CO_2 emissions at the stage of manufacture of chemical products: 1.29 million tons

  735 kg-CO_2/kW×1.76 million kW = 1,294 kt-CO_2

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[13] Ministry of Economy, Trade and Industry, Agency for Natural Resources and Energy "On the Framework for the Total Buy-Back System for Renewable Energy" (August 4, 2010) http://www.meti.go.jp/committee/summary/0004629/framework03.pdf

Table 5. CO_2 emissions per kW in the manufacturing stage of chemical products

	Multicrystalline Si solar cell
1) CO_2 emissions in stages from raw materials to manufacture ($kg\text{-}CO_2/kW$)	
• Transportation of SiO_2 and manufacture of Si metal[13]	57.95
• Multicrystalline Si agglomerate[13]	445.91
• Manufacture of multicrystalline Si ingots[13]	26.72
• Manufacture of wafers[13]	145.02
• Sealing materials[14]	42.9
• Back sheets[14]	16.5
Total in the manufacturing stage ($kg\text{-}CO_2/kW$)	**735**

Note: From the mining of SiO_2, manufacture of Si metal, through manufacture of Si wafer, procurement of the raw materials of sealing materials and back sheets, to the manufacture of such materials and sheets.

4.2 Renewable energy 2 - materials for wind turbine power generation

(1) Overview of carbon fiber

PAN-based carbon fiber is a carbon material in the form of fiber that has a minute graphite crystalline structure. It is obtained by polymerization/forming into acrylonitrile yarn, of which the raw material is naphtha, and by heat-treating the yarn. It is widely used in various applications because of its light and strong mechanical performance (high specific strength, high specific modulus of elasticity) as well as its features that derive from its carbon-based properties (low density, low coefficient of thermal expansion, heat resistance, corrosion resistance, chemical stability, X-ray permeability, self-lubricating properties, etc.).

It is rare for carbon fiber is used independently. Instead, it is usually used as a composite material having matrices of resin, ceramics, metal, etc. A widely used form of these is a composite material made by immersing resin into carbon fiber, i.e. CFRP (carbon-fiber-reinforced plastic).

In this report, the reduction in the environmental load that can be obtained by using this CFRP compared with conventional materials has been evaluated in relation to the applications in which CFRP is used, particularly wind turbine power generation (to be evaluated in this section), applications in automotive materials (Section 4.3) and applications in aircraft materials (Section 4.4).

(2) Overview of wind turbine power generation

Wind turbine power generation has been used as a form of natural energy since olden times, and there are strong expectations that this clean energy will play an important role in preventing global warming.

Apart from medium and large-scale wind turbines, wind turbine power generators come in various sizes, including small generators that generate power in a facility. However, the strongest growth is

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[14] "Solar Power Generation Engineering" (Komiyama et al.) P147

expected from the ultra-large power generators of 3 MW or more, and they are being adopted mainly in Europe, America and Asia. As the capacity of a wind turbine generator is proportional to the square of the blade length, the turbines are expected to increase in size. A 10-MW system having a blade in excess of 70 meters is already being developed.

[1] Details of the avoided CO_2 emissions

Since no fossil fuel is used, no CO_2 is emitted during power generation.

[2] Features of wind turbine power generation

- Of the various forms of natural energy, wind turbines are relatively high in efficiency, with about 40% of the wind energy being converted into electrical energy.
- It has a high utilization rate because, unlike solar power generation, wind turbines operate during the night.
- It is more cost-effective than solar power because of its high utilization rate and high conversion efficiency.
- It has a lower CO_2 emission factor than other types of natural energy. Also, the CO_2 emission factor is expected to become smaller due to further improvements in power generation capacity and the use of larger wind turbine blades.

  Solar power generation: 0.047 kg-CO_2/kWh[15]; Wind turbine power generation: 0.005 kg-CO_2/kWh[16]

[3] Status of the adoption of power generation systems in Japan[17]

- As of 2009: 2,200 MW
- Around 2020: 5,000 - 7,500 MW. The increase in the level of adoption forecast by the national government is 450 MW/year maximum.

[4] Examples of chemical products used in wind turbine power generation

In an ultra-large system having a power generation capacity of 3 MW or more, there is the risk of the blades colliding with the tower and they flex in response to the wind. To prevent such collisions, the girders of the blades are made from carbon fiber, which has a modulus of elasticity that is more than three times greater than that of conventional glass fiber[18].

- Carbon fiber
- Epoxy resin, etc.

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[15] NEDO Report of Business Delegated by NEDO Technical Development of Common Foundations for Solar Power Generation Systems
"Investigational Research on the Life Cycle Assessment of Solar Power Generation Systems" (March 2009)

[16] Report of VESTAS: "Life cycle assessment of offshore and onshore sited wind power plants based on VesTas V90-3.0 MW turbines." (June 2006)

[17] Website of the Ministry of Economy, Trade and Industry http://www.meti.go.jp/committee/summary/0004629/framework.html

[18] Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/

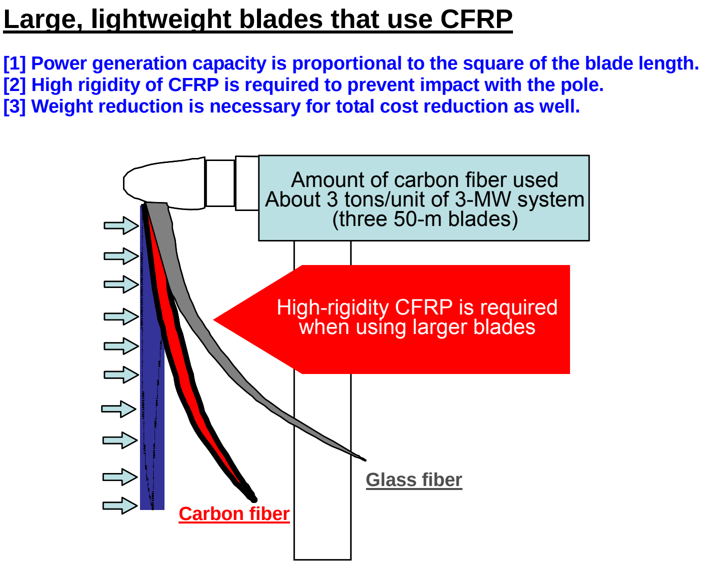

Fig. 27. Comparison between wind turbine blades made from CFRP and those made from glass fiber

(3) Conditions of assessment

[1] Object of assessment and object of comparison

Item	Contents
Chemical products/technologies that help reduce CO_2 emissions	Materials used in wind turbines (carbon fiber, epoxy resin, etc.)
Product under assessment	Large wind turbines that use carbon-fiber-reinforced plastics (3-MW class)
Product for comparison	Utility power (power source mix with thermal power, nuclear power, hydropower, etc. Based on average composition in power generation plants in Japan)
Year under assessment / period under assessment	Year 2020 / period in which the products manufactured during the year under assessment will be used until the end of their life

[2] System boundary (scope of assessment that has been carried out)

The scope for wind turbine power generation includes emissions from raw materials, through manufacture and usage to maintenance (replacement of parts). Calculation relating to disposal has been excluded because there are no previous records. Also, since CO_2 emissions with carbon fiber from the stages of raw materials to manufacture are not taken into account, they were added as an increment during equipment manufacture. However, emissions from materials to be replaced by carbon fiber (e.g. glass fiber, etc.) are not subtracted.

The scope for utility power includes all emissions, from the emissions of power generation systems by means of power source mix to emissions during the stages of raw material procurement, through to manufacture, usage, maintenance (replacement of parts) and disposal. These apply to fuel production, fuel transportation and waste disposal.

[3] Functional unit

Functions of a wind turbine power generation system and utility power, each of which generate 1 kWh of power

[4] Preconditions for calculating emission abatement

- CO_2 emission factor (amount of CO_2 emitted per kWh of power generation)
  Wind turbine power generation: 0.005 kg-CO_2/kWh[16]
  Utility turbine power: 0.33 kg-CO_2/kWh[19]
- Number of years the wind turbine power generation system is used: 20 years
- Amount of carbon fiber used per unit of wind turbine power generator: 3 tons
- Annual reduction in CO_2 emissions per unit of adoption
  (1 unit of wind turbine power generator with an output of 3 MW)
  Difference between CO_2 emissions from utility power and those from wind turbine power generation when generating 1 kWh of power
  × Annual amount of power generation of a 3-MW wind turbine power generator

(4) Result of assessment[20]

[1] Calculation of the avoided CO_2 emissions

With the annual amount of power generated by using a wind turbine power generator with an output of 3 MW/unit being used as the reference, the difference between the CO_2 emissions from wind turbine power generation and those from utility power has been used as emission abatement.

- Annual amount of power generated: 8,760 MWh/year/unit
  Calculated assuming that the output is 3 MW/unit and the amount of power that can be generated per hour is 1 MW/unit
- Annual avoided CO_2 emissions: ▲ 2,847 t-CO_2/unit/year
  Difference from power generated as utility power when a 3-MW unit has been adopted
- The avoided CO_2 emissions: ▲56,940 t-CO_2/unit (20 years)

Table 6. The avoided CO_2 emissions per unit of wind turbine power generator (wind turbine power generation vs. utility power)

	Product under assessment	Product for comparison
	Wind turbine power generation of 3-MW class	Utility power
1) The avoided CO_2 emissions by a wind turbine power generator		
• CO_2 emissions from power generation (kg-CO_2/kWh) (a)	0.005	0.33
• Annual amount of power generation per unit of wind turbine power generator (MWh) (b)	8,760	8,760
• CO_2 emissions relative to annual power generated per unit of wind turbine power generator (t-CO_2/unit/year) (a) x (b)	(c) 43.8	(d) 2,890.8
• Difference in CO_2 emission relative to annual power generated per unit of wind turbine power generator (t-CO_2/unit/year) (c) – (d)	▲2,847	–
2) The avoided CO_2 emission per unit of wind turbine power generator in its lifetime (t-CO_2/unit/20 years)	▲56,940	–

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[19] Action Plan for Low-Carbon Society Target value of the Federation of Electric Power Companies of Japan Target value for 2020 as of 2009

[20] It is different from the result obtained with the model publicized by the "Carbon Fiber Manufacturers Association." For details of this model, refer to 9. Appendix.

[2] Effect of adoption throughout Japan

i) The avoided CO_2 emissions over the life cycle

The avoided CO_2 emissions relative to the amount of production of carbon fiber (wind turbine power generation of 3-MW class) in Japan overall in 2020 have been calculated.

- Number of units expected to be adopted in the year 2020: 150 units

  Amount of carbon fiber to be used in the year 2020: 450 tons

  According to the national government's predictions for adoption[21], wind power generation with a maximum output of 450 MW per year will be adopted in around 2020. Assuming that one unit of wind turbine power generation system has an output of 3 MW, the number of turbines to be introduced by Japanese manufacturers is 150 units. The amount of carbon fiber to be used in the turbines is estimated to be 450 tons as three tons are used per unit.
- The avoided CO_2 emission in the lifetime of wind turbine power generation in 2020:

  ▲8.54 million tons (20 years)

  56,940t-CO_2/unit/20 years × 150 units = 8,541 k t-CO_2

Table 7. The avoided CO_2 emissions by wind turbine power generation systems to be introduced in 2020

1) Level of adoption in around 2020		
• Level of adoption in 2020	(MW)	450
• Number of wind turbine power generators to be adopted in 2020	(units)	150
(Amount of carbon fiber to be used in wind turbine power generators in 2020)	(tons)	(450)
2) CO_2 emissions relative to annual power generated per unit of wind turbine power generator (t-CO_2/unit/year)		43.8
3) The avoided CO_2 emission by wind turbine power generators in their lifetime (in 2020; for the portion of use for 20 years) (10,000 t-CO_2)		▲854

ii) CO_2 emissions in the life cycle of wind turbine power generation

- CO_2 emissions from wind turbine power generation: 130,000 tons

  43.8t-CO_2/unit/year × 20 years × 150 units = 131k t-CO_2

Net increment of carbon fiber per unit. Although the portion of the materials to be substituted (e.g. glass fiber, etc.) is included in the CO_2 emission factor of wind turbine power generation, it is difficult to extract this portion. Therefore this portion is not subtracted from the calculation and the emissions were double-counted.

iii) CO_2 emissions in the procurement of raw materials for and in the manufacture of chemical products (except those during use)

- CO_2 emissions from chemical products (raw materials through manufacture) per unit: 60t-CO_2/unit

  CO_2 emissions per ton of carbon fiber: 20 tons

  Amount of carbon fiber used per unit of wind turbine power generator: 3 tons
- CO_2 emissions at the stage of manufacturing chemical products: 9,000 tons

  Wind turbine power generation: 60 t-CO_2/unit × 150 units = 9 kt-CO_2

4.3 Saving energy 1 - automotive materials (carbon fiber)

(1) Overview of carbon fiber as an automotive material[22]

Carbon fiber is used in various automobile components. The use of carbon fiber enables the automobile weight to be reduced while maintaining the same strength and safety. Reducing the weight of automobiles directly leads to improved fuel consumption and contributes to the reduction in CO_2 emissions in the transportation sector. This report evaluates the reduction in CO_2 emissions through improved fuel consumption when adopting carbon fiber as compared with conventional automobiles[23].

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[21] Website of the Ministry of Economy, Trade and Industry http://www.meti.go.jp/committee/summary/0004629/framework.html

[22] For an overview of carbon fiber, refer to Section 4.2, "Materials for wind turbine power generation."

[23] Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/

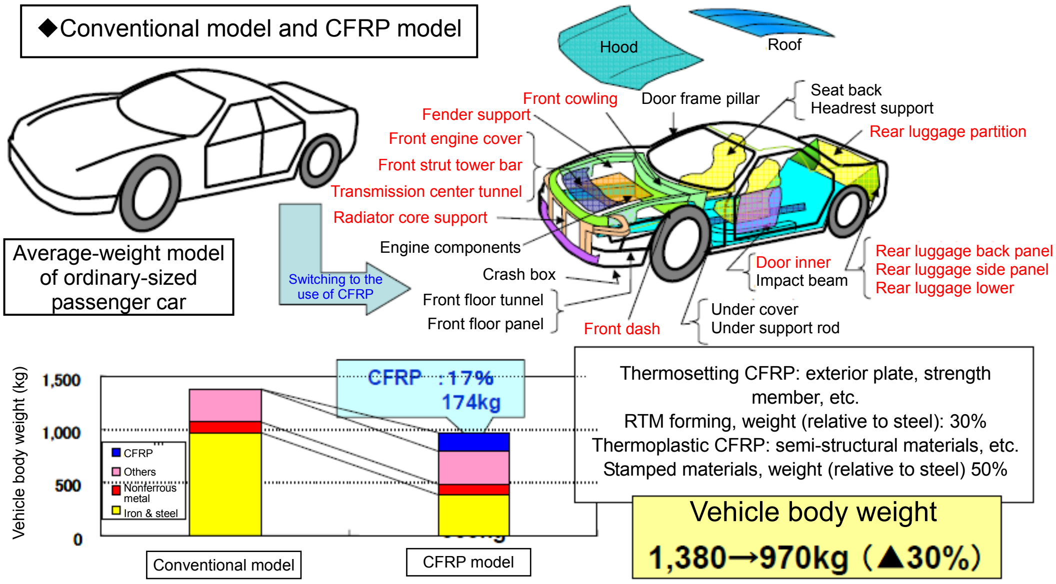

Fig. 28. Carbon fiber for automobiles

[1] Details of the avoided CO_2 emissions

The fuel consumption is improved through weight reduction and the fuel consumption is reduced.

[2] Examples of chemical products used in automobiles

- Carbon fiber
- Epoxy resin

(2) Conditions of assessment

[1] Object of assessment and object of comparison

Item	Contents
Chemical products/technologies that help reduce CO_2 emissions	Automotive materials (carbon fiber, epoxy resin)
Product under assessment	Automobiles in which conventional materials have been replaced with carbon fiber (CFRP model)
Product for comparison	Automobiles in which no carbon fiber is used (conventional model)
Year under assessment / period under assessment	Year 2020 / period in which the products manufactured during the year under assessment will be used until the end of their life

[2] System boundary (scope of assessment that has been carried out)

The entire life cycle of an automobile is considered. The assessment was made on both the CFRP model and conventional model for the stages from the manufacture of raw materials through to parts manufacture, assembly of automobiles, usage (driving), to disposal. Note that in this model, resin and carbon fiber for automotive use are calculated on the basis of reuse as CFRP by crushing them and adding them at the time of injection molding.

[3] Functional unit

Functions that make automobiles under the CFRP model and under the conventional model run the same distance during the same period.

[4] Preconditions for calculating emission abatement

- Automobile under assessment: Automobile that runs on gasoline only
- Vehicle weight assumed: CFRP model: 970 kg/unit
  Conventional model: 1,380 kg/unit
  (average vehicle weight as of 2006)
  → 30% reduction in vehicle weight compared with the conventional model. In all, 174 kg/unit of CFRP is used.
- Fuel consumption assumed[24]: CFRP model: To drive 12.40 km per liter of gasoline
  Conventional model: To drive 9.83 km per liter of gasoline

Note: As shown in Attachment 1 of the cLCA Guidelines[25], various data are available concerning fuel consumption. Since it is difficult to standardize the values in all the examples, the fuel consumption in this example has not been changed from the data before revision.

- Lifetime mileage[26]: Assumed to be 94,000 km over 10 years of use.

(3) Result of assessment[27]

[1] Calculation of the avoided CO_2 emissions

Fuel consumption improves due to the weight reduction resulting from the use of carbon fiber, and the difference in CO_2 emissions from the reduced gasoline consumption has been used as emission abatement.

The CO_2 emissions of the CFRP model from the raw materials used in automobiles through assembly to disposal increase by 0.8 tons/unit as compared with those with the conventional model. When driving, however, the reduction in CO_2 emissions is about ▲5.4 tons/unit with the CFRP model, and the avoided CO_2 emissions over the entire life cycle is about ▲5 tons/unit▪10 years.

- The avoided CO_2 emission: ▲5t-CO_2/unit (10 years)

Table 8. The avoided CO_2 emissions per automobile

		CFRP model	Conventional model
CO_2 emissions during the stages of raw material procurement to material manufacture (t-CO_2/unit)		**5.1**	**3.9**
CO_2 emissions during the stage of automobile assembly (t-CO_2/unit)		**0.8**	**1.2**
In the stage of automobile usage	Fuel consumption while driving (km/ℓ-gasoline)	12.40	9.83
	Lifetime mileage (km)	94,000	
	Lifetime amount of gasoline used (ℓ)	7,580	9,560
	CO_2 emissions during gasoline combustion[28] (kg-CO_2/ℓ)	2.72	
	CO_2 emissions during the usage stage (t-CO_2/unit·10 years)	**20.6**	**26.0**
CO_2 emissions during the stages of disposal/recycling (t-CO_2/unit)		**0.3**	**0.3**
CO_2 emissions over the entire life cycle (t-CO_2/unit·10 years)		**26.8**	**31.4**
The avoided CO_2 emission (t-CO_2/unit·10 years)		**▲5**	

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[24] Specified based on the material of the Japan Automobile Manufacturers Association (material: 2008; historical data: 2006)

[25] Guideline for Calculation of The avoided CO_2 emissions of the Japan Chemical Industry Association (general incorporated association)

[26] Specified based on the material of the Ministry of Land, Infrastructure, Transport and Tourism (investigation: March 2008; historical data: 2006)

[27] Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/

[28] Specified based on the values of the Ministry of the Environment, various associations and various automobile manufacturers.

[2] Effect of adoption throughout Japan

i) The avoided CO_2 emissions over the life cycle

The avoided CO_2 emissions relative to automobiles that will use carbon fiber (CFRP automobiles) in Japan overall in 2020 have been calculated.

- Method of trial calculation of the number of automobiles to be adopted that use carbon fiber

  The number of automobiles to be adopted that use carbon fiber has been obtained by estimating the amount of carbon fiber manufactured by manufacturers in Japan for use in automobiles in 2020, assuming that 100 kg of carbon fiber will be used per unit.

  a. Estimated amount of carbon fiber for automotive use by manufacturers in Japan[29]:

  For Japan: 1,500 tons (about 5% of the whole world)

  b. Amount of carbon fiber used per automobile: 100 kg/unit

  c. Number of automobiles to be adopted: 15,000 automobiles in Japan

- The avoided CO_2 emissions: ▲75,000 tons (10 years)

  5t-CO_2/unit·10 years × 15,000 automobiles = 75,000 t-CO_2

Table 9. The avoided CO_2 emissions by CFRP automobiles to be sold in Japan in 2020

		Japan
1) Level of adoption in 2020		
• Amount of carbon fiber for automotive use in 2020	(tons)	1,500
• Number of automobiles to be adopted that use carbon fiber	(10,000 units)	1.5
2) The avoided CO_2 emissions		
• The avoided CO_2 emission per unit	(t-CO_2/unit·10 years)	▲5
• The avoided CO_2 emission by automobiles (using carbon fiber) in 2020	(10,000 tons-CO_2/10 years)	▲7.5

ii) CO_2 emissions over the life cycle of CFRP automobiles

- CO_2 emissions from CFRP automobiles: 400,000 tons

  26.8t-CO_2/unit·10 years × 15,000 units = 402k t-CO_2

iii) CO_2 emissions during the procurement of raw materials, assembly, and disposal/recycling of finished products (except those during use)

- CO_2 emissions per unit of finished products (CFRP automobiles): 6.2t-CO_2/unit
- CO_2 emissions from finished products (CFRP automobiles): 93,000 tons

  6.2t-CO_2/unit × 15,000 units = 93 kt-CO_2

[3] Effect of global adoption

i) The avoided CO_2 emissions over the life cycle

The avoided CO_2 emissions relative to the number of CFRP automobiles expected to be adopted globally in 2020 has been calculated.

- Method of trial calculation for the number of automobiles using carbon fiber that are expected to be adopted

  The number of automobiles to be adopted that use carbon fiber has been obtained by assuming that 100 kg of carbon fiber is used per unit.

  a. Estimated amount of carbon fiber for automotive use[30]: Globally 30,000 tons

  b. Amount of carbon fiber used per unit: 100 kg/unit

  c. Number of units to be adopted: Globally Approx. 300,000 units

- The avoided CO_2 emission: ▲1.5 million tons (10 years)

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[29] Estimation by the Japan Carbon Fiber Manufacturers Association

[30] Estimation by the Japan Carbon Fiber Manufacturers Association

Table 10.　The avoided CO_2 emissions by CFRP automobiles to be sold globally in 2020

	Global
1) Level of adoption in 2020	
• Amount of carbon fiber to be used in automotive applications in 2020 (tons)	30,000
• Number of automobiles to be adopted that use carbon fiber (10,000 units)	30
2) The avoided CO_2 emissions	
• The avoided CO_2 emission per unit over the life cycle (t-CO_2/unit·10 years)	▲5
• The avoided CO_2 emission by automobiles (using carbon fiber) in 2020 (10,000 tons-CO_2/10 years)	▲150

ii)　CO_2 emissions over the life cycle of a CFRP automobile

- CO_2 emissions from CFRP automobiles: 8.04 million tons

26.8 t-CO_2/unit·10 years × 300,000 units = 8,040 kt-CO_2

iii)　CO_2 emissions during the procurement of raw materials, assembly, and disposal/recycling of finished products (except those during use)

- CO_2 emissions per unit of finished products (CFRP automobiles): 6.2t-CO_2/unit
- CO_2 emissions from finished products (CFRP automobiles): 1.86 million tons

6.2 t-CO_2/unit × 300,000 units = 1,860 kt-CO_2

4.4　Saving energy 2 - aircraft materials (carbon fiber)

(1) Overview of carbon fiber as a material used in aircraft[31]

Carbon fiber is used in various aircraft components. The use of carbon fiber reduces the weight of the aircraft while maintaining the same strength and safety. As with automobiles, weight reduction in aircraft directly leads to improved fuel consumption, thereby contributing to a reduction in CO_2 emissions in the transportation sector. This report evaluates the reduction in CO_2 emissions due to reduced fuel consumption due to the use of carbon fiber as compared with conventional aircraft[32].

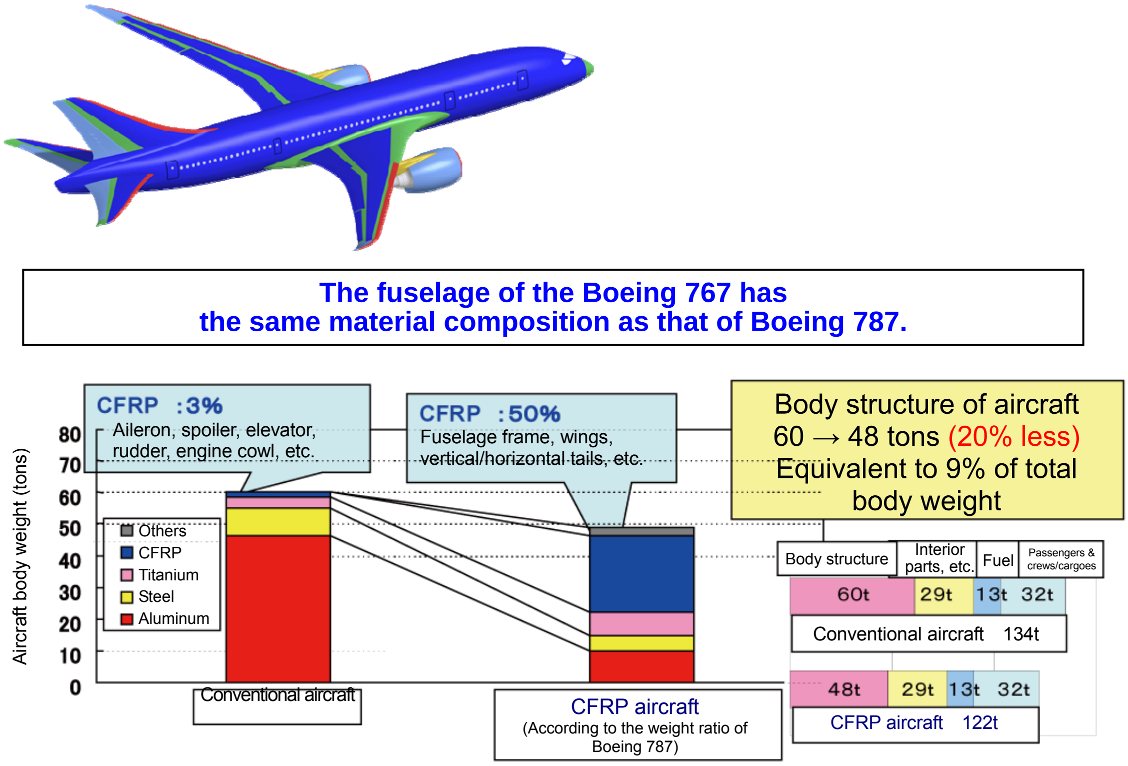

Fig.29.　Carbon fiber for aircraft use

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[31] For an overview of carbon fiber, refer to Section 4.2 "Materials for wind turbine power generation."

[32] Website of the Japan Carbon Fiber Manufacturers Association　http://www.carbonfiber.gr.jp/

[1] Details of emission abatement

The fuel consumption is improved due to weight reduction and reduced fuel consumption.

[2] Examples of chemical products used in aircraft

- Carbon fiber
- Epoxy resin

(2) Conditions of assessment

[1]Object of assessment and object of comparison

Item	Contents
Chemical products/technologies that help reduce CO_2 emissions	Materials for aircraft (carbon fiber, epoxy resin)
Product under assessment	An aircraft body in which CFRP is used in 50% of its body structure (CFRP aircraft): Boeing 767
Product for comparison	An aircraft body in which CFRP is used in 3% of its body structure (conventional aircraft): Boeing 787
Year under assessment / period under assessment	Year 2020 / period in which the products manufactured during the year under assessment will be used until the end of their life

[2] System boundary (scope of assessment that has been carried out)

The entire life cycle of aircraft is considered. Both the CFRP aircraft and conventional aircraft were assessed at the stages of the manufacture of raw materials through to the manufacture of parts, assembly of the aircraft, and usage (aviation). The stage of disposal was excluded from calculation because no historical data is available.

[3] Functional unit

Functions that make both aircraft of the CFRP model and aircraft of the conventional model fly the same distance over the same period.

[4] Preconditions for calculating the avoided CO_2 emissions

- Body weight: Conventional aircraft 60 tons/unit, Proportion of CFRP used 3%
  CFRP aircraft 48 tons/unit Proportion of CFRP used 50%
  20% reduction as compared with the conventional aircraft
- Fuel consumption:Conventional aircraft Aviation of 103 km per kiloliter of jet fuel
  CFRP aircraft Aviation of 110 km per kiloliter of jet fuel
- Lifetime aviation mileage: Annual aviation of 2,000 flights between the Haneda Airport and New chitose Airport (500 miles) over 10 years of use.

(3) Result of assessment[33]

[1] Calculation of The avoided CO_2 emissions

The weight reduction resulting from the use of carbon fiber improves fuel consumption. The difference in the CO_2 emissions of the jet fuel reduced thereby has been used as the avoided CO_2 emissions.

The CO_2 emissions from the procurement of raw materials to the manufacture of materials per unit of aircraft increase by 0.2 kt-CO_2 as compared with conventional aircraft. During assembly, however, the reduction in CO_2 emissions is ▲0.8 kt-CO_2 with the CFRP aircraft, and ▲26.3 kt-CO_2 during aviation, with The avoided CO_2 emissions in the entire life cycle becoming ▲27 kt. -CO_2

- The avoided CO_2 emissions: ▲27 kt-CO_2/unit (10 years)

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[33] Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/

Table 11. The avoided CO_2 missions per unit of aircraft

		CFRP aircraft	Conventional aircraft
CO_2 emissions during the stages of raw material procurement - manufacture of materials (kt-CO_2/unit)		**0.9**	**0.7**
CO_2 emissions during the stage of aircraft assembly (kt-CO_2/unit)		**3.0**	**3.8**
During the stage of aircraft usage	**Fuel consumption during aviation (km/kℓ-jet fuel oil)**	110	103
	Lifetime aviation mileage (miles)	500 miles × 20,000 flights	
	Lifetime amount of gasoline used (kℓ/unit)	145,500	155,300
	CO_2 emissions during combustion of jet fuel [34] (kg-CO_2/ℓ)	2.5	
	CO_2 emissions during the usage stage (kt-CO_2/unit·10 years)	**364**	**390**
CO_2 emissions during the stage of disposal (kt-CO_2/unit)		**No Data**	**No Data**
CO_2 emissions over the entire life cycle (kt-CO_2/unit·10 years)		**368**	**395**
The avoided CO_2 emission (kt-CO_2/unit·10 years)		**▲27**	

[2] Effect of adoption throughout Japan

i) The avoided CO_2 emissions over the life cycle

The avoided CO_2 emissions relative to the number of units of CFRP aircraft that will be adopted in Japan overall in 2020 has been calculated.

- Method of trial calculation of the number of aircraft expected to be adopted that use carbon fiber

  The number of units of aircraft adopted that use carbon fiber has been obtained by estimating the amount of carbon fiber manufactured by manufacturers in Japan for aircraft use in 2020, assuming that 20 tons of carbon fiber is used per unit.

  a. Estimated amount of use of carbon fiber for aircraft use by manufacturers in Japan[35]:
  For Japan: 900 tons (approx. 5% of the global amount)
  b. Amount of carbon fiber used per unit: 20 tons/unit
  c. Number of units adopted: Japan 45 units

- The avoided CO_2 emission: ▲1.22 million tons (10 years)
  27 kt-CO_2/unit·10 years × 45 units = 1,215 kt-CO_2

Table 12. The avoided CO_2 emissions by CFRP aircraft to be adopted in Japan in 2020

1) Level of adoption in 2020	Japan
• Amount of carbon fiber used for aircraft in 2020 (tons)	900
• Number of aircraft adopted that use carbon fiber (units)	45
2) The avoided CO_2 emissions	
• The avoided CO_2 emission over life cycle per unit (kt-CO_2/unit·10 years)	▲27
• The avoided CO_2 emission by CFRP aircraft (using carbon fiber) in 2020 (10,000 tons -CO_2/10 years)	▲122

ii) CO_2 emissions over the life cycle of CFRP aircraft

- CO_2 emission from CFRP aircraft: 16.56 million tons (10 years)
  368 kt-CO_2/unit·10 years × 45 units = 16,560 kt-CO_2

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[34] Specified based on the material of airline companies.

[35] Estimation by the Japan Carbon Fiber Manufacturers Association

iii) CO_2 emissions during the procurement of raw materials, assembly, and disposal of finished products (CFRP aircraft) (except those during use)

- CO_2 emission per unit of finished products (CFRP aircraft): 3.9 kt-CO_2/unit
- CO_2 emission from finished products (CFRP aircraft): 176,000 tons

  3.9 kt-CO_2/unit × 45 units = 176 kt-CO_2

[3] Effect of global adoption

i) The avoided CO_2 emissions over the life cycle

The avoided CO_2 emissions relative to the number of units of CFRP aircraft to be adopted globally in 2020 has been calculated.

- Method of trial calculation of the number of units of aircraft using carbon fiber that are expected to be adopted
  - a. Estimated amount of carbon fiber used for aircraft by manufacturers[36]:
    Globally: 18,000 tons
  - b. Amount of carbon fiber used per unit: 20 ton/unit
  - c. Number of units to be adopted: Globally Approx. 900 units
- The avoided CO_2 emission: ▲24.3 million tons (10 years)

Table 13. The avoided CO_2 emissions by CFRP aircraft to be adopted globally in 2020

1) Level of adoption in 2020		Globally
• Amount of carbon fiber used for aircraft in 2020	(tons)	18,000
• Number of units of aircraft adopted that use carbon fiber	(units)	900
2) The avoided CO_2 emissions based on the scenario for adoption	(kt-CO_2)	
• The avoided CO_2 emission over life cycle per unit	(kt-CO_2/unit·10 years)	▲27
• The avoided CO_2 emission by CFRP aircraft (using carbon fiber) in 2020	(10,000 tons -CO_2/10 years)	▲2,430

ii) CO_2 emissions over the life cycle of CFRP aircraft

- CO_2 emissions from CFRP aircraft: 331.2 million tons

  368 kt-CO_2/unit·10 years × 900 units = 331,200 kt-CO_2

iii) CO_2 emissions during the procurement of raw materials, assembly, and disposal of finished products (CFRP aircraft) (except those during use)

- CO_2 emissions per unit of finished products (CFRP aircraft): 3.9 kt-CO_2/unit
- CO_2 emissions from finished products (CFRP aircraft): 3.51 million tons

  3.9 kt-CO_2/unit × 900 units = 3,510 kt-CO_2

4.5 Saving energy 3 - materials for fuel efficient tyres

(1) Overview of fuel efficient tyres

Fuel efficient tyres reduce the fuel consumption of automobiles by reducing their rolling resistance, and they contribute greatly to the CO_2 emissions reduction in the transportation sector.

With regard to improvements in fuel consumption, the tread portion that directly comes into contact with the ground (the portion where the tire contacts the road surface and which protects the road surface against impact and external damage) makes a great contribution to the improvements, whereas at the same time the tread portion is required to have gripping performance (braking performance). Chemical products play a great role in meeting the contradictory requirements for performance in which the fuel consumption is improved and gripping performance is maintained.

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[36] Estimation by the Japan Carbon Fiber Manufacturers Association

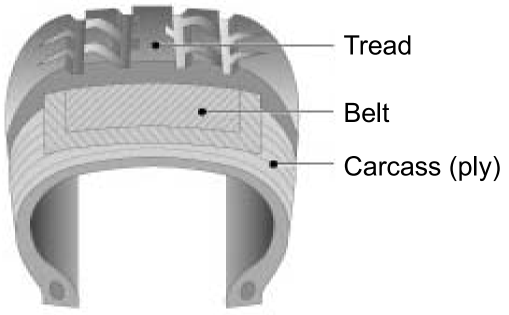
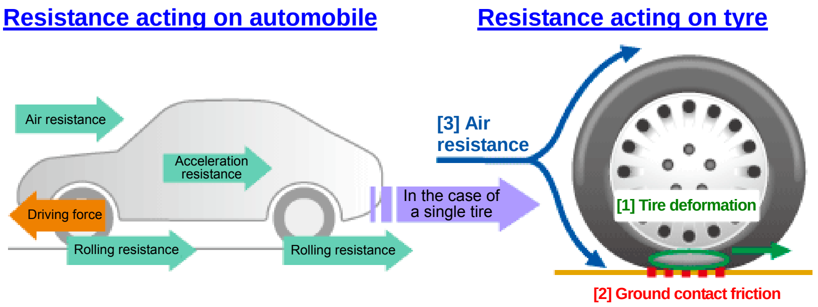


Fig. 30. Construction of a radial tyre [37]

What is rolling resistance?

When an automobile runs, it receives various types of resistance to the driving force.

Specifically, the types of resistance include air resistance acting on the vehicle body, etc., and acceleration resistance generated by an inertia force during acceleration, as well as resistance acting on the tyres, which is the rolling resistance.



Energy losses associated with rolling resistance are as follows.

[1] Energy loss due to deformation of the tyre during driving
[2] Energy loss due to ground contact friction between tread rubber and ground surface
[3] Energy loss due to air resistance associated with tyre rotation

Fig. 31. Explanation of rolling resistance [37]

The tread portion uses rubber that has been made by the vulcanization and molding of rubber compounds that contain rubber chemicals, etc. such as natural rubber and synthetic rubber, fillers such as carbon black and silica, etc., silane coupling agents, vulcanizing agents and vulcanizing accelerators, etc. While the types of raw materials and the proportion of materials used vary with the use of tyres, those mainly used for synthetic rubber are SBR (styrene-butadiene rubber), BR (butadiene rubber), and others. SBR that has been synthesized by the solution polymerization process transforms the physical properties by controlling the primary construction of polymers, and has the functions of reducing the loss of energy as caused by tire friction while an automobile moves, and these functions contribute to the improvements in fuel consumption. Also, the addition of silica has become an important point in making reduced rolling resistance compatible with maintaining grip.

In January 2010, Japan introduced a labeling system that uses markings based on the grading system (rating system) for both the types of performance, i.e. rolling resistance and grip, and fuel efficient tyres have become increasingly important.

[1] Details of the avoided CO_2 emissions

The fuel consumption is improved by the use of fuel efficient tyres that reduce the fuel consumed.

[2] Examples of chemical products used in fuel efficient tyres

- Solution-polymerized SBR (styrene-butadiene rubber)
- BR (butadiene rubber)
- Carbon black (that has been subjected to chemical denaturation)
- Silane coupling agents
- Silica
- Zinc oxide

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[37] Website of the Japan Automobile Tire Manufacturers Association, Inc. (general incorporated association) http://www.jatma.or.jp/labeling/faq01.html

- Various types of rubber chemicals

(2) Conditions of assessment

[1] Object of assessment and object of comparison

Item	Contents
Chemical products/technologies that that help reduce CO_2 emissions	Materials for fuel efficient tyres
Product under assessment	Fuel efficient tyres that are fitted to automobiles (passenger vehicles and trucks/buses)
Product for comparison	Non fuel efficient tyres that are fitted to automobiles (passenger vehicles and trucks/buses)
Year under assessment / period under assessment	Year 2020 / period in which the products manufactured during the year under assessment will be used until the end of their life

[2] System boundary (scope of assessment that has been carried out)

The entire life cycle of the tyres is considered. Assessment was made on each of the fuel efficient tyres and conventional tyres at the stages of the procurement of raw materials to manufacture/distribution/usage (at the time of driving the vehicle)/disposal.

Note that during the usage stage of tyres, the amount of fuel consumed (fuel consumption) is calculated with the tyres fitted to the automobile.

[3] Functional unit

Functions that make both automobiles fitted with fuel efficient tyres and those fitted with conventional tyres run the same distance during the same period.

[4] Preconditions for calculating emission abatement

Table 15 shows the avoided CO_2 emissions per automobile at the usage stage.

The service life of tyres and the amount of fuel the automobile consumes that become preconditions for calculating the avoided CO_2 emissions have been cited from "LCCO_2 Calculation Guidelines for tyres, Ver. 2.0" of the Japan Automobile Tire Manufacturers Association, Inc. (general incorporated association).

- Service life For passenger vehicles (PCR[38]): 30,000 km
  For trucks/buses (TBR[38]): 120,000 km

Note 1: As shown in Attachment 1 of the cLCA Guidelines[39] prepared by this association, various types of data for fuel consumption are available. The fuel consumption in this table is different from that in the example of CFRP automobiles (9.83 km/ℓ) in this report, but since the numerical values themselves are similar, the data on fuel consumption given in the guidelines prepared by the Japan Automobile Tire Manufacturers Association have been used.

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[38] PCR stands for Passenger Car Radial, and TBR stands for Truck and Bus Radial.

[39] "Guideline for Calculation of the avoided CO_2 emissions", Japan Chemical Industry Association (general incorporated association)

Table 14. The avoided CO_2 emissions per automobile during the usage stage

Item	PCR		TBR	
	Non fuel efficient tyre	Fuel efficient tyre	Non fuel efficient tyre	Fuel efficient tyre
Fuel consumption while driving (l/km)*	0.1	0.0975	0.25	0.2375
Number of tyres fitted (units)	4		10	
Tyre service life (km)	30,000		120,000	
Amount of fuel used (l)	3,000	2,925	30,000	28,500
CO_2 emissions during fuel combustion (kg-CO_2e/l)	Volatile oil (gasoline); 2.81		Light oil; 2.89	
CO_2 emissions per automobile during the usage stage (kg-CO_2e/unit)	8,430	8,219	86,700	82,365
The avoided CO_2 emissions (kg-CO_2e/unit)		▲211		▲4,335
The avoided CO_2 emissions per tyre (kg-CO_2e/tyre)		▲52.75		▲433.5

* Although the fuel consumption while driving varies with the car model and driving conditions, these numerical values are typical values based on experiments/literature.

(3) Result of assessment

[1] Calculation of the avoided CO_2 emissions

The result for passenger vehicles fitted with fuel efficient tyres and non fuel efficient tyres is shown in Table 15, and the result for trucks/busses in Table 17.

Note that the CO_2 emissions of tyres at the stages from the procurement of raw materials through to production and distribution as well as usage (while the vehicle is being driven) to disposal/recycling have been cited from the "LCCO$_2$ Calculation Guidelines for tyres, Ver. 2.0" of the Japan Automobile Tire Manufacturers Association.

i) For passenger vehicles (PCR)

Table 15. The avoided CO_2 emissions per automobile over the entire life cycle

For passenger vehicles: PCR		fuel efficient-tyres	Non fuel efficient tyres
CO_2 emissions during the stages of raw material procurement to manufacture of materials	**(kg-CO_2/unit)**	**95.6+A**	**100.0+A**
Production stage	**(kg-CO_2/unit)**	**28.0+B**	**31.2+B**
Distribution stage	**(kg-CO_2/unit)**	**6.0+C**	**6.4+C**
Usage stage	**(kg-CO_2/unit)**	**8,219**	**8,430**
CO_2 emissions during the stage of disposal/recycling	**(kg-CO_2/unit)**	**2.8+D**	**11.6+D**
CO_2 emissions over the entire life cycle	**(kg-CO_2/unit)**	**8,351.9+A+B+C+D**	**8,579.2+A+B+C+D**
Avoided CO_2 emission	**(kg-CO_2/unit)**	**▲227.3**	
Avoided CO_2 emission per tyre	**(kg-CO_2/tyre)**	**▲56.8**	

Note: The CO_2 emissions from the stages of raw material procurement to the manufacture of materials include those for the transportation of raw materials.

A: CO_2 emissions during the stage of the manufacture of raw materials other than tyres that are used in automobiles, B: CO_2 emissions during the stage of the production of parts other than tyres that are used in automobiles, C: CO_2 emissions during the stage of distribution of parts other than tyres that are used in automobiles, D: CO_2 emissions during the stage of disposal/recycling of raw materials and parts other than tyres that are used in automobilesThe details of Table 15 are as follows.

☐Fuel efficient tyres

◆ Procurement of raw materials for tyres - production/distribution: 129.6 kg-CO_2/4 tyres.

- Synthetic rubbers, organic rubber chemicals, etc. used as raw materials: 95.6 kg-CO_2/4 tyres (including transportation of raw materials)
- During the stage of tire production: 28.0 kg-CO_2/4 tyres
- During the distribution stage: 6.0 kg-CO_2/4 tyres

◆ During use (while the vehicle is being driven): See Table 14.

CO_2 emitted during use (while driving 30,000 km) is 8,219 kg-CO_2/4 tyres.

Calculation process

- Amount of fuel consumed per automobile/per km: 0.0975 ℓ/km·4 tyres
- CO_2 emission (basic unit for volatile oil): 2.81 kg-CO_2/ℓ
- CO_2 emissions during use: 0.0975 ℓ/km·4 tyres×30,000 km × 2.81 kg-CO_2/ℓ
  = 8,219 kg-CO_2/4 tyres

◆ During the stage of tire disposal/recycling (including emission during transportation of used tyres)

- CO_2 emitted during the stage of disposal of fuel efficient tyres is 52.8 kg-CO_2/4 tyres.
- The reduction through recycling is ▲50 kg-CO_2/4 tyres.

When the reduction through recycling is taken into account, the effect is 2.8 kg-CO_2/4 tyres.

Supplement: According to the Guidelines of the Japan Automobile Tire Manufacturers Association, during the stage of tire disposal/recycling for passenger vehicles, thermal utilization accounts for 75% and disposal other than recycling accounts for 25%. The portion equivalent to the energy utilized as thermal recycling has been subtracted assuming that the energy to be collected by thermal utilization is substituted for Class C heavy oil.

Specific ways of approaching this matter and the details are shown in Table 16.

☐Non fuel efficient tyres

◆ Procurement of raw materials for tyres - production/distribution:

- CO_2 emitted during the procurement of raw materials for non fuel efficient tyres (for passenger vehicles) is 100.0 kg-CO_2/4 tyres (including transportation of raw materials).
- During the production stage: 31.2 kg-CO_2/4 tyres
- During the distribution stage: 6.4 kg-CO_2/4 tyres

◆ During use (when the vehicle is being driven): See Table 14.

CO_2 emitted during use (when driving 30,000 km) is 8,430 kg-CO_2/4 tyres.

Calculation process

- Amount of fuel consumed per automobile/per km: 0.1ℓ/km·4 tyres
- CO_2 emission (basic unit for volatile oil): 2.81 kg-CO_2/ℓ
- CO_2 emissions during use: 0.1ℓ/km·4tyres × 30,000 km × 2.81 kg-CO_2/ℓ = 8,430 kg-CO_2/4 tyres

◆ During the stage of tire disposal/recycling

- CO_2 emitted during the disposal stage of non fuel efficient tyres is 64.0 kg-CO_2/4 tyres.
- The effect of reduction by recycling is ▲52.4 kg-CO_2/4 tyres (See the supplementary material below for the status of disposal/recycling and the process for calculating the reduction through recycling.)

When the reduction due to recycling has been taken into account, the effect is 11.6 kg-CO_2/4 tyres.

Supplementary material

The details of calculating CO_{2e} during the disposal/recycling stage of fuel efficient tyres and non fuel efficient tyres are shown in Table 16.

Table 16. GHG emissions and the reduction in emissions during the stage of disposal/recycling (unit: kg-CO_{2e}/4 tyres)

		Non fuel efficient tyres	Fuel efficient tyres
Proportion of recycling	Thermal utilization	75%	75%
	Other than recycling	25%	25%
GHG emissions	Transportation for procurement	1.6	1.6
	Thermal utilization a)	46.8	38.4
	Simple incineration b)	15.6	12.8
	Total A	64.0	52.8
Reduction in emissions	Thermal utilization c) B	-52.4	-50.0
CO_2 emissions during the disposal/recycling stage	A+B	11.6	2.8

a) 75% of used tyres are utilized as heat.

● Difference between non fuel efficient tyres and fuel efficient tyres:

[1] Weight of used tyres: Non fuel efficient tyres 7.3 kg, Fuel efficient tyres 7.0 kg

[2] Carbon content of used tyres: Non fuel efficient tyres 58%, Fuel efficient tyres 50%

(As shown in the raw materials composition ratio in Table 19, the content of synthetic rubber and carbon black in fuel efficient tyres is smaller than that in non fuel efficient tyres.)

(GHG emissions for every four used tyres during combustion)

= (carbon content of used tyres) × 44/12 × (Weight of used tyres) × 4

The content is calculated by multiplying the aforesaid calculated value by 0.75.

b) 25% of used tyres are incinerated.

c) 75% of used tyres are utilized as heat.

Heat collection efficiency factor: 0.9; the substitute fuel is Class C heavy oil.

(Reduction in GHG emissions by thermal utilization of 4 used tyres)

= (Combustion heat from tyres) × (GHG emission factor of Class C heavy oil) × (Heat collection efficiency factor) × (Weight of used tyres) × 4

■The avoided CO_2 emissions

- ◆The avoided CO_2 emission per automobile when the entire life cycle is taken into account (difference between fuel efficient tyres and non fuel efficient tyres)
  For passenger vehicles: 227.3 kg-CO_2/4 tyres
- ◆The avoided CO_2 emissions per tyre (difference between fuel efficient tyres and non fuel efficient tyres)
  For passenger vehicles: 56.8 kg-CO_2/tyre

ii) For trucks/buses (TBR)

Table 17. The avoided CO_2 emissions per automobile

For trucks/buses: TBR	fuel efficient tyres	Non fuel efficient tyres
CO_2 emissions during the stages of raw material procurement - manufacture of materials (kg-CO_2/unit)	**1,397+A**	**1,480+A**
Production stage (kg-CO_2/unit)	**352 +B**	**356 +B**
Distribution stage (kg-CO_2/unit)	**101+C**	**104+C**
Usage stage (kg-CO_2/unit)	**82,365**	**86,700**
CO_2 emissions during the stage of disposal/recycling(kg-CO_2/unit)	**▲309+D**	**▲311+D**
CO_2 emissions over the entire life cycle (kg-CO_2/unit)	**83,906+A+B+C+D**	**88,329+A+B+C+D**
The avoided CO_2 emission (kg-CO_2/unit)	**▲4,423**	
The avoided CO_2 emission per tire (kg-CO_2/tyre)	**▲442.3**	

Note: The CO_2 emissions during the stages of raw material procurement through to manufacture of materials include those for the transportation of raw materials.

A: CO_2 emissions during the stage of the manufacture of raw materials other than tyres that are used in automobiles, B: CO_2 emissions during the stage of the production of parts other than tyres that are used in automobiles, C: CO_2 emissions during the stage of distribution of parts other than tyres that are used in automobiles, D: CO_2 emissions during the stage of the disposal/recycling of raw materials and parts other than tyres that are used in automobiles

□Fuel efficient tyres

◆ Procurement of raw materials for tyres - production/distribution

- ● CO_2 emitted by the procurement of raw materials, such as natural rubber, synthetic rubber, organic rubber chemicals, non-organic compounding agents, etc., is 1,397 kg-CO_2/10 tyres (including transportation of raw materials).
- ● During the stage of tire production: 352 kg-CO_2/10 tyres
- ● During the distribution stage: 101 kg-CO_2/10 tyres

◆ During use (when the vehicle is being driven): See Table 15.

CO_2 emitted during use (when driving 120,000 km) is 82,365 kg-CO_2/10 tyres.

Calculation process

- Amount of fuel consumed per automobile/per km: 0.2375 ℓ/km·10 tyres
- CO_2 emission (basic unit for light oil): 2.89 kg-CO_2/ℓ
- CO_2 emissions during use: 0.2375 ℓ/km · 10tyres × 120,000 km × 2.89 kg-CO_2/ℓ
  = 82,365 kg-CO_2/10 tyres

◆ During the stage of tire disposal/recycling (including emission during transportation of used tyres)

- ● CO_2 emitted during the disposal stage of fuel efficient tyres is 545 kg-CO_2/10 tyres.
- ● The reduction due to recycling is ▲854 kg-CO_2/10 tyres.

When the portion of reduction by recycling is taken into account, the effect is ▲309 kg-CO_2/10 tyres.

Supplement: According to the Guideline of the Japan Automobile Tire Manufacturers Association[92], during the stage of the disposal/recycling of tyres for trucks/buses, thermal utilization accounts for 41%, product reuse (retreading) 16%, material reuse (material recycling) 18%, and disposal other than recycling 25%.

- Thermal recycling: The portion equivalent to the energy utilized has been subtracted, assuming the energy collected by thermal utilization as being substituted for Class C heavy oil.
- Product reuse: The reduction achieved by recycling has been calculated under the following conditions: CO_2 during the manufacture and transportation of raw materials used for retread compounds, during the mixing of retread compounds, and during the production of retread tyres is included; the reused products have been substituted for the manufacture and transportation of raw materials for new tyres and the production of new tyres.
- Material reuse: The reduction achieved by recycling has been calculated with CO_2 during the manufacture of rubber powder and reclaimed rubber included, assuming that the reused materials are substituted for the manufacture of rubber compound.

□Non fuel efficient tyres

◆ Procurement of raw materials for tyres - production/distribution

- CO_2 emitted by the procurement of raw materials, such as natural rubber, synthetic rubber, organic rubber chemicals, non-organic compounding agents, etc. is 1,480 kg-CO_2/10 tyres (including transportation of raw materials).
- During the production stage: 356 kg-CO_2/10 tyres
- During the distribution stage: 104 kg-CO_2/10 tyres

◆ During use (while the vehicle is being driven): See Table 14.

CO_2 emitted during use (while driving 120,000 km) is 86,700 kg-CO_2/10 tyres.

Calculation process

- Amount of fuel consumed per automobile/per km: 0.25ℓ/km·10 tyres
- CO_2 emission (basic unit for light oil): 2.89 kg-CO_2/ℓ
- CO_2 emissions during use: 0.25 ℓ/km·10tyres×120,000 km × 2.89 kg-CO_2/ℓ
  = 86,700 kg-CO_2/10 tyres

◆ During the stage of tire disposal/recycling

- CO_2 emitted during the stage of the disposal of non fuel efficient tyres is 582 kg-CO_2/10 tyres.
- The reduction by recycling is ▲893 kg-CO_2/10 tyres.
  When the portion of reduction by recycling is taken into account, the effect is ▲311 kg-CO_2/10 tyres.

■**The avoided CO_2 emissions**

◆The avoided CO_2 emissions per automobile when the entire life cycle is taken into account (difference between fuel efficient tyres and non fuel efficient tyres)
For trucks/buses: 4,423 kg-CO_2/10 tyres

◆The avoided CO_2 emission per tire (difference between fuel efficient tyres and non fuel efficient tyres)
For trucks/buses: 442.3 kg-CO_2/tyre

[2] Effect of adoption throughout Japan

i) The avoided CO_2 emissions over the life cycle

The avoided CO_2 emissions relative to the level of adoption in Japan overall in 2020 have been calculated.

The result of this calculation is shown in Table 18.

■ Ratios of demand for tyres in Japan[40] (2011):

For passenger vehicles	85,275,000 tyres	(93.5%)
For trucks/buses (excluding small-sized trucks)	5,920,000 tyres	(6.5%)
Total	91,195,000 tyres	

■ Quantity of fuel efficient tyres expected to be sold annually in 2020: 78,000,000 tyres
The quantity of tyres expected to be sold annually in 2020 has been specified as 78,000,000 tyres, assuming that annual growth is 2% in addition to the 70,000,000 tyres that is the quantity of fuel efficient tyres expected to be sold annually in 2015[41] (estimation by this association).

■ Quantity of fuel efficient tyres expected to be sold annually in 2020 (estimation by this association):
The quantity of each type of tire expected to be sold annually has been calculated by using the ratios of demand for tyres in Japan in 2011.

For passenger vehicles 78,000,000 tyres × 0.935 = 73,000,000 tyres
For trucks/buses 78,000,000 tyres × 0.065 = 5,000,000 tyres

■ The avoided CO_2 emission by fuel efficient tyres sold in 2020: ▲6.36 million t-CO_2

For passenger vehicles ▲56.8 kg-CO_2/tyre × 73,000,000 tyres = ▲4.15 million t-CO_2
For trucks/buses ▲442.3 kg-CO_2/tyre × 5,000,000 tyres = ▲2.21 million t-CO_2

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[40] "Data for the Domestic Demand for Automotive tyres in 2011" Japan Automobile Tire Manufacturers Association, Inc. (general incorporated association)

[41] "Current Situation Concerning Plastic Highly Functional Materials and Future Outlook in 2011" Fuji Chimera Research Institute, Inc.

Table 18. The avoided CO_2 emissions by fuel efficient tyres sold in 2020

1) Forecast demand for 2020 and The avoided CO_2 emissions per tire	For passenger vehicles	For trucks/buses	Total
• Forecast demand for tyres (thousand tyres)	73,000	5,000	78,000
• Difference in The avoided CO_2 emission per tire as achieved by fuel efficient tyres (kg-CO_2/tyre)	▲56.8	▲442.3	
2) The avoided CO_2 emission (10,000 t-CO_2)	▲415	▲221	▲636

ii) CO_2 emissions in the procurement of raw materials, manufacture and disposal for finished tyres and chemical products

a. CO_2 emissions during the stages of raw material procurement to the manufacture of materials, production, distribution, disposal and recycling of finished tyres (excluding those during use): 3.19 million tons

For passenger vehicles

Fuel efficient tyres 33.1 kg-CO_2/tyre* × 73,000,000 tyres = 2,416 kt-CO_2

* Using Table 15, 95.6/4+28.0/4+6.0/4+2.8/4 = 33.1 kg-CO_2/tyre

For trucks/buses

Fuel efficient tyres 154.1 kg-CO_2/tyre × 5,000,000 tyres = 771 kt-CO_2

b. CO_2 emissions during the procurement of raw materials and the manufacture of chemical products (excluding those during use and disposal): 1.74 million tons

For passenger vehicles

Fuel efficient tyres 18.5 kg-CO_2/tyre × 73,000,000 tyres = 1,351 kt-CO_2

For trucks/buses

Fuel efficient tyres 76.7 kg-CO_2/tyre × 5,000,000 tyres = 384 kt-CO_2

CO_2 emissions during the procurement of raw materials, manufacture and disposal of chemical products have been calculated using the following table (extracted from the Guideline of the Japan Automobile Tire Manufacturers Association).

Table 19. Composition ratio of raw materials in tyres and CO_2 emissions per tire

	For passenger vehicles (PCR)				For trucks/buses (TBR)			
	Composition of raw materials		GHG emissions (kg-CO_2e/tyre)		Composition of raw materials		GHG emissions (kg-CO_2e/tyre)	
	Non fuel efficient	Fuel efficient	Non fuel efficient	Fuel efficient	Non fuel efficient	Fuel efficient	Non fuel efficient	Fuel efficient
New rubber	100.0	100.0	–	–	100.0	100.0	–	–
Natural rubber	39.0	46.4	1.0	1.1	77.0	78.8	12.7	12.9
Synthetic rubber	**61.0**	**53.6**	**6.1**	**4.8**	**23.0**	**21.2**	**14.3**	**13.0**
Carbon black	**50.0**	**41.3**	**6.7**	**5.0**	**52.0**	**47.3**	**43.1**	**38.8**
Process oil	**8.0**	**9.6**	**0.5**	**0.6**	**2.0**	**1.8**	**0.8**	**0.7**
Total for organic rubber chemicals	**8.0**	**13.1**	**3.1**	**4.6**	**10.0**	**8.3**	**24.0**	**19.7**
Non-organic compounding agents	**7.0**	**22.8**	**–**	**–**	**9.0**	**9.9**	**–**	**–**
Zinc oxide	**3.0**	**3.4**	**0.3**	**0.3**	**5.0**	**4.4**	**2.6**	**2.3**
Sulfur	**3.0**	**2.5**	**0.001**	**0.001**	**3.0**	**2.7**	**0.006**	**0.005**
Silica	**1.0**	**16.9**	**0.1**	**1.3**	**1.0**	**2.8**	**0.5**	**1.5**
Total for fibers	**10.0**	**8.0**	**2.7**	**1.9**	**0.0**	**0.4**	**0.0**	**0.7**
Steel cord	15.0	14.1	1.5	1.3	33.0	31.5	21.0	19.9
Bead wire	8.0	9.5	0.8	0.9	11.0	13.3	7.0	8.4
Total	206.0	218.4	22.8	21.7	217.0	212.5	126.2	117.9
Total for chemical products			19.5	18.5			85.3	76.7

Note 1: The composition of raw materials has been specified assuming that the weight of new rubber is 100.
Note 2: CO_2 emissions during the transportation of raw materials are not included.
Note 3: The underlined values indicate those for chemical products.

4.6 Saving energy 4 - LED-related materials

(1) Overview of LED lighting

An LED (light emitting diode) is a semiconductor (diode) that emits light when electric current passes through it. A light bulb that uses an LED as its light source is an LED light bulb. LED light bulbs have attracted attention as an energy-efficient form of lighting of the next generation, together with organic EL lighting. These forms of lighting hold the promise of a high level of light-emitting efficiency (lm/W), which is one of the indices of energy reduction. LED light bulbs are being increasingly used in various applications that include lighting, the display devices of IT equipment and electronic equipment, and automotive lamps, etc.

[1] Details of the avoided CO_2 emissions

Long service life, with low power consumption.

[2] Features of the LED light bulbs

- High light-emitting efficiency (lm/W)
  LED light bulbs: 150 lm/W (expected value around 2015[42])
  Fluorescent lamps: Around 100 lm/W (at present)
  Incandescent light bulbs: Around 15 lm/W (at present)
- Small, with a long service life and small heat generation
- Superior light-adjusting functions
  There is the possibility that it will become a key technology in energy utilization by being incorporated into energy management systems, such as HEMS/BEMS.

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[42] Japan LED Association, "Technical Roadmap of White LEDs" (2008)

[3] Examples of chemical products used in LEDs

- LED packages, chips
- LED printed circuit boards (GaAs, GaP, GaN, SiC, sapphire)
- Organic metals for use in MO-CVD
- LED sealing materials (epoxy, silicone)
- LED resin packages (reflector resins: polyamide based, silicone, liquid crystal polymer)
- LED ceramic packages
- Fluorescent substance, printed circuit boards with high heat dissipation, high-reflectance film, paint for improving luminance, etc.

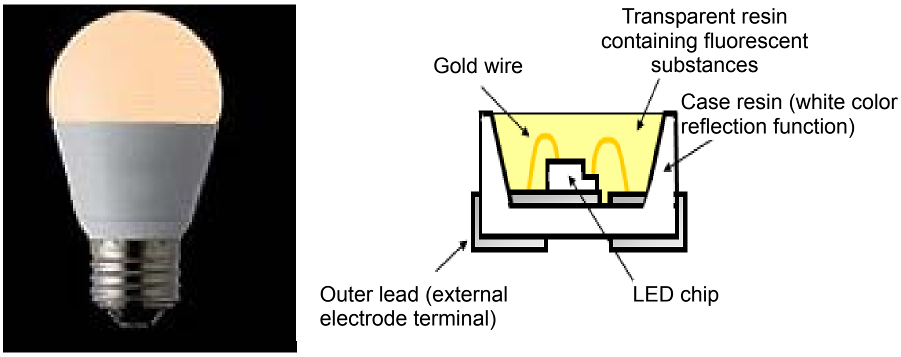

Fig. 32. Appearance and construction of an LED light bulb

(2) Conditions of assessment

[1] Object of assessment and object of comparison

Item	Contents
Chemical products/technologies that that help reduce CO_2 emissions	Materials for LEDs
Product under assessment	LED light bulb
Product for comparison	Incandescent light bulb
Year under assessment / period under assessment	Year 2020 / period in which the products manufactured during the year under assessment will be used until the end of their life

[2] System boundary (scope of assessment that has been carried out)

All the processes related to the procurement of raw materials, manufacture of products, usage and disposal for finished products (light bulbs) fall within the scope of the assessment. Concerning disposal, it has been assumed that the products will be discharged as noncombustible trash and will be disposed of by landfill after intermediate treatment.

[3] Functional unit

Functions that provide the same brightness during the same period irrespective of whether the product is an LED light bulb or an incandescent light bulb.

[4] Preconditions for calculating the CO_2 emissions

- The product service life of an LED is 25,000 hours. Due to the difference in product service life, it takes 25 incandescent light bulbs to substitute for one LED light bulb.

- Annual reduction in CO_2 emissions per unit of the level of adoption
  With the life of one LED light bulb, i.e. 25,000 hours, used as the datum, a comparison of CO_2 emissions in the entire life cycle has been made with regard to the number of required light bulbs that meet the datum (one LED light bulb for 25 incandescent light bulbs).

Table 20. Product under assessment made from LED-related materials (LED lighting) and product for comparison (incandescent light bulb)[43]

		Product under assessment LED light bulb	Product for comparison Incandescent light bulb
Product service life	(hours)	25,000	1,000
Number of units required for 25,000 hours of lighting	(piece)	1	25
Power consumption	(W/piece)	8	40

(3) Result of assessment

[1] Calculation of the avoided CO_2 emissions

- Comparison of CO_2 emissions from electricity used during the stages from raw material procurement through to manufacture and disposal

  Although the power consumption per piece during manufacture is around 16 times greater with LED light bulbs (LED: 9.9 kWh/piece; incandescent: 0.612 kWh/piece), the subtotal becomes smaller with LED light bulbs if the consumption is converted to that per unit service life of the product (25,000 hours).
- Comparison of power consumption during use

  Since LED light bulbs have low power consumption per piece (LED: 8 W/piece; incandescent: 40 W/piece) and because they have a greatly extended service life (LED: one piece for 25,000 hours; incandescent: 25 units for 25,000 hours), the reduction in power consumption during use leads to substantial avoided CO_2 emissions.
- CO_2 emission factor (CO_2 emissions per kWh of power generation)

  Utility power: 0.33 kg-CO_2/kWh[44]
- The avoided CO_2 emission per LED light bulb: ▲266 kg-CO_2 (25,000 hours)

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[43] OSRAM " Life Cycle Assessment of Illuminants:A Comparison of Light Bulbs, Compact Fluorescent Lamps and LED Lamps" (December 2009)

[44] Action Plan for Low Carbon Society Target value of the Federation of Electric Power Companies of Japan Target value for Year 2020 as of 2009

Table 21. The avoided CO_2 emissions per piece of LED light bulb[43]

Process being assessed	LED light bulb	Incandescent light bulb
1. During procurement of raw materials - manufacture/assembly		
Power consumption during procurement of raw materials - manufacture/assembly (kWh/piece)	9.9	0.612
Number of units manufactured corresponding to the service life of an LED product (piece)	1	25
CO_2 emissions from electric power[44] (kg-CO_2/kWh)	0.33	0.33
Subtotal: CO_2 emissions related to the procurement of raw materials to manufacture (kg-CO_2)	**3.27**	**5.05**
2. During use		
Power consumption during use for 25,000 hours (kWh)	200	1,000
CO_2 emissions from electric power (kg-CO_2/kWh)	0.33	0.33
Subtotal: CO_2 emissions related to use (kg-CO_2)	**66**	**330**
3. Landfill		
Number of units disposed of by landfill (pieces)	1	25
CO_2 emissions related to landfill (kg-CO_2/piece)	0.002	0.009
Subtotal: CO_2 emissions related to disposal (kg-CO_2)	**0.002**	**0.225**
CO_2 emissions in the entire life cycle (kg-CO_2) (Total of [1] through [3])	**69.272**	**335.275**
The avoided CO_2 emission (kg-CO_2/25,000 hours)	**▲266**	

[2] Effect of adoption throughout Japan

i) The avoided CO_2 emission over the life cycle

The avoided CO_2 emission relative to the expected volume of sales in Japan overall in 2020 has been calculated.

- Expected annual sales of LED light bulbs in 2020[45]: 28 million units
- The avoided CO_2 emission: ▲7.45 million tons (10 years)
  266 kg-CO_2/piece × 28,000,000 pieces = 7,448 kt-CO_2

Table 22. The avoided CO_2 emissions by LED light bulbs sold in 2020

1) Forecast sales volume in 2020 and avoided CO_2 emissions	
• Sales volume of LED light bulbs (million units)	28
• Avoided CO_2 emission per LED light bulb (kg-CO_2/piece)	▲266
2) Avoided CO_2 emission (10,000 t-CO_2)	▲745

ii) CO_2 emissions over the life cycle of LED light bulbs

- CO_2 emissions from LED light bulbs: 1.94 million tons
  69.272 kg-CO_2/piece × 28 million pieces = 1,940 kt-CO_2

iii) CO_2 emissions during the procurement of raw materials, manufacture and landfill for finished products (excluding those during use)

- CO_2 emissions from finished products (raw materials/manufacture/landfill): 92,000 tons
  3.272 kg-CO_2/piece × 28 million pieces = 91.6 kt-CO_2

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[44] Electric power emission factor (power receiving end) in FY2020: Target value of the Federation of Electric Power Companies of Japan

[45] Fuji Chimera Research Institute, Inc. "General Investigation of LED Related Markets in 2010 (first volume)"

4.7 Saving energy 5 - thermal insulation for housing

(1) Overview of thermal insulation for housing

Of the energy consumed by housing, by far the greatest is that used in heating, and to a lesser extent, cooling. To thoroughly exploit the energy savings associated with heating and cooling, it is necessary to improve the thermal insulation performance and air tightness of housing. This is because, when there is a temperature differential between the inside and the outside of a house, heat flows out or in through the walls, ceilings, roof, floor, windows, entrances, etc., even when a comfortable temperature has been achieved indoors through cooling/heating. To avoid this energy loss, the thermal insulation performance of housing can be improved by covering the inside of a room with thermal insulation as though wrapping the house interior.

[1] Details of the avoided CO_2 emissions

To reduce power consumption in cooling and heating by means of thermal insulation

[2] Types of thermal insulation for housing currently used

- Materials that use rock wool, glass wool, etc.
- Those that use resin materials mainly consisting of polystyrene and urethane

In this assessment, a comparison has been made between housing that uses thermal insulation and housing that does not use it. Expanded polystyrene foam is used as the object of assessment because the difference in CO_2 emissions between glass wool and resin materials is small in terms of LCA. (Although thicker units of glass wool are used during construction, as compared with resin materials, to obtain the same degree of thermal insulation, the emissions during the manufacture of glass wool are small). Another reason for using expanded polystyrene foam, which is a resin material, as the object of assessment is that it accounts for the majority of Japan's shipment volumes.

[3] Features of expanded polystyrene foam[46]

- A typical foamed-plastic-based thermal insulation material developed in Germany
- The material is called EPS, which is an acronym for expanded polystyrene.

Manufacturing method: Raw material in the form of beads consisting of polystyrene resins and hydrocarbon-based foaming agents are subjected to preparatory foaming. They are then foamed to about 30 to 80 times in size by putting them into molds and heating them. Various shapes of products can be manufactured by changing the shape of the mold.

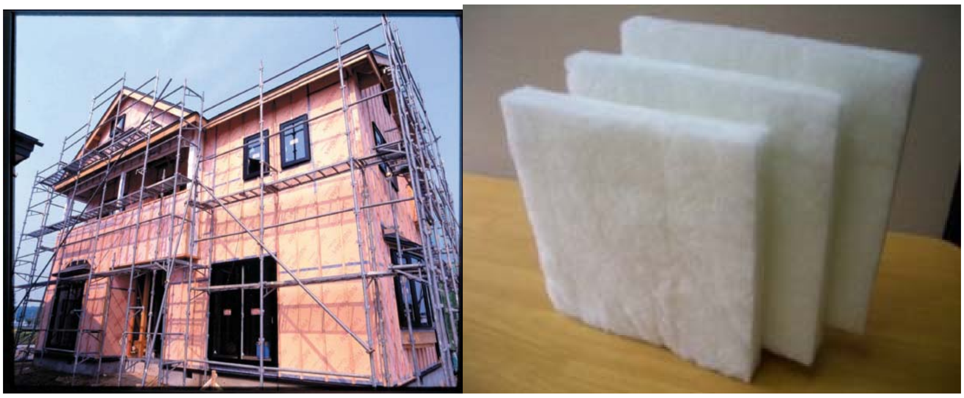

Fig. 33. Thermal insulation

[4] Examples of chemical products used in thermal insulation

- Extruded polystyrene foam, expanded polystyrene foam
- Hard urethane foam, urethane resin, propylene oxide
- Highly expanded polystyrene foam, phenol foam
- PVC sash, PVC resin
- Heat shielding paint, heat shielding sheets, heat shielding film, highly thermally insulated curtains, nonwoven fabrics, alumina fiber

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[46] "Overview of EPS Construction Materials" from the website of the Japan Expanded Polystyrene Association, EPS Construction Materials Promotion Department http://www.epskenzai.gr.jp/what/what01.html

(2) Conditions of assessment

[1] Object of assessment and object of comparison

Item	Contents
Chemical products/technologies that that help reduce CO_2 emissions	Thermal insulation for housing (expanded polystyrene foam, etc.)
Product under assessment	Housing that uses thermal insulation
Product for comparison[note)]	Housing before the energy-saving standard of 1980 (housing that does not use thermal insulation)
Year under assessment / period under assessment	Year 2020 / period in which the products manufactured during the year under assessment will be used until the end of their life

Note): An investigation carried out after the first edition was issued revealed that, with regard to the energy-saving performance of existing housing in Japan (about 50 million houses), housing built prior to the introduction of the energy-saving standard in 1980 (whose outer walls and ceiling are not thermally insulated) accounts for 55% (about 27.5 million houses). The number of new houses being built per year is currently about 800,000 (FY2010). Assuming that old houses are demolished and replaced with new houses, it is considered that replacing an old house with a new house takes at least 34 years. The Ministry of Land, Infrastructure, Transport and Tourism has also announced a policy to make it mandatory in 2020 to build houses that meet the energy-saving standard of 1999.

Therefore, this report uses housing built before the energy-saving standard of 1980 as the product for comparison based on the scenario that housing built before this standard will be replaced by housing that meets the energy-saving standard of 1999.

[Energy-saving performance of existing housing (about 50 million houses)]

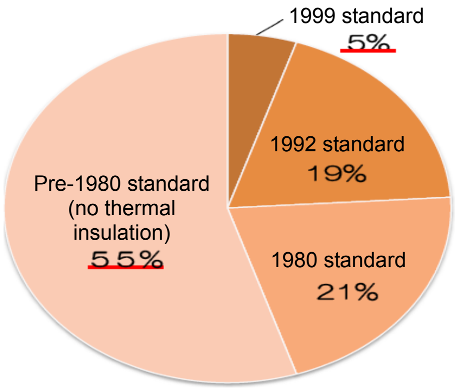

Fig. 34. Energy-saving performance of existing housing (about 50 million houses)[47]

[2] System boundary (scope of assessment that has been carried out)

- Processes of housing to be assessed that uses thermal insulation
    a. Processes related to the procurement of raw materials through to manufacture and the disposal of thermal insulation. Incineration has been specified as the form of disposal.
    b. Usage processes for housing (mainly air conditioning)
- Processes of housing to be assessed that does not use thermal insulation
    a. Usage processes for housing only (mainly air conditioning)
- Processes not assessed
    a. Construction work for the housing itself
    b. Energy consumption other than that of air conditioning during use (e.g. gas stoves, etc.)
    The reason for excluding the use of gas stoves and suchlike is that the difference in CO_2 emissions is negligible, irrespective of whether thermal insulation is used or not.

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[47] The 15th Energy Subcommittee of the Advisory Committee for Natural Resources and Energy (December 2011)

[3] Functional unit

- Functions of housing that enable conditions such as the prescribed space and prescribed temperatures to be achieved in a prescribed period.

(If no thermal insulation is used, cool air and warm air generated by air conditioners and heating systems that are used in housing are likely to be lost as compared with housing that uses thermal insulation, and so more electricity and fuel will be consumed to compensate for the loss of cool air and warm air.)

[4] Preconditions for calculating the avoided CO_2 emissions

- Number of years that each dwelling is used[48]: Detached houses 30 years; apartments 60 years

Assessment has been carried out assuming that the housing will be used for the same number of years irrespective of whether thermal insulation is used or not.

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[48] Japan Expanded Polystyrene Recycling Association "EPS Product Environmental Load (LCI) Analysis and Investigation Report" (April 2007)

(3). Result of assessment

[1] Calculation of the avoided CO_2 emissions

When thermal insulation is used, the CO_2 emissions required for the manufacture of thermal insulation increase as compared with cases in which it is not used. However, when the housing is used, cases where thermal insulation is used involve smaller CO_2 emissions, thereby helping to reduce emissions. Also, there is a regional difference in the avoided CO_2 emissions per dwelling until the end of its life (detached houses: 30 years; apartments: 60 years)[48]. The reduction is 9 tons - 45 tons/dwelling in the case of detached houses, or about 26 tons/dwelling on average, and 44 tons - 170 tons/dwelling in the case of apartments, or about 105 tons/dwelling on average.

- The avoided CO_2 emissions :Detached houses Average ▲25,975 kg-CO_2/dwelling (30 years)
  Apartments Average ▲104,705 kg-CO_2/dwelling (60 years)

Table 23. The avoided CO_2 emissions per dwelling for detached houses (unit: kg-CO_2/dwelling·30 years)

Region	CO_2 emissions during raw material procurement - manufacture of thermal insulation	The avoided CO_2 emissions during use of housing	CO_2 emissions during disposal of thermal insulation	Total
Sapporo	2,295	▲49,443	2,412	▲44,736
Morioka	1,687	▲40,564	1,773	▲37,104
Sendai	1,520	▲28,613	1,598	▲25,495
Tokyo	1,520	▲16,642	1,598	▲13,524
Kagoshima	1,520	▲12,140	1,598	▲9,022
Average	**1,709**	▲29,480	**1,796**	▲25,975

Table 24. The avoided CO_2 emissions per dwelling for apartments (unit: kg-CO_2/dwelling·60 years)

Region	CO_2 emissions during raw material procurement - manufacture of thermal insulation	The avoided CO_2 emissions during use of housing	CO_2 emissions during disposal of thermal insulation	Total
Sapporo	1,145	▲173,405	1,204	▲171,056
Morioka	855	▲146,661	899	▲144,908
Sendai	714	▲100,622	751	▲99,157
Tokyo	687	▲65,361	722	▲63,952
Kagoshima	687	▲45,861	722	▲44,452
Average	**818**	▲106,382	**859**	▲104,705

[2] Effect of adoption throughout Japan

i) The avoided CO_2 emissions over the life cycle

Based on the aforesaid result of assessment per dwelling on average, the avoided CO_2 emissions has been obtained for which the end of the life of new dwellings built in 2020 has been taken into account, by multiplying the value by the number of new detached houses or apartments to be built in 2020.

- Number of dwellings in which thermal insulation will be adopted in 2020[49]:
  1 million houses
- Ratio of detached houses/apartments[50]: Detached houses 36.7% (367,000 houses)
  Apartments 63.3% (633,000 houses)
  * Calculation process: Calculated from the ratio of the number of apartments in a housing development project to the number of new detached houses to be built
- The avoided CO_2 emission due to the thermal insulation in new houses to be built in 2020:
  ▲76 million tons

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[49] Specified based on the "Thermal Insulation Materials Market White Paper" (2009 Edition) by the Yano Research Institute Ltd.

[50] Ministry of Land, Infrastructure and Transport "Construction Statistics Annual Report" (2006)

Table 25. The avoided CO_2 emissions due to the thermal insulation used in new houses to be built in 2020

1. Number of houses that will adopt thermal insulation in 2020	
• Detached houses	367,000 dwellings
• Apartments	633,000 dwellings
[2] The avoided CO_2 emissions per dwelling due to the adoption of thermal insulation	
• Detached houses (for 30 years) (t-CO_2/dwelling)	▲26
• Apartments (for 60 years) (t-CO_2/dwelling)	▲105
[3] The avoided CO_2 emissions	
• Detached houses (for 30 years) (10,000 t-CO_2)	▲950
• Apartments (for 60 years) (10,000 t-CO_2)	▲6,650
Total (10,000 t-CO_2)	▲7,600

ii) CO_2 emissions per dwelling in the procurement of raw materials, manufacture and disposal of chemical products (excluding those during use)

- Chemical products (raw materials/manufacture/disposal):
  Detached houses Average 3,505 kg-CO_2/dwelling
  Apartments Average 1,677 kg-CO_2/dwelling
- CO_2 emission from chemical products (raw materials/manufacture/disposal):
  2.35 million tons

4.8 Saving energy 6 - Hall effect devices and Hall effect ICs

(1) Roles of DC brushless motors and Hall effect devices

The indoor and outdoor units of an air conditioner are equipped with motors for fans. Motors can be classified into DC brushless motors and AC motors (induction motors). An air conditioner equipped with DC brushless motors is called an inverter air conditioner. It enables the voltage, current, and frequency to be controlled, making it possible to control the temperature more minutely than that in the case of a non-inverter air conditioner (equipped with AC motors), thereby reducing power consumption. Conventionally, AC motors were used for the fans of the indoor and outdoor units of an air conditioner. But due to Japan's stringent energy-saving regulations, DC brushless motors that have superior energy efficiency are used.

The DC brushless motors now in widespread use are highly compact and minimize loss reduction by incorporating Hall effect devices, which enable the rotation to be precisely controlled. Hall effect devices offer three advantages: [1] high durability due to the contactless detection of positions, [2] good resistance to impurities, such as powdery dirt, dust, oil, etc. because magnetism is used for detection, and [3] miniaturization, weight reduction, and loss reduction.

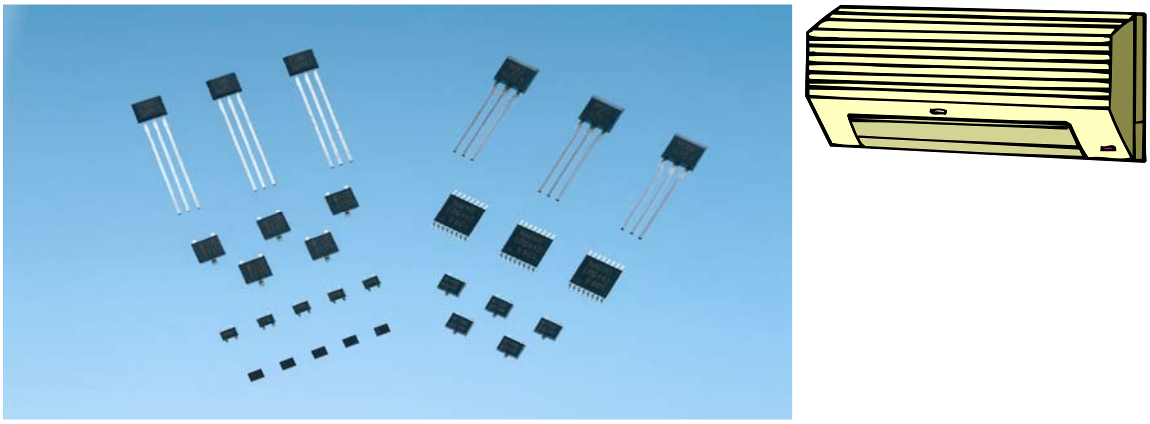

Fig. 35. Hall effect device, Hall IC, and air conditioner

[1] Details of the avoided CO_2 emissions

Inverter air conditioners that use DC motors consume less power than that of conventional non-inverter air conditioners.

[2] Features and type of air conditioners

- Inverter air conditioner: An air conditioner equipped with DC brushless motors. These motors have higher efficiency than AC motors, and help reduce energy consumption.
- Non-inverter air conditioner: A conventional air conditioner equipped with AC motors.

(2) Conditions of assessment

[1] Object of assessment and object of comparison

Item	Contents
Chemical products/technologies that that help reduce CO_2 emissions	Hall effect device, Hall effect IC
Product under assessment	Inverter air conditioner (an air conditioner equipped with DC brushless motors)
Product for comparison	A non-inverter air conditioner equipped with AC motors
Year under assessment / period under assessment	Year 2020 / period in which the products manufactured during the year under assessment will be used until the end of their life

[2] System boundary (scope of assessment that has been carried out)

The process to be assessed herein is shall that related to the use of air conditioners.

Concerning CO_2 emissions over the life cycle of air conditioners, those during the stage of usage account for the majority, while those during the stages of procurement of raw materials, manufacture, distribution, and disposal are relatively small[51]. Also, since DC motors are generally smaller than AC motors[52], it can be considered that CO_2 emissions from DC motors during the stages of procurement of raw materials, manufacture/distribution, and disposal are smaller. Based on these considerations, the cases of offsets in the guidelines[53] have been applied.

No data are available in Japan concerning CO_2 emissions from inverter and non-inverter air conditioners during the stages of procurement of raw materials, manufacture/distribution, and disposal that have been calculated under similar conditions. Also, no data are available from various foreign countries concerning CO_2 emissions during the stages of procurement of raw materials, manufacture/distribution, and disposal. Therefore, it has been decided that CO_2 emissions only during the usage stage will be included in the calculation of CO_2 emissions.

[3] Functional unit

Functions of cooling and heating to the same level during the same period both for inverter air conditioners and non-inverter air conditioners

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[51] According to the website of Daikin Industries, Ltd., of the life cycle CO_2 emissions from 2.8 kW-class air conditioners for housing (those for FY2010), the emissions in the stage of usage accounts for 95.2%. http://www.daikin.co.jp/csr/environment/production/01.html

[52] According to the website of Fujitsu General, the total weight of the motors for outdoor and indoor units is 2.3 kg for DC motors and 2.6 kg for AC motors. http://www.fujitsu-general.com/jp/products/motor/lineup.html

[53] Guidelines for Calculating the avoided CO_2 emissions of the Japan Chemical Industry Association (general incorporated association)

[4] Preconditions for calculating emission abatement

- Product service life[54]: 14.8 years (both types of products have the same service life)
- Annual power consumption: Inverter air conditioner 845 kWh/unit[55]
  Non-inverter air conditioner
  1,268 kWh/unit (845 kWh/year × 1.5 times)
  The value for non-inverter air conditioners has been specified by making use of the following ratio of motor efficiency.
- Motor efficiency: Since no information on power consumption under the same conditions was available, power consumption during the stage of usage of a non-inverter air conditioner equipped with AC motors has been estimated by using the efficiency of each motor. Regarding the efficiency of AC motors, CO_2 emissions have been calculated assuming that the power consumption of the non-inverter air conditioner is 1.5 times that of an inverter air conditioner. This figure was obtained in reference to the following examples.

Table 26. Motor efficiency

	AC motor efficiency	DC motor efficiency	
Example 1[56]	55%	80%	About 1.5 times
Example 2[57]	70%	85%	About 1.2 times
Example 3[58]	39%	58%	About 1.5 times

- Rate of adoption of inverter air conditioners[59]

  Currently available data for the adoption rate of inverter air conditioners that are being used in each region are shown below. It is necessary to predict the adoption rate of inverter air conditioners in 2020 when calculating the effects of adoption in 2020. Since no such information is available, the adoption rate currently available is used as a conservative estimate.

Table 27. Rate of adoption of inverter air conditioners in each region

	Japan	China[60]	Asia	North America	Central/South America	Europe	Others
Rate of adoption	100 %	30 %	10 %	0 %	0 %	30 %	10 %

- Forecast quantity of air conditioners to be delivered for home use:

Japan	7,950,000 units
Globally	186,160,000 units (including Japan)

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[54] FY2010 Report on "Investigation on the Number of Years Elapsed, Etc. for Four Used Electric Home Appliances" (March 2011) Association for Electric Home Appliances

[55] Ministry of Economy, Trade and Industry, Agency for Natural Resources and Energy "Energy-saving Performance Catalogue" (Winter, 2011)
Simple average values of typical energy-saving models both for cooling and heating/wall type/2.8 kW-class cooling capacity

[56] Example 1 Dow Chemical Company "Heat and the Environment" (2006) (20rps)

[57] Example 2 Dow Chemical Company "Heat and the Environment" (2006) (40rps)

[58] Example 3 Website of Uyemura & Co., Ltd. http://kami-kogyo.co.jp/main2.html

[59] Material of the Global Environment Subcommittee, Central Environment Council, Ministry of the Environment (Daikin Industries' Approaches for Addressing Environmental Problems)
www.env.go.jp/council/06earth/y0611-02/mat02_4.pdf

[60] Website of Daikin Industries, Ltd. http://www.daikin.co.jp/csr/environment/production/02.html

Table 28. Forecast demand trends of air conditioners for home use in each region

In thousand units

	2020 (expected)		
	Quantity delivered[61]	Inverter air conditioner	Non-inverter air conditioner
Japan	7,950	7,950	0
China	110,730	33,219	77,511
Asia	23,710	2,371	21,339
North America	15,500	0	15,500
Central/South America	12,800	0	12,800
Europe	11,120	3,336	7,784
Others	4,350	435	3,915
Total	186,160	47,311	138,849

Note 1: The numbers of units of inverter air conditioners and non-inverter air conditioners have been calculated by using the adoption rate of inverters.

Note 2: The forecast values for 2020 assume that the demand forecast for each region in 2017 will remain flat.

(3) Result of assessment

[1] Calculation of the avoided CO_2 emissions

◆During the stage of procurement of raw materials

As indicated in [2] System boundary in the preceding section, an offset is made for the stage of procurement of raw materials, so it has been excluded from the object of calculation.

◆During the manufacturing/distribution stage

As indicated in [2] System boundary in the preceding section, an offset is made for the stage of manufacture/distribution, so it has been excluded from the object of calculation.

◆During the usage stage

- Products under assessment (inverter air conditioners)

  CO_2 emissions during the usage stage of inverter air conditioners have been calculated based on 845 kWh/year[62], assuming that the product service life is 14.8 years as indicated in (2) Conditions of assessment.

- Products for comparison (non-inverter air conditioners)

  CO_2 emissions from inverter air conditioners during their usage stage have been calculated assuming that the power consumption is 1,268 kWh/year (845 kWh/year × 1.5 times) by referring to the efficiency indicated in (2) Conditions of assessment. Regarding the basic unit for CO_2 emissions associated with the use of electricity, the same data as those of the products under assessment in [1] in the preceding section have been used.

◆During the disposal stage

As indicated in [2] System boundary in the preceding section, an offset is made for the disposal stage, so it has not been included in the object of calculation.

The avoided CO_2 emissions

Based on the CO_2 emissions from inverter air conditioners and non-inverter air conditioners over their life cycle, the avoided CO_2 emissions per functional unit of inverter air conditioners is as follows.

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[61] Fuji Chimera Research Institute, Inc. "2012 General Investigation of Worldwide Electronics Markets"

[62] Ministry of Economy, Trade and Industry, Agency for Natural Resources and Energy "Energy-saving Performance Catalogue" (Winter, 2011) http://www.enecho.meti.go.jp/policy/saveenergy/seinoucatalog_2011winter.pdf

Table 29. Preconditions and the CO_2 emission factor of electric power in each region

		DC brushless motor	AC motor
Processes related to those during use			
Annual power consumption [kWh/Year/Unit]		845	1,268
Number of years of operation		14.8	14.8
Total electric energy in the operating years [kWh/unit]		12,506	18,766
CO_2 emission factor of electric power[63] [kg-CO_2/kWh]	Japan	0.330	0.330
	China	0.743	0.743
	Asia	0.745	0.745
	North America	0.466	0.466
	Central/South America	0.175	0.175
	Europe	0.326	0.326
	Others	0.500	0.500
CO_2 emissions related to use [kg-CO_2/unit]	Japan	**4,127**	**6,190**
	China	**9,292**	**13,938**
	Asia	**9,317**	**13,975**
	North America	**5,828**	**8,742**
	Central/South America	**2,189**	**3,283**
	Europe	**4,077**	**6,115**
	Others	**6,253**	**9,380**
The avoided CO_2 emissions [kg-CO_2/unit](14.8 years)	Japan	2,063	
	China	4,646	
	Asia	4,658	
	North America	2,914	
	Central/South America	1,094	
	Europe	2,038	
	Others	3,127	

[2] Effect of adoption throughout Japan

i) The avoided CO_2 emissions over the life cycle

- Expected annual quantity of inverter air conditioners to be delivered in 2020: 7.95 million units
- The avoided CO_2 emission by inverter air conditioners to be sold in 2020

  Inverter air conditioner ▲2,063 kg-CO_2/unit × 7.95 million units = ▲16.4 million t-CO_2 (14.8 years)

Table 30. The avoided CO_2 emissions by inverter air conditioners to be sold in 2020 in Japan

1) Expected quantity to be delivered and avoided CO_2 emissions in 2020		Inverter air conditioner
• Number of inverter air conditioners to be delivered	(10,000 units)	795
• Reduction in CO_2 emissions by inverter air conditioners	(kg-CO_2/unit)	▲2,063
2) The avoided CO_2 emission	(10,000 t-CO_2)	▲1,640

ii) CO_2 emissions from inverter air conditioners over their life cycle (excluding raw materials/manufacture/disposal)

CO_2 emissions from inverter air conditioners over their life cycle: 32.81 million tons

4,127 kg-CO_2/unit·14.8 years × 7.95 million umits = 32,809 kt-CO_2

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[63] CO_2Emissions from Fuel Combustion 2011 (International Energy Agency). The data in 2009 have been used. For the regions belonging to "Others," world average values have been used.

[3] Effect of global adoption

i) The avoided CO_2 emissions over the life cycle

- The avoided CO_2 emissions in each region
  The avoided CO_2 emissions per unit in each region × Expected quantity of inverter air conditioners to be delivered in the region

Table 31. The avoided CO_2 emissions by inverter air conditioners to be sold globally in 2020

1) Level of adoption in 2020		
• Number of inverter air conditioners to be adopted (10,000 units)	Japan	795
	China	3,322
	Asia	237
	North America	0
	Central/South America	0
	Europe	334
	Others	44
2) The avoided CO_2 emissions		
• The avoided CO_2 emissions per unit (kg-CO_2/unit)	Japan	2,063
	China	4,646
	Asia	4,658
	North America	2,914
	Central/South America	1,094
	Europe	2,038
	Others	3,127
• The avoided CO_2 emissions by inverter air conditioners in 2020 (10,000 tons-CO_2)	Japan	1,640
	China	15,433
	Asia	1,105
	North America	0
	Central/South America	0
	Europe	680
	Others	136
	Total	18,995

- The avoided CO_2 emission globally in 2020: 189.95 million tons (14.8 years)

ii) CO_2 emissions from inverter air conditioners over their life cycle

CO_2 emissions from inverter air conditioners over their life cycle: 379.94 million tons

Japan 4,127 kg-CO_2/unit·14.8 years × 7.95 million units = 32,810 kt-CO_2
China 9,292 kg-CO_2/unit·14.8 years × 33.22 million units = 308,680 kt-CO_2
Asia 9,317 kg-CO_2/unit·14.8 years × 2.37 million units = 22,081 kt-CO_2
North America 5,828 kg-CO_2/unit·14.8 years × 0 units = 0 kt-CO_2
Central/South America 2,189 kg-CO_2/unit·14.8 years × 0 units = 0 kt-CO_2
Europe 4,077 kg-CO_2/unit·14.8 years × 3.34 million units = 13,617 kt-CO_2
Others 6,253 kg-CO_2/unit·14.8 years × 0.44 million units = 2,751 kt-CO_2
Total 379,939 kt-CO_2

4.9 Saving energy 7 - piping materials

(1) Overview of polymer piping materials

Polymer piping includes polyvinyl chloride piping, polyethylene piping, polybutene piping, etc. Together with metal piping (carbon steel pipes, zinc plated steel pipes, resin coated steel pipes, stainless steel pipes, copper pipes, aluminum pipes, cast iron pipes and lead pipes), polymer pipes are widely used as water supply pipes (water distribution piping, water supply piping, drainage piping) and gas pipes (low pressure conduit piping)[64].

Common features shared by polymer piping materials are that they are highly flexible and have superior antiseismic performance. However, since they are degraded by sunlight, they are mainly used as subterranean piping and indoor piping.

Of the various forms of polymer piping, polyvinyl chloride piping has superior anticorrosive properties and it is widely used in drainage equipment and as sewerage pipes in homes. It is also widely used for water supply pipes from waterworks, together with ductile cast iron piping.

Polyvinyl chloride piping is widely used in water supply and sewerage applications, whereas polyethylene piping is used for gas supply. Polyethylene piping features superior antiseismicity partly because the joints can be connected by fusing (electrofusion joining). It is therefore suitable for gas piping in Japan, which is prone to earthquakes.

Aside from the above, familiar polymer piping materials include polyethylene piping and polybutene piping that are used for hot water pipes.

Fig. 36 Polymer pipes

[1] Details of the avoided CO_2 emissions

Low energy consumption because high temperatures are not used during manufacture.

[2] Chemical products used as piping materials

- Polyvinyl chloride (EDC, monomer, polymer)
- High-density polyethylene
- Polybutene

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[64] "Plastic Piping Materials - Recent Trends" (Website of the Building Construction, Civil Engineering, and Plant Equipment of Mitsubishi Chemical/Mitsubishi Resin Group. Topic posted on August 27, 2008) (http://www.construction-biz.com/topics/topics080827.html)

(2) Conditions of assessment

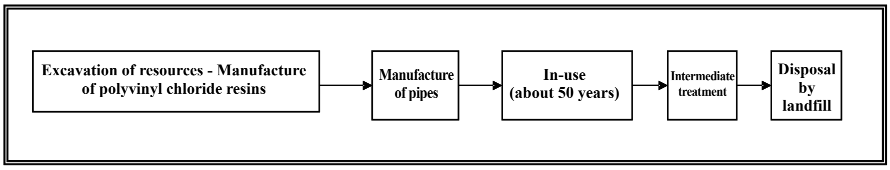
[1] Object of assessment and object of comparison

Item	Contents
Chemical products/technologies that that help reduce CO_2 emissions	Piping materials (polyvinyl chloride piping, etc.)
Product under assessment	Polyvinyl chloride piping
Product for comparison	Ductile cast iron piping
Year under assessment / period under assessment	Year 2020 / period in which the products manufactured during the year under assessment will be used until the end of their life

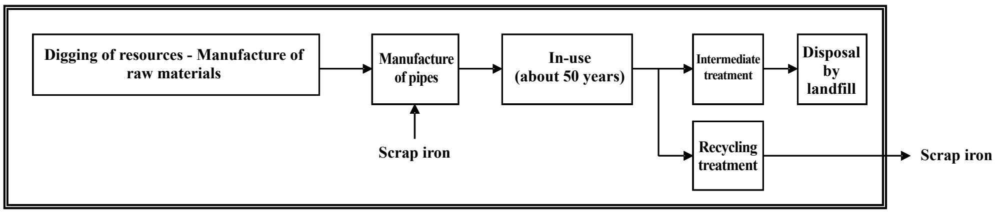
[2] System boundary (scope of assessment that has been carried out)

The processes assessed herein relate to the procurement of the raw materials for products (procurement of resources - manufacture of unprocessed materials), production (processing) of products, and disposal of products (specified as disposal by landfill after intermediate treatment of the entire quantity). The processes that relate to the stage of product usage and the transportation of products have been excluded from the scope of assessment.

Life cycle flow of pipes made of polyvinyl chloride



Life cycle flow of pipes made of ductile cast iron



Note 1: The double line shows the system boundary (scope of assessment that has been carried out).
Note 2: According to a source, about 90% of the raw materials used in ductile cast iron piping are scrap iron.

Fig.37. System boundary for piping

[3] Functional unit

Functions of piping, the quantity of which is equivalent to 1 kg of polyvinyl chloride piping, 150 mm in diameter.

Since polyvinyl chloride piping and ductile cast iron piping differ in both specific gravity and estimated service life, the corresponding corrections have been made.

[4] Preconditions for calculating the avoided CO_2 emissions

• Weight when the diameter is 150 mm:	polyvinyl chloride piping	6.7 kg/m
	ductile cast iron piping	23.8 kg/m
• Estimated service life:	polyvinyl chloride piping	50 years
	ductile cast iron piping	45 years

- Weight of ductile cast iron piping equivalent to 1 kg of polyvinyl chloride piping when the service life is taken into account: 3.95 kg
- In general, ductile cast iron piping is stronger than polyvinyl chloride piping, and in applications that require a certain level of strength, safety is given preference as a matter of course. However, in this assessment the weight and service life of products were used as the preconditions for assessment, and strength and safety were not incorporated into the result of assessment. For this reason, no substitution by using polyvinyl chloride piping in all the

applications was taken into account. Considering that there will be some applications where no substitution is possible in 2020 with regard to the production volume of polyvinyl chloride piping, moderate assessment was carried out concerning the demand forecast, assuming that the demand will be the same as that in FY2005.

(3) Result of assessment

[1] Calculation of the avoided CO_2 emissions

With regard to CO_2 emissions from 1 kg of polyvinyl chloride piping over its life cycle and CO_2 emissions from 1kg of ductile cast iron piping over its life cycle, examples of assessment contained in the literature are shown below[65]. After corrections are made for the weight required per meter and service life, it is found that the reduction in CO_2 emissions over the life cycle is ▲6.7 kg-CO_2 /kg per kg of polyvinyl chloride piping.

- The avoided CO_2 emission per kg of polyvinyl chloride piping: ▲6.7 kg-CO_2 /kg

Table 32. The CO_2 emissions per kg of polyvinyl chloride piping

	Polyvinyl chloride piping	Ductile cast iron piping
Procurement of raw materials (procurement of resources - manufacture of unprocessed materials) (kg-CO_2/kg)	1.4	0.146
Production (processing) of products (kg-CO_2/kg)	0.1	1.925
Disposal (landfill) of products (kg-CO_2/kg)	0.018	0.018
Total (kg-CO_2/kg)	**1.5**	**2.1**

Table 33. The avoided CO_2 emissions per kg of polyvinyl chloride piping

	Polyvinyl chloride piping	Ductile cast iron piping
Weight of 150 mm in diameter/per meter in length (kg)	6.7	23.8
Estimated service life (years)	50	45
Weight equivalent to 1 kg of polyvinyl chloride piping (kg)	1.0	3.95
The CO_2 emissions (kg-CO_2/kg)	**1.5**	**8.2**
The avoided CO_2 emission (kg-CO_2/kg)	**▲6.7**	–

[2] Effect of adoption throughout Japan

i) The avoided CO_2 emissions over the life cycle

Calculated assuming that the quantity of polyvinyl chloride piping produced in 2020 will be the same as that in FY2005[66].

Reduction in CO_2 emissions due to the substitution of raw materials for equivalent ductile cast piping comes to 3.03 million tons.

In addition, by adding the effect of raw material substitution for the joints used to connect the pipes, the reduction in CO_2 emissions comes to 3.3 million tons.

- The avoided CO_2 emission: ▲3.3 million tons (50 years)

▲6.7 kg-CO_2/kg·50 years × 493,092 t = 3,304 kt-CO_2

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[65] Japan PVC Environmental Affairs Council "Life Cycle Assessment of Polyvinyl Chloride Resin Products" (July 1995)

[66] Website of the Japan PVC Pipe and Fittings Association http://ppfa.gr.jp

Table 34. The avoided CO_2 emissions by polyvinyl chloride piping to be sold in 2020

	Polyvinyl chloride piping	Joints	Total
Estimated quantity to be produced in 2020 (tons) (Assuming that it is equivalent to the values for FY2005)	452,878	40,214	493,092
The avoided CO_2 emission (10,000 tons)	**303**	**27**	**330**

ii) CO_2 emissions in the procurement of raw materials, manufacture, and disposal of chemical products (excluding those during use)

- CO_2 emissions from chemical products (raw materials/manufacture/disposal): 0.74 million tons
  1.5 kg-CO_2/kg·50 years × 493,092 t = 740 kt-CO_2

4.10 Saving energy 8 - materials for desalination plants (RO membranes)

(1) Overview of RO membranes and desalination plants

RO membranes (reverse osmosis membranes) are semipermeable membranes that prevent impurities other than water, such as ions and salts, etc., from permeating at a molecular level. The membranes have the function of separating fresh water from salts, etc.

Permeation is a phenomenon in which solvents transfer from a diluted solution to a more concentrated solution via a semipermeable membrane. The difference in pressure that occurs between the two liquids when the action of permeation has ceased and a balance has been achieved is called osmotic pressure. Reverse osmosis is a phenomenon in which the solvent transfers from the concentrated solution to the diluted solution by applying a pressure greater than the osmotic pressure to the concentrated solution. Utilizing this principle makes it possible to obtain fresh water by allowing only water to permeate through the reverse osmosis membrane when pressure is applied to the solution containing substances to be removed, such as salts, etc. (seawater, etc.). This phenomenon is utilized in desalination technology.

Fig. 38. RO membranes

[1] Details of the avoided CO_2 emissions

Low energy consumption because no heating is required.

[2] Types of desalination plants

- Evaporation process: Method of making distilled water by evaporating seawater
- Membrane process: Method of removing salt content by means of RO membranes

[3] Trend of desalination plants

Desalination using the evaporation process was previously the mainstream process. However, desalination using the membrane process consumes significantly less energy and it has become the mainstream method used in large-scale plants.

In line with the increasing demand for fresh water on a global scale, the trend of increasing demand for larger desalination plants is expected to persist. The membrane process is expected to remain the preferred method as it involves less energy consumption, is able to produce large quantities of fresh water with small running costs, and is more environmentally friendly due to its small CO_2 emissions.

(2) Conditions of assessment

[1] Object of assessment and object of comparison

Item	Contents
Chemical products/technologies that that help reduce CO_2 emissions	Materials for desalination plants (RO membranes)
Product under assessment	Desalination plants that use the RO membrane process
Product for comparison	Desalination plants that use the evaporation process
Year under assessment / period under assessment	Year 2020 / period in which the products manufactured during the year under assessment will be used until the end of their life

[2] System boundary (scope of assessment that has been carried out)

With regard to both the object of assessment and object of comparison, processes related to the manufacture of materials, construction of plants, and the use of desalination plants are included in the system boundary.

The assessment of CO_2 emissions with the use of RO membranes assumes that RO membrane elements are disposed of in landfill as industrial waste. Processes related to the disposal of materials constituting plants other than the RO membrane elements and the transportation process for materials are not included in the system boundary, but CO_2 emissions from each of these processes are negligible.

[3] Functional unit

- Functions that make fresh water from the same volume of seawater.

[4] Preconditions for calculating the avoided CO_2 emissions

- CO_2 emissions reduced per unit of the level of adoption
  The CO_2 emissions generated over the entire life cycle when desalination of 26,000 m^3 of seawater is performed, taken as the datum volume of lifetime desalination with one RO membrane element, are compared with the same volume of desalination performed by the evaporation process.
- Service life of RO membranes: Trial calculation has been made assuming that the life is five years.

(3) Result of assessment

[1] Calculation of the avoided CO_2 emissions

The CO_2 emissions over the entire life cycle of a desalination plant to be assessed (RO membrane process) to produce 26,000 m^3, which is the lifetime desalination per RO membrane element, is 53.0 tons. When compared with the CO_2 emissions of the object of comparison (evaporation process), 335.9 tons, there are ▲282.9 tons of the avoided CO_2 emissions.

- The avoided CO_2 emission per RO membrane element:
  ▲282.9 tons-CO_2/piece (amount of desalination: 26,000 m^3)

Table 35. The avoided CO_2 emissions per piece of RO membrane elements that are the materials of desalination plants[67]

Unit: tons-CO_2/amount of desalination: 26,000 m^3 (per RO membrane element)		Product under assessment	Product for comparison
Manufacture of raw materials Manufacture of plant	Manufacture of RO membrane elements	0.01	–
	Manufacture of the raw materials of RO membrane elements	0.1	–
	Manufacture of raw materials other than RO membrane elements, plant construction	2.2	12.4
Use		50.5	323.5
Disposal	Waste disposal of RO membrane elements	0.15	–
	Plant dismantling Disposal of raw material other than RO membrane elements	(Outside of system boundary)	
Total	**(tons-CO_2/amount of desalination: 26,000 m^3)**	52.96	335.9
The avoided CO_2 emission	**(tons-CO_2/amount of desalination: 26,000 m^3)**	**▲282.9**	

[2] Effect of global adoption

i) The avoided CO_2 emissions over the life cycle

Since the level of adoption of desalination plants in Japan is small and they are more widely adopted overseas, evaluation of the **effect of the global adoption of RO membranes** has been made.

Also, since no objective data on the level of adoption in 2020 is available, the level of adoption[68] material data[69] for 2016, which is the data most closely related, have been used as the data for 2020.

- Global desalination capacity of new RO membranes adopted in 2016:
  About 8.7 million m^3/day
- Volume of desalination per service life of one RO membrane:
  8.7 million m^3/day × 365 days × 5 years = 15.8775 billion m^3
- Number of RO membrane elements required:
  15.8775 billion m^3 ÷ 26,000 m^3 = 610,000 units
- The avoided CO_2 emission (2020; globally): ▲172.57 million tons (5 years)

Table 36. The avoided CO_2 emissions by desalination plants to be constructed globally in 2020

1) Demand forecast for 2020 and the avoided CO_2 emissions	
• Number of RO membrane elements in demand (thousand pieces)	610
• Difference in the avoided CO_2 emissions by RO membrane elements (kg-CO_2/piece)	▲282.9
2) The avoided CO_2 emission (10,000 t-CO_2)	▲17,257

ii) CO_2 emissions from RO membranes over their life cycle

- CO_2 emissions from RO membranes: 32.31 million tons (5 years)

  52.96t-CO_2/piece × 610,000 pieces = 32,306 kt-CO_2

iii) CO_2 emissions in the procurement raw materials, manufacture, and disposal of finished products (excluding those during use)

- CO_2 emission from finished products: 1.5 million tons

  2.46t-CO_2/piece × 610,000 pieces = 1,501 kt-CO_2

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[67] Data provided by Toray Industries, Inc. Estimation for FY2010

[68] Desalination Markets 2010, P. 54

[69] Report of the Council on Competitiveness-Nippon
"Technology for Effective Utilization of Water Treatment and Water Resources [Approach to the Rapidly Expanding Global Water Treatment Market]" (March 18, 2008)

4.11 Saving energy - materials for high-durability apartments

(1) Overview of drying shrinkage-reducing agents

Since large quantities of materials are used during the construction of apartments and office buildings, they are buildings that involve a large amount of CO_2 emissions associated with the consumption of materials. If the durability of buildings can be improved and their service life can be increased, the frequency of rebuilding can be reduced, and consequently CO_2 emissions associated with the consumption of materials can be reduced.

Causes that reduce the durability of concrete that affects the service life of buildings made of reinforced concrete include the following two points.

[1] As a result of the shrinkage of concrete that is constricted by steel bars when it dries, cracks occur and the strength is impaired.

[2] Furthermore, carbon dioxide in the air penetrates through these cracks, neutralizing the concrete and promoting corrosion of the steel bars inside.

Drying shrinkage-reducing agents for concrete are added as admixtures together with water when making ready-mixed concrete. The role of drying shrinkage-reducing agents is to reduce the occurrence of cracks in the concrete that occurs during drying by reducing the capillary tension that occurs when moisture inside the concrete evaporates. The result is improved durability of reinforced concrete, making it possible to extend the service life of buildings made from reinforced concrete.

[1] Details of the avoided CO_2 emissions

Drying shrinkage-reducing agents improve the durability of concrete and enable the service life of apartments to be extended, thereby reducing the number of times apartments are rebuilt, thus saving the resources that are used during construction of apartments.

[2] Major chemicals used to improve the durability of concrete

- Drying shrinkage-reducing agent (special polyoxy alkylene glycol derivative)
- High-performance AE water reducing agent (polycarbonic acid-based high-performance AE water reducing agent)
- Water reducing agent (lignin sulfonic acid salt)

(2) Conditions of assessment

[1] Object of assessment and object of comparison

Item	Contents
Chemical products/technologies that that help reduce CO_2 emissions	Drying shrinkage-reducing agents
Product under assessment	High-durability apartments that have been built using drying shrinkage-reducing agents
Product for comparison	Ordinary apartments
Year under assessment / period under assessment	Year 2020 / period in which the products manufactured during the year under assessment will be used until the end of their life

[2] System boundary (scope of assessment that has been carried out)

Assessment has been carried out on high-durability apartments and ordinary apartments, each during the stages of procurement of raw materials through to manufacture (construction), use/maintenance and management, and disposal. The use of energy in each dwelling, such as that for cooling and heating, is assumed to be the same in both high-durability apartments and in ordinary apartments. Therefore, the simplified calculation method in the Guidelines[70] has been applied, and it has been excluded from the object of assessment by offsetting equivalent portions.

[3] Functional unit

To evaluate residential space for one dwelling to be provided by apartments made of reinforced concrete for 100 years as a functional unit.

[4] Preconditions for calculating the avoided CO_2 emissions

- Assessment period (period of use/product service life)

Service life of high-durability apartments: 100 years[71] (long-term use class)
Service life of ordinary apartments: 50 years[72] (shared dwellings made of steel frames)

High-durability apartments are disposed of after they have been used for 100 years, and ordinary apartments are disposed of after they have been used for 50 years and then will be rebuilt and disposed of after use for additional 50 years. The specifications of the apartments (space, construction, thermal insulation functions, etc.) shall be the same, and at the time of rebuilding ordinary apartments as well, they shall be rebuilt into apartments having equivalent functions.

Table 37. Specifications of an apartment[73]

Region	Tokyo suburbs
Construction	RC-made
Total floor area	7280.85 m^2
Number of floors	9 above-ground floors
Number of dwellings	88 dwellings

(3) Result of assessment

[1] Calculation of the avoided CO_2 emissions

CO_2 emissions from high-durability apartments over their entire life cycle are 271,376 kg-CO_2/apartment, and those from ordinary apartments are 308,174 kg-CO_2/apartment. The avoided CO_2 emissions from high-durability apartments is obtained as the difference between them and those for ordinary apartments. The avoided CO_2 emission that results from extending the service life becomes 36,798 kg-CO_2/apartment. The reason that high-durability apartments involve a larger amount of CO_2 emissions regarding repair is that no repairs are required for ordinary apartments as they are rebuilt after 50 years.

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[70] Guideline for Calculation of the avoided CO_2 emissions - Japan Chemical Industry Association

[71] Japanese Architectural Standard Specifications (JASS5 Reinforced Concrete Work/Architectural Institute of Japan)

[72] Ministry of Finance/PRE Strategy Study Committee
http://www.mof.go.jp/national_property/councils/pre/shiryou/221021_05.pdf

[73] Calculated by referring to examples of apartments in "LCA Policy for Buildings" (3rd Edition) of the Architectural Institute of Japan.

Table 38. The avoided CO_2 emissions per apartment (100 years)

		High-durability apartments	Ordinary apartments
CO_2 emissions associated with construction			
Design and supervision	**(kg-CO_2/apartment)**	**4,517**	**4,493**
New construction (including rebuilding)	**(kg-CO_2/apartment)**	**79,974**	**159,948**
Admixture	**(kg-CO_2/apartment)**	**3,888**	**194**
CO_2 emissions associated with use, maintenance and management			
Mending	**(kg-CO_2/apartment)**	**58,073**	**58,073**
Repair	**(kg-CO_2/apartment)**	**104,571**	**61,349**
Maintenance and management	**(kg-CO_2/apartment)**	**13,635**	**13,635**
CO_2 emissions associated with disposal/recycling	**(kg-CO_2/apartment)**	**6,718**	**10,483**
CO_2 emissions over the entire life cycle	**(kg-CO_2/apartment)**	**271,376**	**308,174**
The avoided CO_2 emission	**(kg-CO_2/apartment)**	**▲36,798**	

Note 1: Mending means CO_2 related to the mending of materials for external finishes such as roofs, external walls, external openings, etc., and the mending of materials for internal finish such as internal floors, internal walls, internal openings, ceilings, etc.

Note 2: Repair means CO_2 related to the repair of materials for external finishes such as roofs, external walls, external openings, etc., and the repair of materials for internal finish such as internal floors, internal walls, internal openings, ceilings, etc.

Note 3: Maintenance and management means CO_2 associated with the provision of security, hygiene and cleaning, elevators, matters related to electrical and mechanical equipment, etc.

[2] Effect of adoption throughout Japan

i) The avoided CO_2 emissions over the life cycle

The avoided CO_2 emissions corresponding to the number of apartments to be built throughout Japan in 2020 has been calculated.

- Number of apartments whose construction will start in 2020: 61,000 apartments

  The number of apartments to be supplied in 2010 is 92,000 apartments[74], and the estimated number[75]of new dwellings whose construction will start in 2020 has been specified as being equal to two thirds of the current value.

  - The avoided CO_2 emission: 2.24 million tons (100 years)

    36,798 kg-CO_2/apartment × 61,000 apartments = 2,244 kt-CO_2

Table 39. The avoided CO_2 emissions due to new high-durability apartments built in 2020

1) Number of apartments to be built in 2020		
• Number of apartments in high-durability apartments to be built	(apartments)	61,000
2) The avoided CO_2 emissions (100 years)		
• The avoided CO_2 emission per apartment	(kg-CO_2/ apartment)	▲36,798
• The avoided CO_2 emission by high-durability apartments to be built in 2020	(10,000 tons-CO_2)	▲224

ii) CO_2 emissions from high-durability apartments over their life cycle

- CO_2 emissions from high-durability apartments: 16.55 million tons

  271,376 kg-CO_2/apartment × 61,000 apartments = 16,553 kt-CO_2

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[74] Number of apartments in apartments to be supplied (material of MLIT) http://www.mlit.go.jp/jutakukentiku/house/torikumi/tenpu/H22stock.pdf

[75] Expected number of houses whose construction will be started (material of METI) http://www.meti.go.jp/policy/jyutaku/jyutaku_vision/files/20070423_06.pdf

iii) CO_2 emissions in the procurement of raw materials and the manufacture of chemical products (excluding those during use and disposal)

- CO_2 emissions in the procurement of raw materials and the manufacture of chemical products: 240,000 tons

3,887 kg-CO_2/apartment × 61,000 apartments = 237.5 kt-CO_2

	CO_2 emissions during manufacture (kg-CO_2/kg of product)	Amount used (t/apartment)	CO_2 emissions (t-CO_2/apartment)
High-durability apartments (Drying and shrinkage agents)[76]	4.815	0.791	3.806
(High-performance AE water reducing agent)[134]	4.815	0.017	0.081
Total	–	0.808	3.887

Note: The amount of admixture used has been calculated by assuming that the amount of cement used in one apartment is 16.9 t.

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[76] MiLCA (database ver. 1.0.6) Data for non-ion surface active agents

5. Conclusions and proposals

5.1 Summary of assessed examples

Table 40. Summary of Assessed Examples

◆ **Examples in Japan**

Product under assessment	Finished products: CO_2 emissions from raw materials to manufacture and disposal (10,000 tons) ( ) shows chemical products	Production amount (FY2020)	Avoided CO_2 emissions (10,000 tons)	Service life (years)	Product for comparison
Multicrystalline Si solar cell	(129)	1,760,000 kW	▲898	20	Utility power
CFRP wind turbine power generation	(0.9)	150 units	▲854	20	Utility power
CFRP automobile	9.3	15,000 units	▲7.5	10	Conventional automobile
CFRP aircraft	17.6	45 units	▲122	10	Conventional aircraft
LED light bulb	9.2	28 million units.	▲745	10	Incandescent light bulb
Thermal insulation materials for housing **(Detached house)** **(Apartment)**	(129) (106)	367,000 houses 633,000 apartments	▲950 ▲6,650	30 60	Housing before the energy-saving standard of 1980 (not using thermal insulation materials)
Inverter air conditioner	–	7,460,000 units (number of air conditioners)	▲1,640	14.8	Non-inverter air conditioner
PVC piping materials (Note 1)	(74)	493,092 tons	▲330	50	Ductile cast iron piping
Fuel efficient tyres (Note2)	319 (169)	PCR73,000,000 units TBR5,000,000 units	▲636	PCR 30,000 km TBR120,000 km	Non fuel efficient tyres
High-durability apartments	1,655 (24)	61,000 apartments	▲224	100	Ordinary apartments
Total			**▲13,057**		

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

Note 2: Those for passenger vehicles are indicated as PCR, and those for trucks/buses as TBR.

◆**Global examples**

Example	Finished products: CO_2 emissions from raw materials - manufacture - disposal (10,000 tons) ( ) shows chemical products	Production amount (FY2020)	Avoided CO_2 emissions (10,000 tons)	Service life (years)	Materials for comparison, etc.
Desalination plant that uses the RO membrane process	150	610,000 units	▲17,000	5	Desalination plant that uses the evaporation process
CFRP automobile	186	300,000 units	▲150	10	Conventional automobile
CFRP aircraft	352	900 units	▲2,430	10	Conventional aircraft
Inverter air conditioner	–	47,311,000 units (number of air conditioners)	▲18,995	14.8	Non-inverter air conditioner
Total			▲38,575		

5.2 Conclusions and proposals

It can be seen from the total for the examples, chemical products are a key material in reducing CO_2 emissions by about 130 million tons in Japan and by about 390 million tons globally. Note that the avoided CO_2 emissions includes not only those from chemical products but those from other products related to raw materials and parts as well. However, no means are currently available that enable those of other products to be quantified, and so classification of the emission abatement according to the constituent products has not been done.

Also, it can be inferred from the examples that chemical products contribute to the reduction in CO_2 emissions for finished products in various fields, such as the energy sector (solar power generation, wind turbine power generation), consumer and home sector (LED light bulbs, housing, air conditioners, piping and automobiles), transportation sector (automobiles, aircraft), etc., in cooperation with products that are related to other unprocessed materials and parts.

Based on the above, it is clear that the chemical industry not only has the status of a basic industry that supports industries through supply of raw materials and parts, but also is an industry that makes a social contribution through the reduction in CO_2 emissions in the present age where the environment has become a pressing problem for humanity.

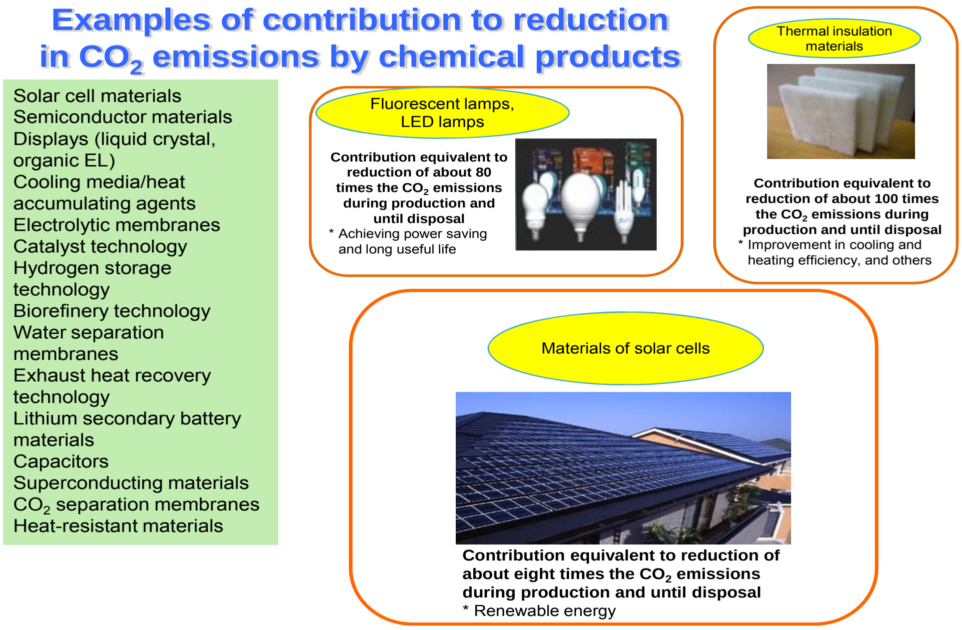
The chemical industry is determined to continue to promote the reduction in CO_2 emissions in society as a whole, aiming at achieving greater emission abatement by utilizing chemical technologies and products over the entire life cycle, without limiting its efforts to pursuing the reduction in CO_2 emissions during manufacture.

6. Plans to be pursued by the chemical industry hereafter

6.1 Increasing the number of examples of assessment using cLCA in Japan and around the world

It can be said that the implementation of cLCA here, as shown in the ten 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 14 examples here.

It is planned that examples of cLCA will be expanded 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. It is necessary that greater understanding of materials that contribute to the reduction in CO_2 emissions be promoted concerning the issue that the proactive use of chemical products leads to a reduction in CO_2 emissions by means of assessment using cLCA, even though they are the products of an industry that consumes a lot of energy.



Fluorescent lamps, LED lamps: Contribution equivalent to reduction of about 80 times the CO_2 emissions during production and until disposal
* Achieving power saving and long useful life

Thermal insulation materials: Contribution equivalent to reduction of about 100 times the CO_2 emissions during production and until disposal
* Improvement in cooling and heating efficiency, and others

Materials of solar cells: Contribution equivalent to reduction of about eight times the CO_2 emissions during production and until disposal
* Renewable energy

Fig. 39. Examples of the avoided CO_2 emissions by chemical products

6.2 Promotion of international contribution

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, 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.

As can be seen in the materials of desalination plants (RO membranes), Hall effect devices for air conditioners, and carbon fiber for automotive and aircraft applications as described in this report, the contribution to the reduction in emissions overseas by means of technical transfer of the chemical products and technologies in Japan will also become increasingly important in the future.

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

Manufacturing technologies: Provision of chemical processes and energy-saving technologies of 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 phthalic 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, CO_2 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: Developed with the support of NEDO

- Reduction in the emissions of three alternatives to Freon by the installation of exhaust gas combustion equipment
- Achieved substantial reduction in PFCs to 80% in the basic unit of discharge relative to that in the reference year, and on SF_6 to 95%.
- From now, reduction in greenhouse gas emissions through transfer of technologies overseas will be promoted in cooperation with the national government through the use of production technologies for reducing the emissions of alternatives to Freon and through the use of exhaust gas combustion equipment that are possessed by businesses.

6.3 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 fuels 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 in 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 the 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"

7. Review Committee for the cLCA Report (First Edition)

7.1 Overview of the Review Committee

A meeting of the review committee for the cLCA Report was held on June 2, 2012, from 3.00 pm to 5.00 pm in room 805, 8th Floor, Tekko Kaikan Building. There were four members of the review committee: 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 (Associate Professor, Graduate School of Environment and Information Sciences, Yokohama National University). Material summarizing the result of investigation had been presented to the members beforehand. Since Yuki Hondo was absent on the day of the meeting, he submitted his opinions before the meeting in an interview.

Note that the review committee members were not concerned with the procurement of data used in the investigation, and did not directly verify the completeness, representativeness or accuracy, etc. of the data used in the report. Therefore, they are responsible only for the portions in which they presented their opinions about the temporal range of effectiveness of the data, and other matters.

The matters pointed out by members of the review committee are given below, itemized as "Overview of the result of review."

7.2 Opinions of the panel of experts on the cLCA Report

(1) Overview of the result of review

1) Calculation of net emission abatement

In only one case, desalination, the object of calculation of the net emission abatement (170 million tons) is located overseas instead of in Japan. Therefore, it should be dealt with separately from the cumulative value of the net emission abatement of the nine examples (281.97 million tons).

2) Degree of contribution of chemical products to net emission abatement

In this report, the object of comparison should basically be a state in which no chemical products to be assessed are available. The contribution of chemical products to the reduction in CO_2 emissions as well as the effect of reduction of all products to be assessed may be given in some examples. For instance, in the examples of automobiles and aircraft as examples for carbon fiber, it can be understood that the effect was produced by weight reduction (change in unprocessed materials), whereas the effect in the example of wind turbine power generation is an effect of reduction of the equipment as a whole instead of an effect produced by the unprocessed materials only, and these two are of a different nature.

3) Suitability of a product for comparison

Although the object of comparison in the example of thermal insulation materials for housing is specified as housing that does not use thermal insulation, there also exist thermal insulation materials that are not chemical products. Therefore, there is some deviation from reality, and there is some doubt as to the suitability of the object of comparison.

4) Description of disposal

In the portion related to the evaluation of plastics, incineration is not considered at the stage of disposal. Consequently the portion equivalent to the CO_2 emissions generated at the time of combustion of plastics is calculated to be less than the actual value. This may cause some suspicion that the result is advantageous to chemical products. There should be a clear description of how the CO_2 emissions at the stage of disposal are evaluated.

5) Way of thinking about the reduction in CO_2 emissions

When viewed from the perspective of how the BAU (business-as-usual) should be regarded, which is the object of comparison for the evaluation of the avoided CO_2 emissions, the method of assessment in this report in which it is assumed that no chemical products are available is a unique method when compared with the methods employed in investigations that are ordinarily carried out.

6) Status of the years 2005 and 2020

What are the statuses of the year 2005, which is the reference year, and the year 2020 that is considered in the assessment? Six years have elapsed since 2005, and the situation in society has already changed. When 2005 is to be evaluated, the value in 2005 should be used with regard to utility power as well, instead of using the value planned for 2020.

7) Communications with the parties concerned

As a general rule, when carrying out investigations and publishing the results of comparison, it is necessary that all the parties concerned that become the object of comparison and assessment participate in the review. From this point, it is desirable that there is communication with the parties concerned about the contents of this report.

8) On the significance of this report

It would be a good opportunity for having various stakeholders focus on how the contribution of unprocessed materials (the contribution of chemistry) should be considered in the future.

9) Individual matters

[1] Solar power generation

Instead of saying that "the difference between the cumulative level of adoption of solar power generation systems in 2005 and that in 2020 was calculated, and …… dividing the difference by 15 years," it is better to say, "consideration has been given so that evaluation of the reduction in CO_2 emissions will not become excessive.”

[2] Wind turbine power generation

Since the examples of assessment are those obtained in Japan, it is considered that there is contribution not only of large wind turbine power generators of the 3-MW class, but also of small wind turbine power generators. Since it is believed that they generate differing quantities of power, it would be better to carry out sensitivity analysis. In addition, there was an opinion that this investigation is an analysis that includes future predictions where there are great fluctuations, and so it would be difficult to carry out analysis of individual parameters.

[3] Automobiles

It is thought that the weight, fuel consumption data, and lifetime mileage of a conventional model used as the object of comparison are worse than the values at present. Examination of temporal effectiveness is required to check whether the cited data are older than those obtained for the reference year.

[4] Piping

Piping made of polyvinyl chloride and piping made of ductile cast iron used according to different applications and it might not be possible to say that they are always interchangeable. It is better to describe the situation of use according to each application.

[5] Sources

It is desirable to include a statement to the effect that the description of sources is not a simplified one, such as that found on the website of the Ministry of Economy, Trade and Industry, but that the information is given in detail, including the year of issuance and the representativeness of the data, and that the range of temporal effectiveness is described as far as possible.

[6] Others

- It is helpful for readers to incorporate the Executive Summary in the material for review into this report (either in the conclusion or at the beginning). It is also better to include in the report statements corresponding to the "details of contribution" that are given in the Executive Summary.
- Regarding the items in section 6.3, “Development of innovative technologies," a more elaborate description should be given and the items should have richer content.

(2) Examination of and response to the result of review

1) Calculation of net emission abatement (geographical conditions)

As the committee member pointed out, since the object of calculation is desalination only, it has been determined that the calculation shall be dealt with separately from that for other examples in Japan and, at the same time, that its result shall not be added to the net reduction in emissions in Japan.

2) Degree of contribution of chemical products in the net reduction in emissions

As the committee member pointed out, emission abatement includes those by chemical products as well as those by other products related to raw materials and parts. However, the present a technique for quantitatively distinguishing between emission abatement by chemical products and those by non-chemical products has not been established. Therefore, in this report, the emission abatement has not been distinguished according to each constituent product, and a description has been given clearly to that effect.

3) Suitability of the product for comparison

On this occasion, as a result of carefully investigating prior literature to look for a product for comparison that is necessary for calculating the effect of thermal insulation materials, no appropriate object of comparison was found, except for housing with no thermal insulation. Therefore, this housing was adopted as the product for comparison. The following two issues have been left as problems to be addressed hereafter in the improvement of the method of calculation:[1] The determination of differences in the number of houses and the thermal insulation properties among housing with no thermal insulation, the former criteria for energy saving, new criteria for energy saving, and the next generation criteria for energy saving, and [2] comparisons with thermal insulation materials made of other unprocessed materials such as rock wool or glass wool, etc.

4) Description of disposal

The evaluation of CO_2 emissions during the stage of disposal in each example has been described as shown below, and at the same time it has been added to the text.

[1] Solar cells
- Aluminum frames and terminal boxes (including cables for wiring) that have been separated from removed and collected solar cell modules shall be recycled by recycling service suppliers.
- It has been specified that other modules shall be treated as industrial waste, and materials that can be recycled after the intermediate treatment of such waste shall be recycled, and those that cannot be recycled shall be disposed of in landfill.

[2] Materials for wind turbine power generation

Since there is no historical data concerning disposal, it has been excluded from the calculation.

[3] Automotive materials

It has been specified in this model that resins and carbon fiber for automotive use will be recycled as CFRP by crushing them and adding them at the time of injection molding.

[4] Materials for aircraft

As there is no historical data for disposal, it has been excluded from the calculation.

[5] LEDs

It has been specified that they will be discarded as noncombustible trash and will be disposed of in landfill after intermediate treatment.

[6] Thermal insulation materials (polystyrene foam made using the bead process)

It has been specified that the materials will be incinerated.

[7] Hall effect device/IC

Air conditioners will be treated according to the method specified in the Electric Appliance Recycling Law if they are for home use. Since the treatment processes for air conditioners are varied, they have been excluded from the calculation in this report.

[8] Piping materials

It has been specified that they will be disposed of by landfill after intermediate treatment.

[9] Desalination

It has been specified that RO membrane elements will be disposed of by landfill as industrial waste.

5) Way of thinking about the reduction in CO_2 emissions

The products under assessment are based on products and technologies as of 2010. Products that are expected to come into widespread use in 2020 through technological progress are not used as the object. Also, the objects of comparison are products that have to be used when no chemical products are available. Emission abatement is calculated based on this basis by multiplying the value thus obtained by the expected amount of manufacture in 2020.

The points mentioned above are already stated in this report.

6) Status of the years 2005 and 2020

Although FY2005 is significant as the reference year in the mid-term target, no comparison has been made with FY2005 in this report. Also, the reason that FY2020 has been used as the year under assessment has been added in section 3.1, “Background and purpose."

7) Communications with the parties concerned

It is planned that after completion of this cLCA report, deeper communications will be made with the parties concerned through dialogs with various stakeholders, such as industrial, academic and administrative sectors as well as members of the public, etc.

8) Individual matters

[1] Solar power generation

The reason that the difference between the cumulative level of adoption of solar power generation systems in 2005 and that in 2020 was calculated and the value obtained by dividing the difference by 15 years was used as the level of adoption has been added to "2. Effect of adoption throughout Japan."

[2] Wind turbine power generation

It is expected that the adoption of renewable energy will continue to be promoted in the future. Therefore, it is planned that the contribution of small wind turbine power generators will also be reviewed when the plan for installation has been made clear in the future.

[3] Automobiles

The actual years for data that form the basis and the fiscal years for the issuance of sources have been added.

[4] Piping

It has been added that, considering the fact that substitution cannot be done in piping made of polyvinyl chloride in some applications, evaluation of the forecast demand for piping made of polyvinyl chloride was deliberately conservative.

[5] Sources

Fiscal years, names of reports, URLs, etc. have been comprehensively included.

[6] Others

- According to the matter pointed out, the contents of the Executive Summary have been incorporated into the report.
- The column for 6.3 “Development of innovative technologies" has been revised by adding more specific development items.

8. Review of cLCA Report (Second Edition)

8.1 Overview of the review

In October, 2012, the cLCA Report (Second Edition) was presented to panel of experts and their opinions were solicited. Four people expressed their opinions: Masahiko Hirao (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, any data other than the portions in which they presented their opinions about the temporal range of effectiveness of the data, and others, were not considered in the review.

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

8.2 Opinions of panel of experts concerning the cLCA Report (second edition)

(1) Overview of the results of review

1) Clear description that among GHGs, only CO_2 is considered

If this report considers CO_2 only, a statement to that effect should be added. If GHGs in general are to be considered or plants and agriculture are to be handled, calculation of GHGs such as N_2O will be required.

2) Addition of a column for "production amount" to the table in the Executive Summary

Since the emission abatement is value that corresponds to the production amount, it will be better to add a column for the production amount in 2020.

3) Distribution of the avoided CO_2 emissions

The "Guidelines for Calculation of the avoided CO_2 emissions" issued by JCIA has the following statement about the rate of contribution. "If a reduction in CO_2 emissions has been achieved by a certain product to be evaluated, it is rare that the effect is produced by an individual product. In almost all cases, multiple constituent elements contribute to the effect. In such cases, if the rate of contribution according to the degree of contribution of 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, but no technique for the objective and reasonable calculation of the rate of contribution has been established and it is difficult to obtain the rate of contribution. Therefore, no technique for calculating the rate of contribution has been defined in these guidelines."

However, in the example of fuel efficient tyres, when calculating the amount of fuel consumed per tire/per km, the contribution of the tyres was given (described in the source as the rate of contribution of tyres to fuel consumption), and this contradicts the aforesaid assertion.

Regarding this, the following points of response can be considered.

[1] If the assertion that the contribution of the tyres cannot be given is to be maintained, then the contribution of the tyres shall not be calculated, and only the fuel consumption of automobiles shall be calculated. Therefore, only a statement shall be included such that fuel efficient tyres are key parts for improving fuel consumption.

[2] It should also be explained that not only the assertion that it is difficult to determine the contribution of the tyres but the fact that there are some examples where a reasonable calculation of the contribution was made should also be explained. At the same time, a statement shall be added to the effect that the contribution is a problem to be examined hereafter.

Matters related to contribution are also being examined, and efforts toward solving the problem are required.

4) 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?

5) Individual matters

[1] Aircraft

This report states that the product service life is 10 years. What are the grounds for this assumption?

[2] Fuel efficient tyres

i) The contribution assigned to tyres (for passenger vehicles: 0.125, for trucks/buses: 0.25) is stated as being based on the results of an investigation conducted by the Japan Automobile Tire Manufacturers Association. The data should be given greater transparency.

ii) With regard to CO_2 emissions during the stage of disposal/recycling of tyres for passenger vehicles, emissions from fuel efficient tyres and those from non fuel efficient tyres are given as follows: non fuel efficient tyres: 2.9 kg CO_2/tyre, fuel efficient tyres: 0.7 kg CO_2/tyre. What are the details of these figures?

iii) Explanation of the settings of the market size of fuel efficient tyres in 2020
It is desirable that the scenario be described in an easy-to-understand way.

(2) Examination of and response to the results of the review

1) Clear description that of the different GHGs, only CO_2 is considered
A description has been added to section 1. “Overview and conclusions" in this report.

2) Addition of a column for "production amount" to the table in the Executive Summary
A column for the production amount in 2020 has been added to the table.

3) Assignment of the avoided CO_2 emissions
The matter pointed out by the reviewer has been checked with the cited source. The source, Japan Automobile Tire Manufacturers Association, conducted a global investigation of the literature concerning the relationships between fuel consumption and the rolling resistance of tyres, and it also possesses data based on actual tests. However, the data used for the work performed here were not based on the assignment of fuel consumption. Instead, a comparison was made between non fuel efficient tyres and fuel efficient tyres on CO_2 emissions for each automobile fitted with the tyres.

The contradiction was caused by our lack of understanding. To avoid any misunderstanding, a table of the data based on the direct comparison and a description of the procedure for calculation of the avoided CO_2 emissions has been added.

4) Calculation of the avoided CO_2 emissions in 2020
Based on an understanding that the matter pointed out is a problem to be examined hereafter in the LCA WG, we would like to proceed with the work for such examination while seeking guidance also from the panel of experts as well.

5) Individual matters

[1] Aircraft

The number of years of service stated as ten years in the "Ministerial Order Concerning the Number of Years of Service of Depreciable Assets, Schedule 1, Aircraft, having a maximum takeoff weight of 130 tons” by the Ministry of Finance has been used.

[2] Fuel efficient tyres

i) With regard to providing the data for the contribution assigned to tyres (for passenger vehicles: 0.125, for trucks/buses: 0.25) with greater transparency.

The assignment of the contribution is stated in 3) of (2). Regarding the fuel consumption while the vehicle is being driven, a note has been added stating that "although the fuel consumption while the vehicle is being driven varies with the car model and driving conditions, these numerical values are typical values based on experiments and literature."

ii) CO_2 emissions during the stage of disposal/recycling

The following table and explanations have been added to the text (evaluation based on four tyres).

GHG emissions and the reduction in emissions during the stage of disposal/recycling (unit: $kgCO_{2e}$/4 units)

		Non fuel efficient tyres	Fuel efficient tyres
Proportion of recycling	Thermal utilization	75%	75%
	Except recycling	25%	25%
GHG emissions	Transportation for procurement	1.6	1.6
	Thermal utilization[a)]	46.8	38.4
	Simple incineration [b)]	15.6	12.8
	Total A	**64.0**	**52.8**
Reduction in emissions	Thermal utilization[c)] B	**-52.4**	**-50.0**
CO_2 emissions during the stage of disposal/recycling	A+B	**11.6**	**2.8**

a) 75% of used tyres are utilized as heat.

● Difference between non fuel efficient tyres and fuel efficient tyres:

[1] Weight of used tyres: Non fuel efficient tyres 7.3 kg, Fuel efficient tyres 7.0 kg

[2] Carbon content of used tyres: Non fuel efficient tyres 58%, Fuel efficient tyres 50%

(As shown in the raw materials composition ratio in Table 17, the content of synthetic rubber and carbon black in fuel efficient tyres is smaller than that in non fuel efficient tyres.)

(GHG emissions from four used tyres during combustion)
= (Carbon content of used tyres) × 44/12 × (Weight of used tyres) × 4
The content is calculated by multiplying this calculated value by 0.75.

b) 25% of used tyres are incinerated.

c) 75% of used tyres are utilized as heat.
Heat collection efficiency factor: 0.9; the substitute fuel is Class C heavy oil.
(Reduction in GHG emissions by thermal utilization of 4 used tyres)
= (Combustion heat from tyres) × (GHG emission factor of Class C heavy oil)
× (Heat collection efficiency factor) × (Weight of used tyres) × 4

iii) Market size of fuel efficient tyres in 2020

Corrections have been made to the explanations concerning the quantity of fuel efficient tyres expected to be sold annually in 2020.

(3) Result of response to the problems to be examined in the first edition

◆ Suitability of products for comparison

Problems to be examined in the first edition

After thoroughly investigating the literature for products for comparison that are required for calculating the effect of thermal insulation materials, no appropriate object of comparison was found other than housing with no thermal insulation. Therefore, this housing was adopted as the product for comparison. Two issues have been left as problems to be addressed hereafter in the improvement of the method of calculation. They are: [1] Identifying the differences in the number of houses and thermal insulation properties among housing with no thermal insulation, former criteria for energy saving, new criteria for energy saving, and the criteria for the next generation of energy saving; and [2] comparisons with thermal insulation materials made with other unprocessed materials, such as rock wool or glass wool, etc.

Results of the response

An investigation conducted thereafter revealed that, with regard to the energy-saving performance of existing housing in Japan (about 50 million houses), housing built prior to the adoption of the energy-saving standard in 1980 (whose outer walls and ceiling are not thermally insulated) accounts for 55% (about 27.5 million houses)Note). The number of new houses currently being built per year is about 800,000 (FY2010). Assuming that old houses are demolished and replaced by new houses, it is considered that shifting to new houses requires at least 34 years. In addition, the Ministry of Land, Infrastructure, Transport and Tourism has also announced a policy to make it mandatory in 2020 to build houses that meet the energy-saving standard of 1999.

Therefore, in this report, housing built before the energy-saving standard of 1980 has been used as the product for comparison based on the scenario that housing built before the energy-saving standard of 1980 will be replaced by housing that meets the energy-saving standard of 1999.

Note: The 15th Energy Subcommittee of the Advisory Committee for Natural Resources and Energy (December 2011)
The data are based on those obtained in 2010.

9.Acknowledgements

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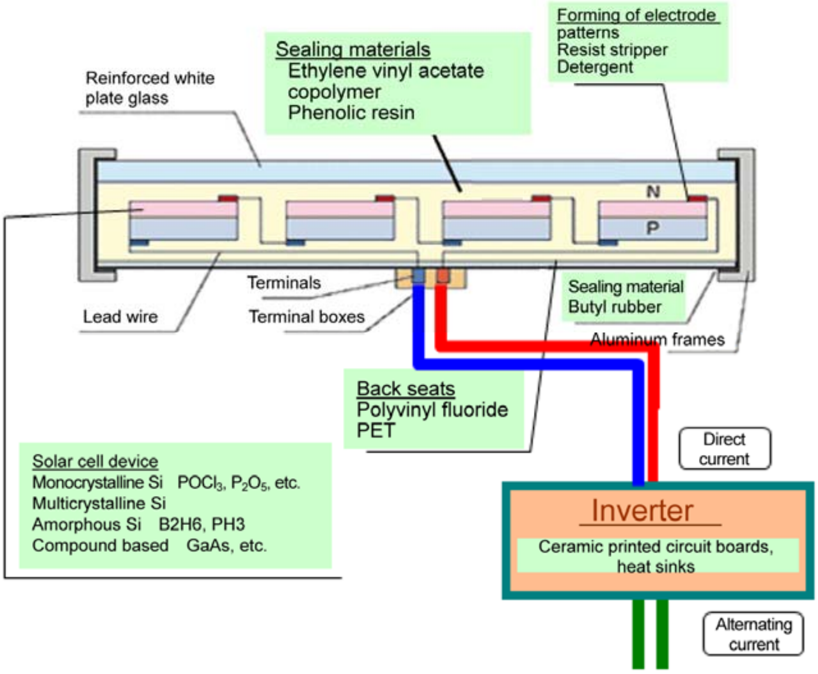
10. Appendix - cLCA Fact Sheet

■ Materials for solar power generation

No.	Item	Contents
1	Product overview	What is a solar cell? A solar cell is a device that directly converts the energy of sunlight into electrical energy by utilizing the principle of a semiconductor. Since power can be generated in any location and since the size of the system can be freely selected, it is possible to introduce the system into ordinary houses. It is expected that the adoption rate of solar cells will continue to increase as a form of renewable energy. Composition of a solar cell   Examples of chemical products used in solar cells • Multicrystalline Si, SiH_4 gas, Si wafer • Sealing materials for solar cells (ethylene vinyl acetate copolymer, phenolic resin) • Back seat for solar cells (polyvinyl fluoride, PET) • Various types of chemicals (detergent, resist stripper) • Diethylzinc, BCl_3, CVD materials • Ceramic printed circuit board for inverters, heat sink

2	Scope of assessment using cLCA	
2-1	Product system to be assessed	Product under assessment • Multicrystalline silicon solar cell, number of years of use: 20 years, output: 4-kW class Product for comparison • Utility power (power source mix)
2-2	Functions	• Supply of a constant amount of electricity
2-3	Functional unit and reference flow	Functional unit • Amount of power generated: 902 kWh (amount of power generated per kW of output) @Tokyo[77] Reference flow • Solar power generation: portion equivalent to 1 kWh (annual power generation of 902 kWh per kW) • Utility power (power source mix)
2-4	System boundary	Processes to be assessed • Regarding solar power generation, including all emissions in processes from the raw materials through manufacture, usage, maintenance (replacement of parts) to disposal of power generation systems using multicrystalline silicon solar cells • Regarding utility power, including all emissions from power generation systems based on the power source mix and in processes from the fuel production, fuel transportation, raw materials through manufacture, usage, maintenance (replacement of parts) to disposal for waste disposal (estimated value for the year 2020)
2-5	Preconditions for cLCA	• The portion of the increase in CO_2 emissions from chemical products includes that for the manufacture of multicrystalline Si, sealing materials and back seats. • Emission abatement is calculated based on a comparison with the amount of power generated as utility power (2-2).

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[77] Report of Business Entrusted by NEDO: Technical Development of Common Foundations for Solar Power Generation Systems
"Investigational Research on the Life Cycle Assessment of Solar Power Generation Systems" (March 2009)

3	Result of assessment using cLCA	
3-1		

	Multicrystalline Si solar cell	Utility power
1) CO_2 emissions in manufacturing stage (kg-CO_2/kW)		
• Transportation of SiO_2 and manufacture of Si metal	57.95	
• Multicrystalline Si agglomerate	445.91	
• Manufacture of multicrystalline Si ingots	26.72	
• Manufacture of wafers	145.02	
• Sealing materials	42.9	
• Back seats	16.5	
Total for manufacturing stage	**735**	–
2) The avoided CO_2 emissions by solar power generation		
• CO_2 emissions during power generation (kg-CO_2/kWh)	0.047	0.33
• Annual amount of power generation per kW of solar power generated (Tokyo, kWh)	902	902
• CO_2 emissions relative per kW of annual amount of power generated by solar power generation (kg-CO_2/kW/year)	42.39	297.66
• The avoided CO_2 emission per kW of annual amount of power generated by solar power generation (kg-CO_2/kW/year)	255.27	
3) The avoided CO_2 emission in the lifetime of solar power generation (kg-CO_2/kW/20 years)	**5,105**	

3-2	The avoided CO_2 emissions per unit of the level of adoption	Preconditions • As the portion of the increase, CO_2 emissions during manufacture of chemical products to be used in solar power generation (crystalline Si wafers, back seats, and sealing materials) were calculated. The portion of the solar power generation CO_2 emission factor, which was an included value, was selected. • The avoided CO_2 emissions relative to utility power (power source mix) that results from electricity generated by a solar power generation system to be produced in 2020 to its end of life shall be obtained (to be calculated as a value per kWh). Result of assessment • The avoided CO2 emissions relative to utility power: 5,105 kg-CO_2/kW (20 years)
4	Assessment based on an adoption scenario	
4-1	Target of adoption of the national government, etc.	• Concerning the level of adoption in 2020, the reduction in CO_2 emissions varies greatly with the level of adoption. To prevent the evaluation from becoming excessive, the difference between the cumulative level of adoption of solar power generation systems in 2005 (1.4 million kW) and that in 2020 (27.8 million kW)[78] was calculated, and the annual average increment was obtained by dividing the difference by 15 years. This value has been taken as the level of adoption.
4-2	Level of adoption	• It is assumed that the level of adoption in 2020 will be 1.76 million kW.

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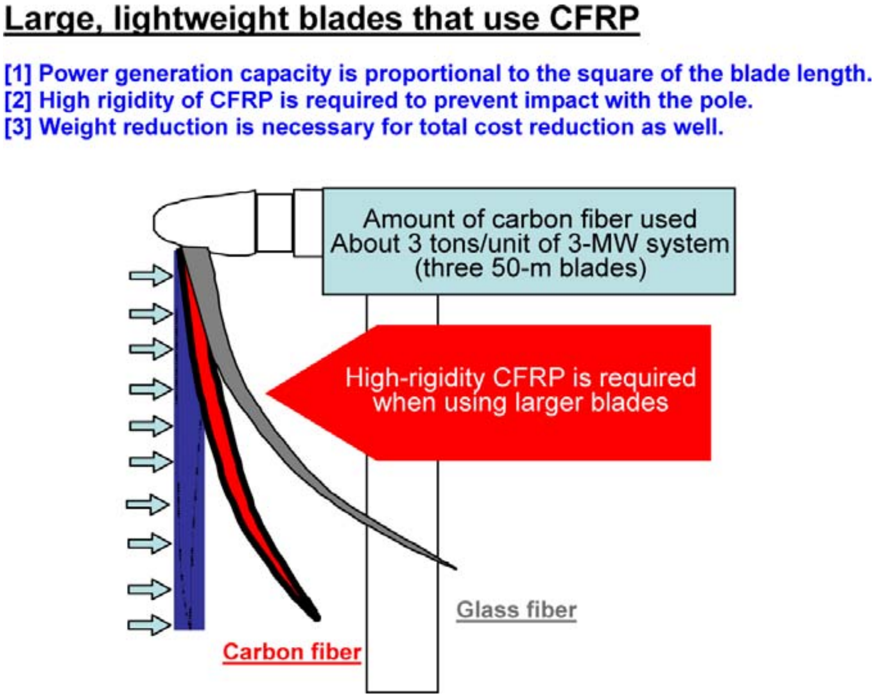
[78] Ministry of Economy, Trade and Industry, Agency for Natural Resources and Energy, "On a Framework for the Total Buy-Back System for Renewable Energy" (August 4, 2010) http://www.meti.go.jp/committee/summary/0004629/framework03.pdf

4-3	CO_2 emissions from solar power generation over its life cycle	• CO_2 emissions over the entire life cycle of solar power generation: 1.49 million t-CO_2 42.39 kg-CO_2/kW/year × 20 years × 1.76 million kW = 1,492 kt-CO_2
4-4	CO_2 emissions from chemical products	• CO_2 emissions from the procurement of raw materials for and manufacture of multicrystalline Si wafers, back seats, and sealing materials: 1.29 million t-CO_2 735 kg-CO_2/kW × 1.76 million kW = 1,294 kt-CO_2
4-5	The avoided CO_2 emissions	Method of calculation • (3-2) × (4-2) Result of calculation • 8.98 million t-CO_2 (20 years)

■ Materials for wind turbine power generation

No.	Item	Contents
1	Product overview	What is wind turbine power generation?  Wind turbine power generation has been used a form of natural energy since olden times, and there are strong expectations that this clean energy will play an important role in preventing global warming. Wind turbine power generation is an inexpensive form of energy because it enables electricity to be generated even at night, giving it a high utilization rate, and it has high conversion efficiency. Increasing the amount of power generated by wind turbines requires the use of longer blades, and these blades require a high level of rigidity to prevent them from colliding with the tower. As carbon fiber has more than three times the modulus of elasticity than that of conventional glass fiber, it is being increasingly used in the girders of the blades. The adoption of large wind turbines, with an output of 3 MW or more, is expected to increase in offshore locations where there are good wind conditions that enable high-speed rotation. There is also increasing use of larger wind turbines with an output of 5 MW and 10 MW, augmenting the importance of carbon fiber in this application.

		Wind turbine[79]  **Large, lightweight blades that use CFRP** [1] Power generation capacity is proportional to the square of the blade length. [2] High rigidity of CFRP is required to prevent impact with the pole. [3] Weight reduction is necessary for total cost reduction as well. Chemical products used in wind turbine power generation • Carbon fiber • Epoxy resin
2	Scope of assessment using cLCA	
2-1	Product system to be assessed	Product under assessment • Large wind turbine that uses carbon fiber reinforced plastics Number of years of use: 20 years, output: rated, 3 MW (effective: 1 MW) (Those that incorporate carbon fiber to provide rigidity for the blade girders) Product for comparison • Utility power (power source mix)
2-2	Functions	• Functions for supplying a constant amount of electricity
2-3	Functional unit and reference flow	Functional unit • Wind turbine power generator: 1 unit of the 3 MW class • Amount of power generated: 175,200 MWh (amount of power generated by wind turbine power generator over its lifetime) • Power source mix: portion equivalent to the above amount of power generated

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[79] Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/

2-4	System boundary	Processes to be assessed • For wind turbine power generation, all emissions in processes from the raw materials through manufacture, usage, maintenance (replacement of parts) to disposal of power generation systems are included. Disposal was excluded from the calculation because there is no historical data. Since CO_2 emissions from the procurement of raw materials to the manufacture of carbon fiber are not taken into account, they have been added as an increment during equipment manufacture. However, emissions from materials substituted by carbon fiber (e.g. glass fiber, etc.) have not been subtracted. • For utility power, all emissions from power generation systems based on the power source mix and in processes from the fuel production, fuel transportation, and raw materials through manufacture, usage, maintenance (replacement of parts) to disposal for waste disposal (expected value for the year 2020) are included.			
2-5	Preconditions for cLCA	• Of the portion of the increase in CO_2 emissions from chemical products, the portion for the manufacture of carbon fiber has been taken into account. • Emission abatement has been calculated based on a comparison between wind turbine power generation and the power source mix on the assumption that the same amount of power will be generated (those which have the functions described in (2-2) in the same manner).			
3	Result of assessment using cLCA		Wind turbine power generation 3-MW class	Power source mix Case A	Thermal power generation Case B
3-1	CO_2 emissions over the entire life cycle	• CO_2 emission from electric power (kg-CO_2/kWh)	0.005 [80]	0.33	0.86
		• Annual amount of power generated per unit of wind turbine power generator (MWh)	8,760	–	–
		• CO_2 emissions corresponding to annual amount of power generated per unit of wind turbine power generator (thousand t-CO_2/unit/year)	0.04	2.9	7.5
		• CO_2 emissions corresponding to the amount of power generated per unit of wind turbine power generator over its lifetime (service life of wind turbine: 20 years) (thousand t-CO_2/unit/year)	0.8	58	150

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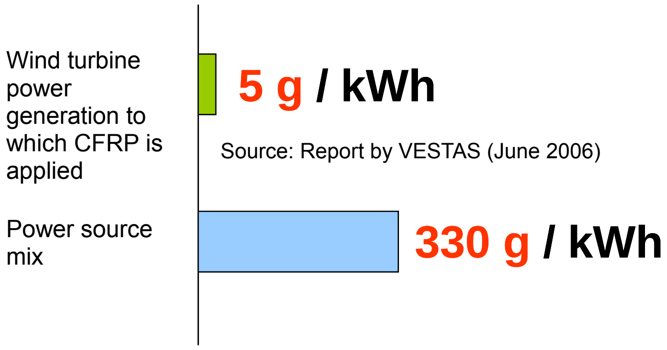
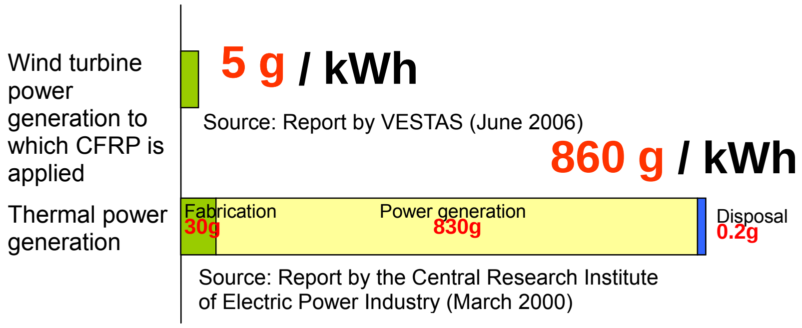
[80] Report by VESTAS, "Life cycle assessment of offshore and onshore sited wind power plants based on VesTas V90-3.0 MW turbines" (June 2006)

		CO$_2$ emissions over the life cycle[81] (per kWh) Case A (relative to power source mix)  Source: Report by VESTAS (June 2006)
		For reference: Case B (relative to thermal power generation)  Source: Report by VESTAS (June 2006) Source: Report by the Central Research Institute of Electric Power Industry (March 2000)

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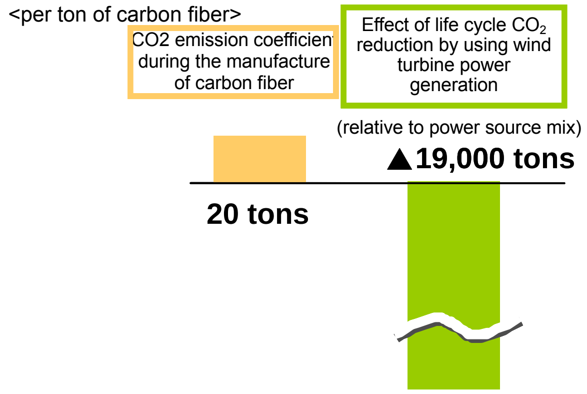
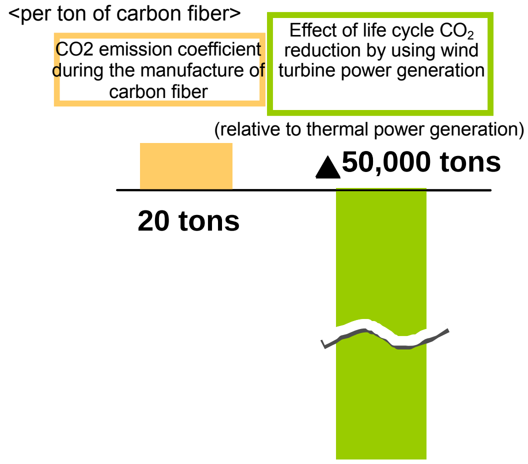
[81] Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/

3-2	The avoided CO_2 emissions per unit level of adoption	Case A (relative to power source mix) • The avoided CO_2 emission: 56,940 (t/unit·20 years) • Amount of CF[108] used: 3 (t/unit) ⇒ The avoided CO_2 emission per ton of CF = 19,000 (t)[82]  For reference: Case B (relative to thermal power generation) • The avoided CO_2 emission: 150,000 t/unit (20 years) • Amount of CF used: 3 (t/unit) ⇒ The avoided CO_2 emission per ton of CF = 50,000 (t) 

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[82] Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/

4	Assessment by using a scenario for adoption	
4-1	Predicted level of adoption	(Calculation on a trial basis based on the national government's predicted level of adoption) • Annual output from the wind turbines adopted in Japan in 2020: 450 (MW) • Amount of CF for use in wind turbine applications in Japan in 2020: 450 (t) For reference: (Value based on calculation on a trial basis by the Carbon Fiber Manufacturers Association) • Annual output from the wind turbines adopted in Japan in 2020 predicted by the Carbon Fiber Manufacturers Association: 1,500 (MW) • Amount of CF for use in wind turbine applications in 2020 (Amount to be produced by three PAN-based CF manufacturers in Japan and used in wind turbines globally) Globally: 30,000 (t) Japan: 1,500 (t) (5% of the amount to be produced globally)
4-2	Level of adoption	(Calculation on a trial basis based on the national government's predicted level of adoption)[83] • Annual output from the wind turbines adopted in Japan in 2020: 450 (MW) • Amount of CF used: 3 (t/unit) • Wind turbine power generator: 3-MW class/1 unit • Number of wind turbines using CFRP in Japan in 2020: 150 (units) For reference: (Value based on calculation on a trial basis by the Carbon Fiber Manufacturers Association) • The amount of use in 2020 is estimated to be 15 times the value for 2007.[84] • Amount of CF used: 3 (t/unit) • Wind turbine power generator: 3-MW class/1 unit • Number of wind turbines using CFRP in 2020 Globally: 10,000 (units) Japan: 500 (units)
4-3	CO_2 emissions by wind turbine power generation over its life cycle	(Calculation on a trial basis based on the national government's predicted level of adoption) • CO_2 emissions over the entire life cycle: 130,000 t-CO_2 43.8 t-CO_2/unit/year × 20 years × 150 units = 131 kt-CO_2 For reference: (Value based on calculation on a trial basis by the Carbon Fiber Manufacturers Association) • CO_2 emissions over the entire life cycle • Globally: 8.76 million t-CO_2 • Japan: 440,000 t-CO_2
4-4	CO_2 emissions from chemical products	(Calculation on a trial basis based on the national government's predicted level of adoption) • CO_2 emissions in the procurement of raw materials for and manufacture of carbon fiber: 9,000 t-CO_2 60t-CO_2/unit/year × 150 units = 9 kt-CO_2 For reference: (Value based on calculation on a trial basis by the Carbon Fiber Manufacturers Association) • CO_2 emissions in the procurement of raw materials for and manufacture of carbon fiber Globally: 600,000 t-CO_2 Japan: 30,000 t-CO_2

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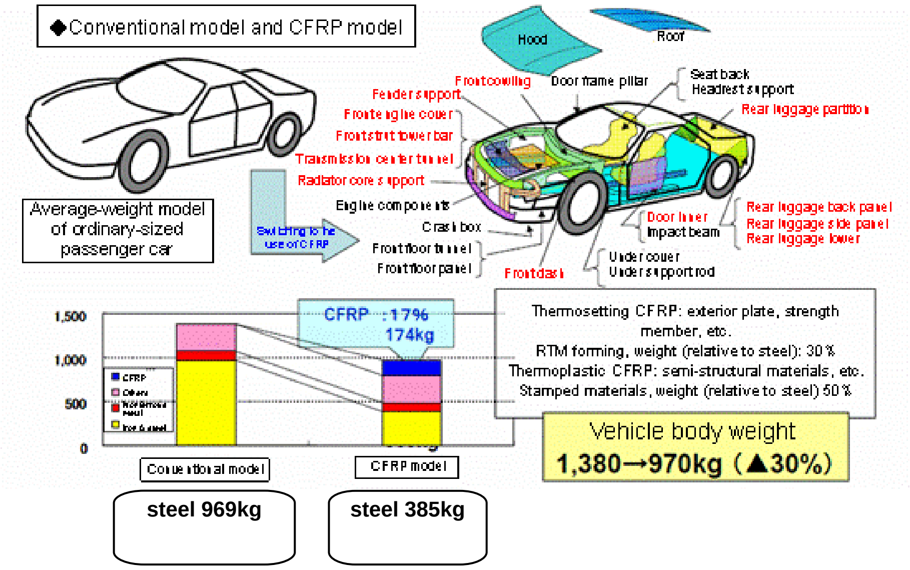
[83] Website of the Ministry of Economy, Trade and Industry
http://www.meti.go.jp/committee/summary/0004629/framework.html

[84] Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/

4-5	The avoided CO_2 emissions	(Calculation on a trial basis based on the national government's predicted level of adoption/relative to power source mix) • The avoided CO_2 emission per ton of CF are 19,000 tons (20 years) • The avoided CO_2 emission in Japan in 2020: 8.54 million t-CO_2 (20 years) For reference: Case B (Value based on calculation on a trial basis by the CF Association/relative to thermal power generation) • The avoided CO_2 emission per ton of CF are 50,000 t (/20 years) • The avoided CO_2 emission in 2020 Globally: 1,500 million t-CO_2 (20 years) Japan: 75 million t-CO_2 (20 years)

■ Automotive materials (carbon fiber)

No.	Item	Contents
1	Product overview	What is automotive carbon fiber? Carbon fiber is used in various components of automobiles. The use of carbon fiber makes it possible to reduce the weight of the automobile while maintaining the same strength and safety. Reducing the weight leads directly to improved fuel consumption, thereby helping to reduce CO_2 emissions in the transportation sector. In this report, the avoided CO2 emissions is evaluated when introducing carbon fiber by reducing fuel consumption, as compared with conventional automobiles[85]. Conventional and CFRP models of mid-sized automobiles[85]  Chemical products used - Carbon fiber - Epoxy resin
2	Scope of assessment using cLCA	
2-1	Product system to be assessed	Product under assessment - CFRP model of mid-sized automobiles Automobiles using CFRP: Use of 17% of CFRP, 30% weight reduction (as compared with conventional automobiles) Vehicle weight: 970 (kg) … A weight reduction of 30% (410 kg) overall by the use of 17% CFRP (174 kg) Lifetime mileage: 94,000 (km) (average number of years of use: 10 years) Fuel consumption: 12.40 (km/l)[86] Product for comparison - Conventional model of mid-sized automobile Vehicle weight: 1,380 (kg) Lifetime mileage: 94,000 (km) [86] (average number of years of use: 10 years) Fuel consumption: 9.83 (km/l)

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[85] Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/

2-2	Functions	• To provide the lifetime mileage and functions of a mid-sized automobile of average weight.		
2-3	Functional unit and reference flow	Functional unit • CFRP model of mid-sized automobile: 1 unit (average number of years of use: 10 years) • Conventional model of mid-sized automobile: 1 unit (average number of years of use: 10 years) • Lifetime mileage: 94,000 km (average number of years of use: 10 years)		
2-4	System boundary	Processes to be assessed • Processes related to raw materials through to manufacture • Process related to product assembly • Process related to the use of products • Process related to the disposal of products Process to be omitted • Process related to product transportation		
2-5	Preconditions for cLCA	• The products to be assessed during use by means of cLCA have been assessed by assuming that they have the functions stated in (2-2) in the same manner and that there are no functions to be added or omitted for the purpose of comparison.		
3	Result of assessment using cLCA	Processes to be assessed	CFRP automobile	Conventional automobile
3-1	CO_2 emissions related to raw material through to materials	CO_2 emissions related to raw materials through to materials (t-CO_2/unit)	5.1	3.9
3-2	CO_2 emissions related to assembling	CO_2 emissions related to assembly (t-CO_2/unit) • Assuming that reduction occurs in terms of the weight ratio	0.8	1.2
3-3	CO_2 emissions related to use	Process related to the combustion of gasoline during use		
		Vehicle weight (kg/unit)	970	1,380
		Fuel consumption (km/l·gasoline)	12.40	9.83
		Amount of gasoline (l/unit) corresponding to lifetime mileage: 94,000 (km)	7,580	9,560
		Basic unit for gasoline combustion (kg-CO_2/l)	2.72	2.72
		CO_2 emissions related to use (t-CO_2/unit·10 years)	20.6	26.0
3-4	CO_2 emissions related to disposal	CO_2 emissions related to disposal (t-CO_2/unit) • 90% or more of ferrous and non-ferrous materials to be recycled. • 100% of CFRP parts are recycled as milled CF (for use in other applications).	0.3	0.3

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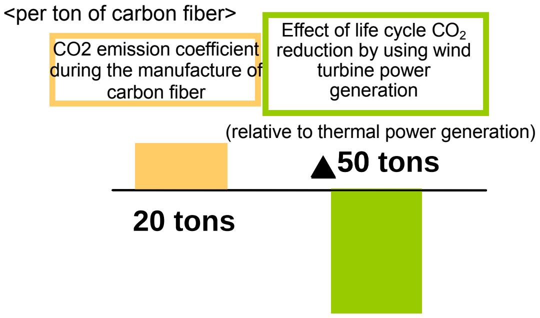
[86] Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/

3-5	CO_2 emissions over the entire life cycle	**CO_2 emissions over the entire life cycle (t-CO_2/unit·10 years) (Total of 3-1 through 3-4)**	**26.8**	**31.4**
3-6	The avoided CO_2 emissions per unit of the level of introduction	• The avoided CO_2 emission: 5t/unit (10 years) • Amount of CF used: 0.1 (t/unit) ⇒ The avoided CO_2 emissionsper ton of CF = 50 (t)[87] 		
4	Assessment by using a scenario for adoption			
4-1	Predicted level of adoption	• Amount of CF to be used in automotive applications in 2020[87] (Amount to be produced globally by three PAN-based CF manufacturers and used for automobiles) Globally: 30,000 (t) Japan: 1,500 (t) (5% of the amount to be produced globally)		
4-2	Level of adoption	• The level of adoption in 2020 is estimated to be 15 times the value for 2007. • Amount of CF used: 0.1 (t/unit) • Number of automobiles using CFRP in 2020 Globally: 300,000 (units) Japan: 15,000 (units)		
4-3	CO_2 emissions from CFRP automobiles over their life cycle	• CO_2 emissions over the entire life cycle Globally: 8.04 million t-CO_2 26.8 t-CO_2/unit × 10 years × 300,000 units = 8,040 kt-CO_2 Japan: 400,000 t-CO_2 26.8t-CO_2/unit × 10 years × 15,000 units = 402 kt-CO_2		
4-4	CO_2 emissions from finished products	• CO_2 emissions from raw materials for the assembly and disposal of CFRP automobiles (excluding those during use) (calculated from 6.2 t-CO_2/unit) For global use: 1.86 million t-CO_2 6.2t-CO_2/unit × 300,000 units = 1,860 kt-CO_2 For Japan: 93,000 t-CO_2 .2 t-CO_2/unit × 15,000 units = 93 kt-CO_2		
4-5	The avoided CO_2 emissions	• The avoided CO_2 emission: 5 (t/unit·10 years) • The avoided CO_2 emission in 2020 Globally: 1.5 million t-CO_2 (10 years) Japan: 75,000 t-CO_2 (10 years)		
4-6	Other special noteworthy matters	• The calculations for resins and carbon fiber for automotive use assume that they will be reused as CFRP by crushing them and adding them during injection molding.		

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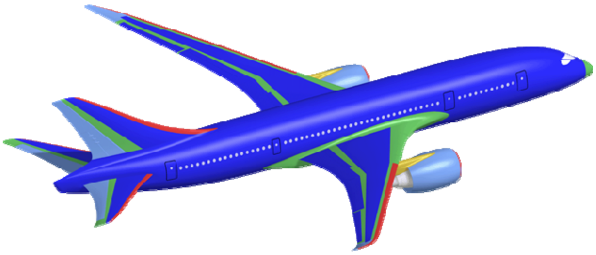
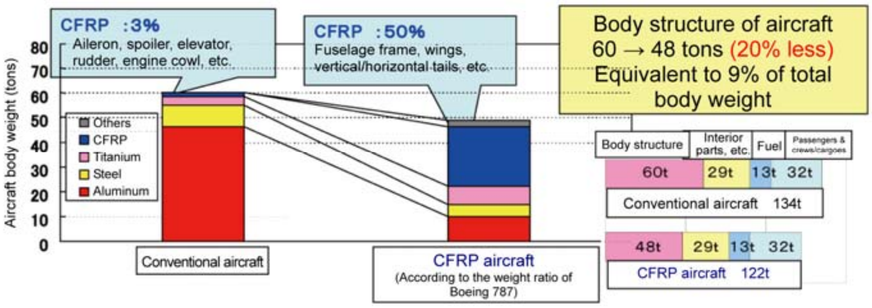
[87] Website of the Japan Carbon Fiber Manufacturers Association http://www.carbonfiber.gr.jp/

■ Materials for aircraft (carbon fiber)

No.	Item	Contents
1	Product overview	What is carbon fiber for aircraft use? Carbon fiber is used in various aircraft components. The use of carbon fiber reduces the weight of the aircraft while maintaining the same strength and safety. As with automobiles, weight reduction in aircraft directly leads to improved fuel consumption, thereby contributing to a reduction in CO_2 emissions in the transportation sector. This report evaluates the avoided CO_2 emissions due to reduced fuel consumption due to the use of carbon fiber as compared with conventional aircraft[87]. Aircraft specifications  **The fuselage of the Boeing 767 has the same material composition as that of Boeing 787.**  Chemical products used • Carbon fiber • Epoxy resin
2	Scope of assessment using cLCA	
2-1	Product system to be assessed	Product under assessment[87] • Using the fuselage of the Boeing 767, which has the same material composition as that of Boeing 787, a 20% weight reduction overall was achieved by making the fuselage from 50% CFRP[88]. This is equivalent to a 9% weight reduction in terms of the total fuselage weight. Operation: Domestic line (Haneda – Chitose: 500 miles). Lifetime operation distance: 2000 flights/year, 10 years Product for comparison • Boeing 767, Number of seats: 280, CFRP is used in 3% of the fuselage structure. Operation: Domestic line (Haneda - Chitose: 500 miles). Lifetime operation distance: 2000 flights/year, 10 years

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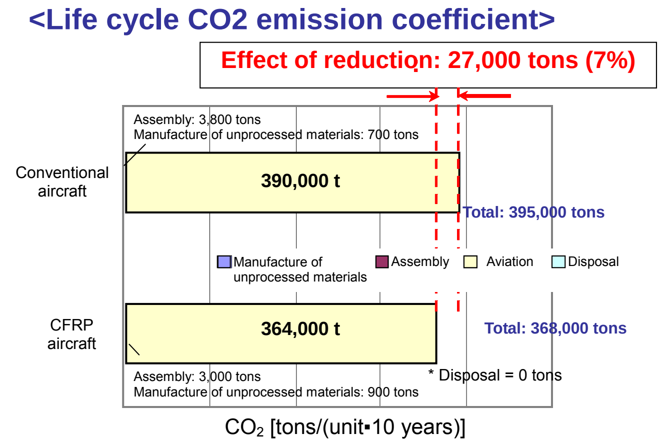
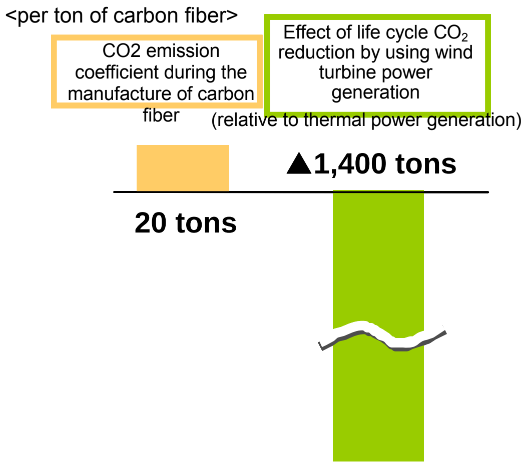
[88] The weight of aircraft consists of that of fuselage structure, interior parts, etc., fuel, occupants/cargo.

2-2	Functions	• Functions that provide the transportation of passengers during the same period as that of the Boeing 767.		
2-3	Functional unit and reference flow	Functional unit • An aircraft having the same material composition as that of a Boeing 787: 1 aircraft (average number of years of use: 10 years) • Boeing 767: 1 aircraft (average number of years of use: 10 years)		
2-4	System boundary	Processes to be assessed • Processes related to the procurement of raw materials through to product manufacture • Process related to product assembly • Process related to the use of products • Process related to product disposal (however, disposal is not considered in the calculation because no data are available.) Process to be omitted • Process related to product transportation • Process related to the manufacture of capital goods		
2-5	Preconditions for cLCA	• The products to be assessed during use by means of cLCA have been assessed assuming that they have the functions described in (2-2) in the same manner and that there are no functions added or omitted for the purpose of comparison.		
3	Result of assessment using cLCA	Processes to be assessed	CFRP aircraft	Conventional aircraft
3-1	CO$_2$ emissions related to raw materials through to manufacture	**CO$_2$ emissions related to raw materials through to manufacture (t-CO$_2$/aircraft)**	**0.9**	**0.7**
3-2	CO$_2$ emissions related to assembly	**CO$_2$ emissions related to assembly (t-CO$_2$/ aircraft)** • Assuming that reduction occurs in terms of the weight ratio	**3.0**	**3.8**
3-3	CO$_2$ emissions related to use	Process related to combustion of fuel during use		
		Fuselage weight (t/aircraft)	48	60
		Fuel consumption (km/kl)	110	103
		Amount of jet fuel used over the lifetime (kl/aircraft)	145,500	155,300
		Basic unit for jet combustion (kg-CO$_2$/l)	2.5	2.5
		CO$_2$ emissions related to use (kt-CO$_2$/aircraft·10 years)	**364**	**390**
3-4	CO$_2$ emissions related to disposal	**CO$_2$ emissions related to disposal (kt-CO$_2$/aircraft)**	**No data**	**No data**

3-5	CO$_2$ emissions over the entire life cycle	**CO$_2$ emissions over the entire life cycle (kt-CO$_2$/aircraft·10 years) (Total of 3-1 through 3-3)**	**368**	**395**
				
3-6	The avoided CO$_2$ emissions per unit level of adoption	• The avoided CO$_2$ emission: 27,000 t/aircraft (10 years) • Amount of CF used: 20 (t/aircraft) ⇒ The avoided CO$_2$ emission per ton of CF = 1,400 (t) 		
4	Assessment by using a scenario for adoption			
4-1	Predicted level of adoption	• Amount of CF to be used in aircraft applications in 2020[88] (Amount to be produced globally by three PAN-based CF manufacturers in Japan and used for aircraft) Globally: 18,000 (t) Japan: 900 (t)(5% of the amount to be produced globally)		
4-2	Level of adoption	• The amount of use in 2020 is estimated to be five times the value for 2007. • Amount of CF used: 20 (t/aircraft) • Number of aircraft using CFRP in 2020 Globally: 900 (aircraft) Japan: 45 (aircraft)		

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[88] Estimation by the Carbon Fiber Manufacturers Association

4-3	CO_2 emissions from CFRP aircraft in their life cycle	• CO_2 emissions in the entire life cycle Global: 331 million t-CO_2 368 kt-CO_2/aircraft·10 years × 900 aircraft =331,200 kt-CO_2 Japan: 16.56 million t-CO_2 368 kt-CO_2/aircraft·10 years × 45 aircraft =16,560 kt-CO_2
4-4	CO_2 emissions from finished products	• CO_2 emissions from the procurement of raw materials, assembly, and disposal of CFRP aircraft (calculated from 3.9 t-CO_2/aircraft) For global use: 3.51 million t-CO_2 3.9 kt-CO_2/aircraft × 900 aircraft = 3,510 kt-CO_2 For Japan: 176,000 t-CO_2 • 3.9 kt-CO_2/aircraft × 45 aircraft = 176 kt-CO_2
4-5	The avoided CO_2 emissions	• The avoided CO_2 emission: 27,000 (t/aircraft·10 years) • The avoided CO_2 emission in 2020 Globally: 24.3 million t-CO_2 (10 years) Japan: 1.22 million t-CO_2 (10 years)

■ Fuel efficient tyres

No	Item	Contents
1	Product overview	What are fuel efficient tyres? Fuel efficient tyres make a direct improvement in the fuel consumption of automobiles by reducing their rolling resistance, and they contribute greatly to the reduction in CO_2 emissions in the transportation sector. With regard to improvements in fuel consumption, the tread portion that directly comes into contact with the ground (the portion where the tire contacts the road surface and which protects the inside against impact and external damage from the road surface) makes a great contribution to the improvements, whereas at the same time the tread portion is required to have gripping performance (braking performance). Chemical products play a great role in meeting the contradictory requirements for performance in which the fuel consumption is improved and gripping performance is maintained. For instance, SBR that is synthesized by the solution polymerization process transforms the physical properties by controlling the primary construction of polymers, and has the function of reducing the loss of energy as caused by tire friction when the automobile is being driven. These functions help improve fuel consumption. The addition of silica has become an important factor in making the reduction in rolling resistance compatible with maintained grip.  Examples of chemical products used in fuel efficient tyres • Solution-polymerized SBR (styrene-butadiene rubber) • BR (butadiene rubber) • Carbon black (that which has been subjected to chemical denaturation) • Silane coupling agents • Silica • Zinc oxide • Various types of rubber chemicals
2	Scope of assessment using cLCA	
2-1	Product system to be assessed	Product under assessment • Fuel efficient tyres fitted to automobiles (passenger vehicles and trucks/buses) Product for comparison • Non fuel efficient tyres fitted to automobiles (passenger vehicles and trucks/buses)
2-2	Functions	• To run the same distance during the same period

No	Item	Contents	
2-3	Functional unit and reference flow	Functional unit • Both fuel efficient tyres and conventional tyres run the same distance during the same period until the end of their life. Reference flow • Automobile fitted with fuel efficient tyres: 1 unit • Automobile fitted with non fuel efficient tyres: 1 unit	
2-4	System boundary	Processes to be assessed • Stages from the procurement of raw materials, through to product manufacture, distribution, usage and disposal	
2-5	Preconditions for cLCA	• Products to be assessed during their use by means of cLCA have been assessed by assuming that they have the functions described in (2-2) in the same manner and that there are no functions added or omitted for the purpose of comparison.	
3	Result of assessment using cLCA	Automobile fitted with fuel efficient tyres	Automobile fitted with non fuel efficient tyres
3-1	CO_2 emissions related to raw material through to manufacture for tyres[89]	Tyres for passenger vehicles Procurement of raw materials: 95.6 kg-CO_2/4 tyres + A Production stage: 28.0 kg-CO_2/4 tyres + B Distribution stage: 6.0 kg-CO_2/4 tyres + C Tyres for trucks/buses Procurement of raw materials: 1,397 kg-CO_2/10 tyres + A Production stage: 352 kg-CO_2/10 tyres + B Distribution stage: 101 kg-CO_2/10 tyres + C A: Emissions from raw materials other than tyres used for vehicles B: Emissions during the production stage of parts other than tyres used for vehicles C: Emissions during the distribution stage of parts other than tyres	Tyres for passenger vehicles Procurement of raw materials: 100.0 kg-CO_2/4 tyres + A Production stage: 31.2 kg-CO_2/4 tyres + B Distribution stage: 6.4 kg-CO_2/4 tyres + C Tyres for trucks/buses Procurement of raw materials: 1,480 kg-CO_2/10 tyres + A Production stage: 356 kg-CO_2/10 tyres + B Distribution stage: 104 kg-CO_2/10 tyres + C
3-2	CO_2 emissions related to use[89]	CO_2 emitted during the use of tyres (while the vehicle is being driven) Tyres for passenger vehicles 8,219 kg-CO_2/4 tyres (driven 30,000 km) Tyres for trucks/buses 82,365 kg-CO_2/10 tyres (driven 120,000 km)	CO_2 emitted during the use of tyres (while the vehicle is being driven) Tyres for passenger vehicles 8,430 kg-CO_2/4 tyres (driven 30,000 km) Tyres for trucks/buses 86,700 kg-CO_2/10 tyres (driven 120,000 km)

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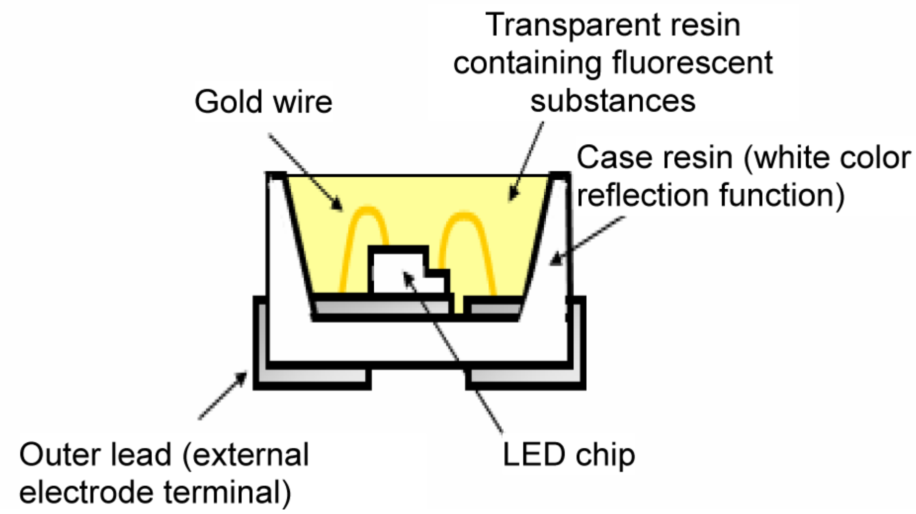
[89] Japan Automobile Tire Manufacturers Association, Inc. (general incorporated association), " $LCCO_2$ Calculation Guideline for tyres, Ver. 2.0"

No	Item	Contents	
3-3	CO_2 emissions related to disposal of tyres [89]	CO_2 to be emitted during the stage of disposal/recycling of tyres Tyres for passenger vehicles 2.8 kg-CO_2/4 tyres + D Tyres for trucks/buses -309 kg-CO_2/10 tyres + D D: Emissions in the stage of disposal/recycling of raw materials and parts other than tyres used for vehicles	CO_2 to be emitted during the stage of disposal/recycling of tyres Tyres for passenger vehicles 11.6 kg-CO_2/4 tyres + D Tyres for trucks/buses -311 kg-CO_2/10 tyres + D
3-4	CO_2 emissions over the entire life cycle[89]	Tyres for passenger vehicles 8,351.9 kg-CO_2/4 tyres + A + B + C + D Tyres for trucks/buses 83,906 kg-CO_2/10 tyres + A + B + C + D	Tyres for passenger vehicles 8,579.2 kg-CO_2/4 tyres + A + B + C + D Tyres for trucks/buses 88,329 kg-CO_2/10 tyres + A + B + C + D
3-5	The avoided CO_2 emissions per tyre level of adoption	• The avoided CO_2 emissions relative to those from conventional tyres: Tyres for passenger vehicles: 227.3 kg-CO_2/4 tyres. The avoided CO_2 emission per tyre: 56.8 kg-CO_2/tyre Tyres for trucks/buses: 4,423 kg-CO_2/10 tyres. The avoided CO_2 emissions per tyre: 442.3 kg-CO_2/tyre	
4	Assessment by using a scenario for adoption		
4-1	Predicted level of adoption	• Expected demand for fuel efficient tyres in 2020 (for passenger vehicles: 73,000 thousand tyres; for trucks/buses: 5,000 thousand tyres)	
4-2	Level of adoption	• The number of tyres to be introduced in 2020 is estimated to be 73,000 thousand tyres for passenger vehicles and 5,000 thousand tyres for trucks/buses.	
4-3	CO_2 emissions from fuel efficient tyres over their life cycle		
4-4	CO_2 emissions from finished products of tyres	• CO_2 emissions during the procurement of raw materials, manufacture, and disposal of finished products of tyres: 3.19 million t-CO_2	
4-5	CO_2 emissions from chemical products	• CO_2 emissions during the procurement of raw materials, manufacture of chemical products such as synthetic rubber, carbon black, silica, etc.: 1.74 million t-CO_2	
4-6	The avoided CO_2 emissions	Method of calculation • (3-5) × (4-2) Result of calculation • 6.36 million t-CO_2 (for passenger vehicles: 4.15 million t-CO_2, trucks/buses: 2.21 million t-CO_2	

■ LED related materials

No.	Item	Contents
1	Product overview	What is an LED? An LED (light emitting diode) emits light when an electric current passes through it, and is one of the semiconductor devices made from compound semiconductors. Unlike the conventional incandescent lamps and fluorescent lamps, an LED emits light without being heated and, for this reason, it is expected to be increasingly used as a highly efficient form of lighting. Composition of an LED   Examples of chemical products used in LEDs • LED packages • LED chips • LED printed circuit boards (GaAs, GaP, GaN, SiC, sapphire) • Organic metals for use in MO-CVD • LED sealing materials (epoxy, silicone) • LED resin packages (reflector resins: polyamide based, silicone, liquid crystal polymer) • LED ceramic packages • Fluorescent substance, high heat dissipation printed circuit boards, high-reflectance film, paint for improving luminance, etc.
2	Scope of assessment using cLCA	

2-1	Product system to be assessed	Product under assessment • LED light bulb, service life[90]: 25,000 (hours/piece), power consumption: 8 (W/piece) Product for comparison • Incandescent light bulb, service life [90]: 1,000 (hours/piece), power consumption: 40 (W/piece)		
2-2	Functions	• The object of assessment using cLCA provides the same brightness over the same period.		
2-3	Functional unit and reference flow	Functional unit • Service life: 25,000 (hours) Reference flow • LED light bulb: 1 piece • Incandescent light bulb: 25 pieces		
2-4	System boundary	Processes to be assessed • Processes related to the procurement of raw materials through to product manufacture • Process related to the use of products • Process related to the disposal of products		
2-5	Preconditions for cLCA	• Products to be assessed during their use by means of cLCA have been assessed assuming that they have the functions described in (2-2) in the same manner.		
3	Result of assessment using cLCA	Processes to be assessed	LED light bulb	Incandescent light bulb
3-1	CO_2 emissions related to the procurement of raw materials through to manufacture	[1] During procurement of raw materials to manufacture		
		Power consumption during manufacture (kWh/piece)	9.9	0.612
		Number of units manufactured	1	25
		CO_2 emission from electric power[91] (kg-CO_2/kWh)	0.33	0.33
		CO_2 emissions related to procurement of raw materials - manufacture (kg-CO_2)	**3.27**	**5**
3-2	CO_2 emissions related to use	[2] During use		
		Power consumption during use (25,000 hours) (kWh)	200	1,000
		CO_2 emission from electric power[91] (kg-CO_2/kWh)	0.33	0.33
		CO_2 emissions related to use (kg-CO_2)	**66**	**330**
3-3	CO_2 emissions related to disposal	[3] Landfill		
		Number of units disposed of as landfill	1	25
		CO_2 emission from landfill (kg-CO_2/piece)	0.002	0.009

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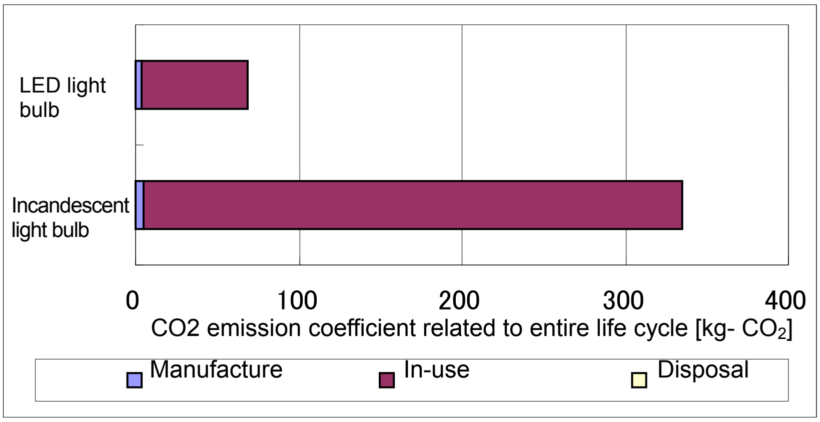
[90] OSRAM "Life Cycle Assessment of Illuminants: A Comparison of Light Bulbs, Compact Fluorescent Lamps and LED Lamps" (December 2009)

[91] Electric power emission factor (power receiving end) in FY2020: Target value of the Federation of Electric Power Companies of Japan

		CO$_2$ emissions related to disposal (kg-CO$_2$)	**0.002**	**0.225**
3-4	CO$_2$ emissions over the entire life cycle	**CO$_2$ emissions over the entire life cycle (kg-CO$_2$/25,000 hours) (Total of [1] through [3])**	**69.272**	**335.225**
				
3-5	The avoided CO$_2$ emissions per unit level of adoption	Preconditions • The avoided CO$_2$ emission has been calculated by making a comparison between the emissions from LED light bulbs produced in a year that remain illuminated until the end of their life and the emissions from incandescent light bulbs substituted thereby. • The assessment assumes that the lifetime of illumination is 25,000 (hours). Result of assessment • 266 (kg-CO$_2$/piece)		
4	Assessment by using a scenario for adoption			
4-1	Target for adoption by the national government, etc.	Basic Energy Plan • To achieve 100% of high-efficiency lighting (LEDs, etc.) in terms of flow in 2020, and 100% in terms of stock in 2030		
4-2	Level of adoption[92]	• The future annual sales forecast is used as the scenario for adoption. • Annual sales of LED light bulbs (thousand units): 28,000 (2020, Japan)		
4-3	CO$_2$ emissions from LED light bulbs over their life cycle	• CO$_2$ emissions over the entire life cycle: 1.94 million t-CO$_2$		
4-4	CO$_2$ emissions from finished products	• CO$_2$ emissions during the procurement of raw materials, manufacture, and landfill of LED light bulbs: 92,000 t-CO$_2$ 3.272 kg-CO$_2$/piece × 28 million pieces = 91.6 kt-CO$_2$		
4-5	The avoided CO$_2$ emissions	Method of calculation • (3-5) × (4-2) Result of calculation • 7.45 million t-CO$_2$ (10 years)		

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[92] Fuji Chimera Research Institute, Inc. "General Investigation of LED Related Markets (First Volume)" (2010)

■ Thermal insulation materials for housing

No.	Item	Contents
1	Product overview	Role of thermal insulation materials for housing[93] Of the energy consumed by housing, by far the greatest is that used in heating, and to a lesser extent, cooling. To thoroughly exploit the energy savings associated with heating and cooling, it is necessary to improve the thermal insulation performance and airtightness of housing. This is because, when there is a temperature differential between the inside and the outside of a house, heat flows out or in through the walls, ceilings, roof, floor, windows, entrances, etc., even when a comfortable temperature has been achieved indoors through cooling/heating. To avoid this energy loss, the thermal insulation performance of housing can be improved by covering the inside of a room with thermal insulation as though wrapping the house interior.  Examples of chemical products used as thermal insulation materials for housing • Extruded polystyrene foam • Expanded polystyrene foam • Hard urethane foam, urethane resin, propylene oxide • Highly expanded polystyrene foam • Phenol foam, PVC sash, PVC resin • Heat shielding paint, heat shielding sheet, heat shielding film, highly thermally insulated curtain, nonwoven fabric • Alumina fiber What is expanded polystyrene foam?[94] Expanded polystyrene foam , known by its acronym, EPS, is a typical foamed plastic based thermal insulation material that was developed in Germany. Expanded polystyrene foam is manufactured by first subjecting raw material beads consisting of polystyrene resins and hydrocarbon based foaming agents to preparatory foaming. They are then foamed to about 30 to 80 times in size by filling them into molds and heating them. Various shapes of products can be manufactured by changing the shape of the mold.

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[93] "Energy-Efficient Housing web Let's Promote Energy-Efficient Housing" in a website of the Japan Federation of Housing Organizations
http://eco.judanren.or.jp/learning/103.html

[94] "Overview of EPS Building Materials" on the website of the Japan Expanded Polystyrene Association, EPS Construction Materials Promotion Department
http://www.epskenzai.gr.jp/what/what01.html

2	Scope of assessment using cLCA	
2-1	Product system to be assessed	Product under assessment[95] • Detached houses (thermally insulated with a single material), service life: 30 years • Apartments (thermally insulated with a single material), service life: 60 years Product for comparison Housing before the energy-saving standard of 1980 (housing that does not use thermal insulation materials) • Detached houses Service life: 30 years • Apartments Service life: 60 years
2-2	Functions	• New housing expected to be built in 2020
2-3	Functional unit and reference flow	Functional unit • Service life: 30 years (detached houses), 60 years (apartments) Reference flow • Detached houses: 367,000 houses (both for product under assessment and for product for comparison) • Apartments: 633,000 houses (both for product under assessment and for product for comparison) • Total: 1 million houses
2-4	System boundary	Processes to be assessed • Processes related to the procurement of raw materials, manufacture, and disposal of thermal insulation materials • Process related to the use of housing Processes to be omitted • Processes related to the building and demolition of housing • Energy consumption other than that of air conditioning to be used during use (e.g. gas cooking stove, etc.)
2	Preconditions for cLCA	• Products to be assessed during their use by means of cLCA shall have the functions described in (2-2) in the same manner.

3	Result of assessment using cLCA (detached houses)	Process being assessed	Sapporo	Morioka	Sendai	Tokyo	Kagoshima	Average
3-1	CO_2 emissions during the stage of manufacture (kg-CO_2/house)		2,295	1,687	1,520	1,520	1,520	1,709
3-2	CO_2 emissions during the stage of usage (kg-CO_2/house)		-49,443	-40,564	-28,613	-16,642	-12,140	-29,480
3-3	CO_2 emissions during the stage of disposal (kg-CO_2/house)		2,412	1,773	1,598	1,598	1,598	1,796

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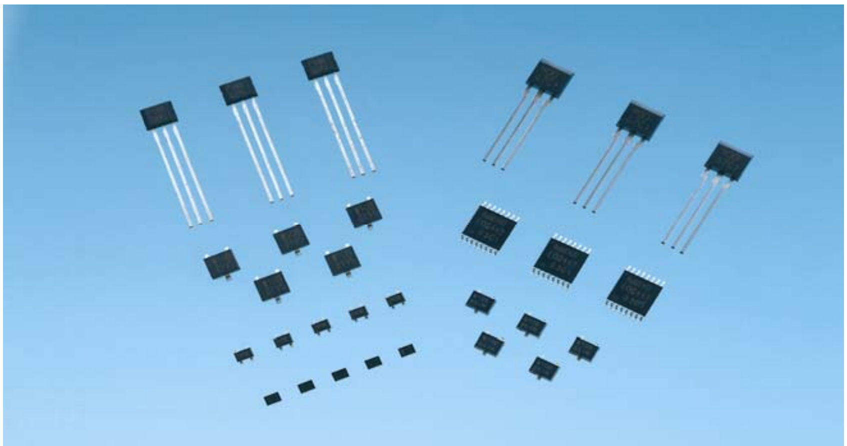
[95] Japan Expanded Polystyrene Recycling Association, "EPS Product Environmental Load (LCI) Analysis and Investigation Report" (April 2007)

3-4	**The avoided CO_2 emissions per house (kg-CO_2/house)**		**-44,736**	**-37,104**	**-25,495**	**-15,122**	**-9,022**	**-25,975**
4	Result of assessment using cLCA (apartments)	Process being assessed	Sapporo	Morioka	Sendai	Tokyo	Kagoshima	Average
4-1	CO_2 emissions during the stage of manufacture (kg-CO_2/house)		1,145	855	714	687	687	818
4-2	CO_2 emissions during the stage of usage (kg-CO_2/house)		-173,405	-146,661	-100,622	-65,361	-45,861	-106,382
4-3	CO_2 emissions during the stage of disposal (kg-CO_2/house)		1,204	899	751	722	722	859
4-4	**The avoided CO_2 emissions per house (kg-CO_2/house)**		**-171,056**	**-144,908**	**-99,157**	**-63,952**	**-44,452**	**-104,705**
5	Assessment by using a scenario for adoption							
5-1	Target of adoption of the national government, etc.	Basic Energy Plan • To realize ZEB/ZEH (zero energy building/zero energy house) by 2030 on average regarding newly built ones						
5-2	Level of adoption	Detached houses • Number of dwellings adopted: 367,000 dwellings Apartments • Number of dwellings adopted: 633,000 dwellings						
5-3	CO_2 emissions from chemical products	CO_2 emissions from chemical products during the procurement of raw materials through to manufacture and disposal: 2.35 million t-CO_2						
5-4	The avoided CO_2 emissions	Detached houses • The avoided CO_2 emission: **9.5 million t-CO_2 in total (30 years)** Apartments • The avoided CO_2 emission: **66.5 million t-CO_2 in total (60 years)**						
5-5	Points to be noted concerning the The avoided CO_2 emissions above	• Since no information is available on the number of houses to be adopted in each region, the values used here are obtained by multiplying a simple average value for all regions by the number of houses to be adopted throughout Japan. A more detailed way of thinking about the number of houses to be adopted in each region is needed.						

■ Hall effect devices and Hall effect ICs

No	Item	Contents
1	Product overview	Roles of Hall effect devices and Hall effect ICs] The indoor and outdoor units of an air conditioner are equipped with motors for fans. Motors can be classified into DC brushless motors and AC motors (induction motors). An air conditioner equipped with DC brushless motors is called an inverter air conditioner. It enables the voltage, current, and frequency to be controlled, making it possible to control the temperature more minutely than that in the case of a non-inverter air conditioner (equipped with AC motors), thereby reducing power consumption. Conventionally, AC motors were used for the fans of the indoor and outdoor units of an air conditioner. But due to Japan's stringent energy-saving regulations, DC brushless motors that have superior energy efficiency are used. The DC brushless motors now in widespread use are highly compact and minimize loss reduction by incorporating Hall effect devices, which enable the rotation to be precisely controlled. Hall effect devices offer three advantages: [1] high durability due to the contactless detection of positions, [2] good resistance to impurities, such as powdery dirt, dust, oil, etc. because magnetism is used for detection, and [3] miniaturization, weight reduction, and loss reduction. Hall effect ICs 
2	Scope of assessment using cLCA	
2-1	Product system to be assessed	Product under assessment • Inverter air conditioner equipped with DC brushless motors Product for comparison • Non-inverter air conditioner equipped with AC motors
2-2	Functions	• Functions that provide the same motor output during the same period

<table>
<tr><td>2-3</td><td>Functional unit and reference flow</td><td colspan="3">Functional unit
• Cooling period: 3.6 months (June 2 - September 21)
• Warming period: 5.5 months (October 28 - April 14)
• Preset temperature: 27°C during cooling/20°C during warming
• Hours of use: 18 hours from 6:00 to 24:00
• Product service life: 14.8 years
Reference flow
• Since the functions of DC brushless motors and those of AC motors are the same, the numbers of the respective motors to be fitted to one air conditioner are the same.</td></tr>
<tr><td>2-4</td><td>System boundary</td><td colspan="3">Processes to be assessed
• Process related to use of products
Processes to be omitted
• Process related to raw materials
• Process related to product manufacture
• Process related to product transportation
• Process related to the manufacture of capital goods
• Process related to product disposal</td></tr>
<tr><td>2-5</td><td>Preconditions for cLCA</td><td colspan="3">• Assessment by using cLCA shall be conducted based on the motors to be fitted to one air conditioner.
• Products to be assessed during their use by means of cLCA are assessed by assuming that they have the functions described in (2-2) in the same manner and that there are no functions added or omitted for the purpose of comparison.
• No data are available in Japan concerning CO_2 emissions from inverter air conditioners and non-inverter air conditioners during the stages of procurement of raw materials, manufacture/distribution, and disposal that have been calculated under fairly similar conditions. Also, no data are available from foreign countries concerning CO_2 emissions during the stages of procurement of raw materials, manufacture/distribution, and disposal. Therefore, only data relating to the stage of usage is included in the scope of calculation of CO_2 emissions.
• CO_2 emissions over the life cycle of air conditioners during the stage of usage account for the majority, and CO_2 emissions during the stages of procurement of raw materials, manufacture, distribution, and disposal are relatively small. Since DC motors are generally smaller than AC motors, it can be assumed that CO_2 emissions from DC motors during the stages of procurement of raw materials, manufacture/distribution, and disposal are smaller. Based on these factors, the cases of offset in the Guideline have been applied to CO_2 emissions excluding those during the stage of usage.</td></tr>
<tr><td>3</td><td>Result of assessment using cLCA</td><td>Processes to be assessed</td><td>Inverter air conditioner equipped with DC brushless motors</td><td>Non-inverter air conditioner equipped with AC motors</td></tr>
<tr><td>3-1</td><td>CO_2 emissions related to raw materials</td><td>Beyond the scope of assessment</td><td>–</td><td>–</td></tr>
<tr><td>3-2</td><td>CO_2 emissions related to manufacture</td><td>Beyond the scope of assessment</td><td>–</td><td>–</td></tr>
</table>

3-3	CO_2 emissions related to use	During use			
		Annual power consumption: [kWh/year/unit]		845	1,268
		Number of years of operation		14.8	14.8
		Total electrical energy during the years of operation [kWh/unit]		12,506	18,766
		Basic unit for electric power [kg-CO_2/kWh]	Japan	0.330	0.330
			China	0.743	0.743
			Asia	0.745	0.745
			North America	0.466	0.466
			Central/South America	0.175	0.175
			Europe	0.326	0.326
			Others	0.500	0.500
		CO_2 emissions related to use [kg-CO_2 /unit]	Japan	**4,127**	**6,190**
			China	**9,292**	**13,938**
			Asia	**9,317**	**13,975**
			North America	**5,828**	**8,742**
			Central/South America	**2,189**	**3,283**
			Europe	**4,077**	**6,115**
			Others	**6,253**	**9,380**
3-4	CO_2 emissions related to disposal	Beyond the scope of assessment		–	–
3-5	CO_2 emissions over the entire life cycle	**CO_2 emissions over the entire life cycle [kg-CO_2 / unit]**	Japan	**4,127**	**6,190**
			China	**9,292**	**13,938**
			Asia	**9,317**	**13,975**
			North America	**5,828**	**8,742**
			Central/South America	**2,189**	**3,283**
			Europe	**4,077**	**6,115**
			Others	**6,253**	**9,380**

<table>
<tr>
<td>3-6</td>
<td>The avoided CO_2 emissions per unit level of adoption</td>
<td>Preconditions
The avoided CO_2 emission is calculated by substituting the air conditioners equipped with DC brushless motors that have been produced in a year for air conditioners equipped with AC motors.
Result of assessment
<table>
<tr><th></th><th>The avoided CO_2 emissions ($kg-CO_2/unit$)</th></tr>
<tr><td>Japan</td><td>2,063</td></tr>
<tr><td>China</td><td>4,646</td></tr>
<tr><td>Asia</td><td>4,658</td></tr>
<tr><td>North America</td><td>2,914</td></tr>
<tr><td>Central/South America</td><td>1,094</td></tr>
<tr><td>Europe</td><td>2,038</td></tr>
<tr><td>Others</td><td>3,127</td></tr>
</table>
</td>
</tr>
<tr>
<td>4</td>
<td colspan="2">Assessment by using a scenario for adoption</td>
</tr>
<tr>
<td>4-1</td>
<td>Predicted level of adoption[96]</td>
<td>• Number of air conditioners in demand globally in 2020: 186,160 (thousand units)
<table>
<tr><th></th><th>Quantity to be delivered (thousand units)</th></tr>
<tr><td>Japan</td><td>7,950</td></tr>
<tr><td>China</td><td>110,730</td></tr>
<tr><td>Asia</td><td>23,710</td></tr>
<tr><td>North America</td><td>15,510</td></tr>
<tr><td>Central/South America</td><td>12,800</td></tr>
<tr><td>Europe</td><td>11,120</td></tr>
<tr><td>Others</td><td>4,350</td></tr>
<tr><td>Total</td><td>186,160</td></tr>
</table>
• With regard to the propagation rate of inverter air conditioners in 2020, the propagation rate that is available at present as a conservative estimate has been used as it assumes that the rate will remain flat[97].
<table>
<tr><th></th><th>Propagation rate (%)</th></tr>
<tr><td>Japan</td><td>100</td></tr>
<tr><td>China</td><td>30[98]</td></tr>
<tr><td>Asia</td><td>10</td></tr>
<tr><td>North America</td><td>0</td></tr>
<tr><td>Central/South America</td><td>0</td></tr>
<tr><td>Europe</td><td>30</td></tr>
<tr><td>Others</td><td>10</td></tr>
</table>
</td>
</tr>
</table>

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[96] Fuji Chimera Research Institute, Inc. "General Investigation of Worldwide Electronics Markets in 2009 - Market Analysis and Trend in Future of AV, Home Electric Appliances, Information/Telecommunications Equipment, Electronic Units" (2009)

[97] Specified by referring to the material of the "Global Environment Subcommittee, Central Environment Council, Ministry of the Environment (Daikin Industries' Approaches for Addressing Environmental Problems)."

[98] Website of Daikin Industries, Ltd. http://www.daikin.co.jp/csr/environment/production/02.html

<table>
<tr><td>4-2</td><td>Level of adoption</td><td>• Number of inverter air conditioners to be introduced in 2020:
47.32 million units
<table>
<tr><td></td><td>Quantity to be delivered (thousand units)</td></tr>
<tr><td>Japan</td><td>7950</td></tr>
<tr><td>China</td><td>33,220</td></tr>
<tr><td>Asia</td><td>2,370</td></tr>
<tr><td>North America</td><td>0</td></tr>
<tr><td>Central/South America</td><td>0</td></tr>
<tr><td>Europe</td><td>3,340</td></tr>
<tr><td>Others</td><td>440</td></tr>
<tr><td>Total</td><td>47,320</td></tr>
</table>
</td></tr>
<tr><td>4-3</td><td>CO_2 emissions from finished products over their life cycle</td><td>• CO_2 emissions from inverter air conditioners in their entire life cycle :
Globally: 379.94 million t-CO_2
Japan: 32.81 million t-CO_2</td></tr>
<tr><td>4-4</td><td>The avoided CO_2 emissions</td><td>Method of calculation
• (3-6) × (4-1) × (4-2)
Result of calculation
Globally: 189.95 million t-CO_2 (14.8 years)
Japan: 16.4 million t-CO_2 (14.8 years)</td></tr>
</table>

■ Piping materials (polyvinyl chloride piping)

No.	Item	Contents
1	Product overview	Polymer piping materials include polyvinyl chloride piping, polyethylene piping, polybutene piping, etc. Together with metal piping materials, they are widely used as water supply piping (water distribution piping, water supply piping and drainpipes) and gas piping (low-pressure conduit piping). Of the various forms of polymer piping, polyvinyl chloride piping is low carbon content, thereby minimizing the use of fossil fuels, and its CO_2 emissions are small throughout its life cycle.  Chemical products used in piping materials • Polyvinyl chloride (EDC, monomer, polymer) • High-density polyethylene • Polybutene
2	Scope of assessment using cLCA	
2-1	Product system to be assessed	Product under assessment: Polyvinyl chloride piping Product for comparison: Ductile cast iron piping
2-2	Functions	• To perform functions as piping for conveying the same fluid during the same period
2-3	Functional unit and reference flow	Functional unit • Polyvinyl chloride piping: 1 kg (equivalent to 150-mm water piping of 14.9 cm) • Estimated service life of polyvinyl chloride piping: 50 years Reference flow • Polyvinyl chloride piping and ductile cast iron piping of the same diameter shall be deemed to have the same fluid transmission performance. • Corrections are made based on the difference in service life.
2-4	System boundary	Processes to be assessed • Processes related to raw materials (procurement of resources - manufacture of unprocessed materials) • Process related to manufacture of products (processing into piping) • Process related to product disposal (landfill) Processes to be omitted • Process related to product transportation • Process related to the use of products • Process related to manufacture of capital goods

2-5	Preconditions for cLCA	• Based on the weight ratio per meter of water piping whose diameter is 150 mm, the coefficient for weight correction of ductile cast iron piping is specified as 3.55 times. • Based on the difference in estimated service life, the coefficient for service life correction for ductile cast iron piping is specified as 0.90. • By making corrections for the unit weight in the same diameter/extension as well as corrections based on the estimated service life, the life cycle CO_2 emissions from 1 kg of polyvinyl chloride piping are compared with the life cycle CO_2 emissions from 3.95 kg of ductile cast iron piping.		
3	Result of assessment using cLCA	Processes to be assessed	Polyvinyl chloride piping	Ductile cast iron piping
3-1	CO_2 emissions related to raw materials[99]	[1] Processes related to procurement of materials (procurement of raw materials - manufacture of unprocessed materials)		
		Unit weight (kg)	1	3.95
		Basic unit up to procurement of raw materials (kg-CO_2/kg)	1.4	0.146
		CO_2 emissions related to procurement of raw materials (kg-CO_2/kg)	1.4	0.577
3-2	CO_2 emissions related to production[99]	[2] Processes related to production (processing)		
		Unit weight (kg)	1	3.95
		Basic unit for processing (kg-CO_2/kg)	0.1	1.925
		CO_2 emissions related to production (kg-CO_2/kg)	0.1	7.60
3-3	CO_2 emissions related to the use of products	Beyond the scope of assessment	–	–
3-4	CO_2 emissions related to disposal	[3] Process related to disposal of products (landfill)		
		Unit weight (kg)	1	3.95
		Basic unit for landfill (kg-CO_2/kg)	0.018	0.018
		CO_2 emissions related to disposal (kg-CO_2/kg)	0.018	0.071
3-5	CO_2emissions over the entire life cycle	**CO_2 emissions related to the entire life cycle (kg-CO_2 / kg) (Total of [1] through [3])**	**1.5**	**8.2**
3-6	The avoided CO_2 emissions per unit level of adoption	Preconditions • The avoided CO_2 emissions over the entire life cycle is obtained by substituting 1 kg of polyvinyl chloride piping that has been produced for ductile cast iron piping. Result of assessment • 6.7 (kg-CO_2/kg)		
4	Assessment by using a scenario for adoption			
4-1	Predicted level of adoption	• Volume of production of polyvinyl chloride piping/joints in 2020: 493,092 (t)		

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[99] Japan PVC Recycling Promotion Council, Investigational Committee, "Life Cycle Assessment of Polyvinyl Chloride Resin Products" (July 1995)

4-2	Level of adoption	• It is assumed that the volume of production in Japan in 2020 will be at the same level as that for FY2005.[100]
4-3	CO_2 emissions from chemical products	• CO_2 emissions in the procurement of raw materials, manufacture, and disposal of chemical products: 740,000 t-CO_2
4-3	The avoided CO_2 emissions	Method of calculation • (3-6) × (4-1) Result of calculation • 3.3 million t-CO_2 (50 years)
4-4	Points to be noted on the avoided CO_2 emissions above	• In recent years, the demand for piping materials has declined due to underlying conditions, such as the decline in domestic population and the stagnant number of housing starts. It is necessary to closely monitor future trends.

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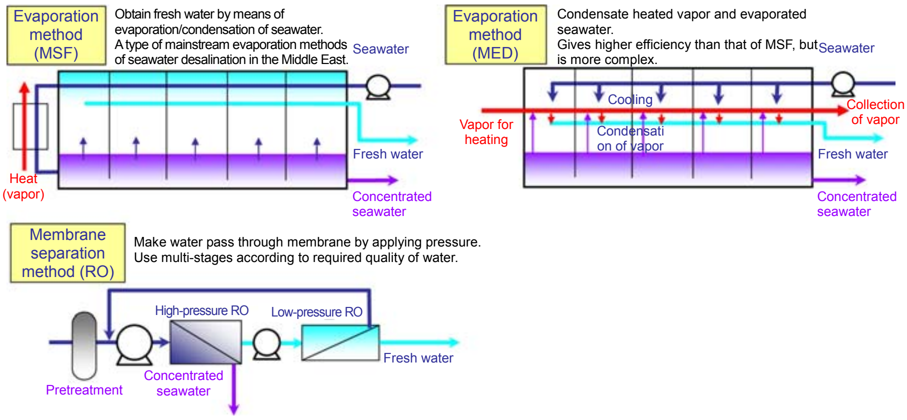
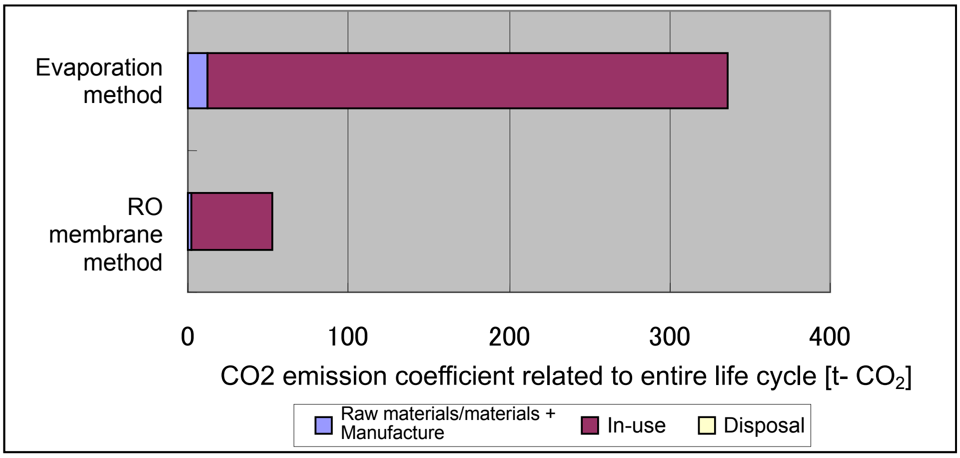
[100] Website of the Japan PVC Pipe and Fittings Association http://ppfa.gr.jp

■ Materials for desalination plants (RO membranes)

No.	Item	Contents
1	Product overview	What are RO membranes? RO membranes (reverse osmosis membranes) are semipermeable membranes used in water treatment that prevent impurities other than water, such as salts, etc., from permeating at a molecular level. The membranes have the function of separating fresh water from salts, etc. Permeation is a phenomenon in which solvents transfer from a diluted solution to a more concentrated solution via a semipermeable membrane. The force that causes this transfer is the osmotic pressure. Reverse osmosis is a phenomenon in which the solvent transfers from the concentrated solution to the diluted solution by applying a pressure greater than the osmotic pressure to the concentrated solution. By utilizing this principle, it is possible to obtain fresh water by allowing water to permeate through the membrane by applying a pressure to a solution containing substances to be removed such as salts, etc. This process is utilized as water treatment technology.  Application to desalination plants The most widely used process in desalination plants at present is the evaporation method, in which fresh water is obtained from gasified seawater or steam. However, this process uses a large amount of energy, which is regarded as a problem. The use of the RO membrane, in which fresh water is obtained from seawater by applying pressure and utilizing reverse osmosis action of RO membranes, is attracting attention as a process that uses far less energy.  Obtain fresh water by means of evaporation/condensation of seawater. A type of mainstream evaporation methods of seawater desalination in the Middle East. Condensate heated vapor and evaporated seawater. Gives higher efficiency than that of MSF, but is more complex. Make water pass through membrane by applying pressure. Use multi-stages according to required quality of water.
2	Scope of assessment using cLCA	
2-1	Product system to be assessed	Product under assessment • Desalination plant that uses RO membranes Product for comparison • Desalination plant that uses the evaporation method
2-2	Functions	• Provision of fresh water from seawater as the raw material

<table>
<tr><td>2-3</td><td>Functional unit and reference flow</td><td colspan="3">Functional unit
• Volume of fresh water provided by one RO membrane element during it lifetime: 26,000 m^3
Reference flow
• Desalination plant that uses RO membranes (equivalent to one RO membrane element)
• Desalination plant that uses the evaporation method (equivalent to one RO membrane element of a desalination plant that uses RO membranes)</td></tr>
<tr><td>2-4</td><td>System boundary</td><td colspan="3">Processes to be assessed
• Process related to the manufacture of products (including the processes for manufacturing raw materials)
• Process related to use of products (including the processes for manufacturing raw materials for the chemicals)
• Process related to product disposal (RO membrane elements and relevant parts only)
Processes to be omitted
• Process related to product transportation
• Process related to the disposal of products (except RO membrane elements and relevant parts)
• Dismantling of the plant</td></tr>
<tr><td>2-5</td><td>Preconditions for cLCA</td><td colspan="3">• Products to be assessed during their use by means of cLCA have been assessed by assuming that they have the functions described in (2-2) in the same manner and that there are no functions added or omitted for the purpose of comparison.</td></tr>
<tr><td>3</td><td>Result of assessment using cLCA</td><td>Processes to be assessed</td><td>RO membrane method</td><td>Evaporation method</td></tr>
<tr><td rowspan="3">3-1</td><td rowspan="3">CO_2 emissions related to raw materials through to manufacture</td><td>Manufacturing process for RO membrane elements (t-CO_2/piece)</td><td>0.01</td><td>–</td></tr>
<tr><td>Manufacturing processes for the raw materials of RO membrane elements (t-CO_2/piece)</td><td>0.1</td><td>–</td></tr>
<tr><td>Manufacturing processes for raw materials other than RO membrane elements and the plant construction process (t-CO_2/piece)</td><td>2.2</td><td>12.4</td></tr>
<tr><td>3-2</td><td>CO_2 emissions related to use</td><td>Energy consumption process by plant operation and manufacturing processes for the raw materials for chemicals (t-CO_2/piece)</td><td>50.5</td><td>323.5</td></tr>
<tr><td>3-3</td><td>CO_2 emissions related to disposal</td><td>Disposal of RO membrane elements and relevant parts (t-CO_2/piece)</td><td>0.15</td><td>–</td></tr>
</table>

3-4	CO_2 emissions over the entire life cycle	**CO_2 emissions over the entire life cycle ($t\text{-}CO_2$/piece) (total of 3-1 through 3-3)**	**53.0**	**335.9**
				
3-5	The avoided CO_2 emissions per unit level of adoption	Preconditions • Using the unit level of adoption per RO membrane element and taking account of the all CO_2 emissions over the life cycle on a plant level with regard to the avoided CO_2 emissions, the reduction in emissions is represented in cases where desalination plants that use RO membranes are substituted for desalination plants that use the evaporation method. Result of assessment • A reduction of 282.9 $t\text{-}CO_2/26{,}000\ m^3$ in the volume of desalination per RO membrane element (From evaporation method - RO membrane method in 3-4)		
4	Assessment by using a scenario for adoption			
4-1	Target of adoption of the national government, etc.	• To cultivate new water supply industries that make optimum use of technology, and to support these industries in becoming leading export industries in Japan in the near future, an appeal is being made in meetings of the Council on Competitiveness-Nippon concerning the need to establishing an overall backup system involving the national government and relevant agencies. RO membranes are being taken up as a technology that exploits technological strengths.		
4-2	Level of adoption	• Global fresh water supply capacity by means of RO membranes for new desalination plants to be adopted in 2016: About 8.7 million m^3/day[101] • Global fresh water supply capacity by means of the RO membranes made by Japanese manufacturers for desalination new plants to be adopted in 2016: About 6.1 million m^3/day (share: 70%)[102]		
4-3	CO_2 emissions from desalination RO membrane plants over their life cycle	• CO_2 emissions from desalination plants that use RO membranes over their entire life cycle: 32.31 million $t\text{-}CO_2$		

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[101] Figure4.2 of Desalination Markets 2010

[102] Report of the Council on Competitiveness-Nippon, "Technology for Effective Utilization of Water Treatment and Water Resources [Approach to the Rapidly Expanding Global Water Treatment Market]" (March 18, 2008); Fig. 9

4-4	CO_2 emissions from finished products	• CO_2 emissions in the procurement of raw materials, manufacture, and disposal of RO membrane plants: 1.5 million t-CO_2
4-5	The avoided CO_2 emissions	Calculations on a trial basis assume that the service life of a membrane is five years, although it is actually between five and seven years. Method of calculation (3-5) × (4-2) × 365 × 5 ÷ (2-3) Result of calculation Globally 172.57 million t-CO_2 (5 years)
4-6	Points to be noted on the above the avoided CO_2 emissions	• Although Japan manufactures most RO membranes, they are mainly used overseas in regions that are susceptible to water shortages. Therefore, the reduction in CO_2 emissions mainly appears overseas.

■ Materials for high-durability apartments

No	Item	Contents
1	Product overview	What are drying shrinkage-reducing agents? Drying shrinkage-reducing agents improve the durability of concrete and extend the service life of apartments, thereby reducing the number of times that the apartments need to be rebuilt. In this way, the agents reduce CO_2 emissions over the entire life cycle. In buildings made from reinforced concrete, [1] The concrete, which is constricted by steel bars, forms cracks as it dries, as a result of the shrinkage, impeding its strength. [2] Air containing carbon dioxide enters through the cracks, neutralizing the concrete and corroding the steel bars, thereby reducing the durability of the buildings. Drying shrinkage-reducing agents (concrete shrinkage-reducing agents) reduce the incidence of cracks by impeding shrinkage through a reduction in the capillary tension that occurs when the moisture in the concrete evaporates. The agents are added together with water when making ready-mixed concrete. The result is that the service life of apartments is extended.  Chemical products used in apartments having a long service life • Drying shrinkage-reducing agent (special polyoxy alkylene glycol derivative) • High-performance AE water reducing agent (polycarbonic acid-based high-performance AE water reducing agent) • Water reducing agent (lignin sulfonic acid salt)
2	Scope of assessment using cLCA	
2-1	Product system to be assessed	Product under assessment • High-durability apartments that have been built with the use of drying shrinkage-reducing agents Product for comparison • Ordinary apartments
2-2	Functions	• To provide residential accommodation during the same period
2-3	Functional unit and reference flow	Functional unit • Residential space for one house to be provided by apartments made of reinforced concrete for 100 years are used as the functional unit. Reference flow • High-durability apartment in which drying shrinkage-reducing agents have been used: one apartment (no rebuilding) • Ordinary apartment: two apartments in total (with rebuilding)

No	Item	Contents		
2-4	System boundary	Processes to be assessed • Apartment life cycle (from the procurement of raw materials to manufacture (construction), use/maintenance and management, and disposal) • Energy consumed by common areas, such as elevators, etc. is included in use/maintenance and management.		
2-5	Preconditions for cLCA	• Equipment and machinery that use energy (air conditioners, cooking equipment, etc.) introduced into apartments can be offset by regarding them equivalent items. Therefore, they are removed from the scope of assessment. • Based on the flow-base method, calculate the avoided CO_2 emissions that results from extending the service life of the apartments (61,000 apartment) provided in 2020		
3	Result of assessment using cLCA	Processes to be assessed	High-durability apartments (kg-CO_2/apartment)	Ordinary apartments (kg-CO_2/apartment)
3-1	CO_2 emissions associated with construction[103]	Design and supervision	4,517	4,493
		New construction (including rebuilding)	79,974	159,948
		Chemicals	3,888	387
3-2	CO_2 emissions associated with use, maintenance and management	Mending	58,073	58,073
		Repair	104,571	61,349
		Maintenance and management	13,635	13,635
3-3	CO_2 emissions associated with disposal/recycling	Disposal/recycling	6,718	10,483
3-4	CO_2 emissions in the entire life cycle	<u>Entire life cycle</u>	271,376	308,174
3-5	The avoided CO_2 emissions per unit level of adoption	• CO_2 emissions from long-service-life apartments relative to those from ordinary apartments: 36,992 kg-CO_2/apartment/100 years		

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[103] Calculated by referring to examples of apartments in "LCA Policy for Buildings (3rd Edition)" of the Architectural Institute of Japan.

No	Item	Contents
4	Assessment by using a scenario for adoption	
4-1	Predicted level of adoption	• The number of apartments for which construction will start in 2020 is estimated to be 61,000 (source: Number of Apartments in the Apartments to Be Supplied: MLIT's material, Estimated Number of New Houses to Be Built: material of the Ministry of Economy, Trade and Industry). • It has been assumed that all these apartments will be replaced by long-service-life apartments.
4-2	Level of adoption	• The number of apartments to be built in 2020 is estimated to be 61,000.
4-3	CO_2 emissions from high durability apartments over its life cycle	• CO_2 emissions from high-durability-apartments over their entire life cycle: 16.55 million t-CO_2
4-4	CO_2 emissions from chemical products	• CO_2 emissions during the procurement of raw materials and manufacture of drying shrinkage-reducing agents and high-performance AE water-reducing agents: 240,000 t-CO_2
4-3	The avoided CO_2 emissions	Method of calculation • (3-5) × (4-2) Result of calculation • 2.24 million t-CO_2 (100 years)

Innovations for Greenhouse Gas Reductions

Life Cycle Analysis of Chemical Products
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