JLCA NEWS ENGLISH EDITION July. 2008

No.5

JLCA NEWS LETTER

Life-Cycle Assessment Society of Japan

Contents

Case Example

Issues in LCA in the Concrete Industry

Yoshitaka Ishikawa
Senior Researcher
Chigasaki Research Institute
Electric Power Development Co., Ltd.

1. Introduction (lifecycle of concrete)

As a concrete researcher, I am inclined to be defensive of the concrete industry, but I must admit that efforts to deal with environmental problems in this industry are no more advanced than other industries. The concrete and cement industry is a key industry, and some streamlining and environmental protection measures have been implemented so far, but I believe there are still essential problems.

In this article, characteristics of the concrete industry are first discussed and then life cycle and material flow will be considered in order to discuss issues in LCA in the concrete industry. Concrete surely is a material that we are all familiar with, but why do we use it so often?

Concrete has high strength and durability. It can be formed into any shape, and it therefore has high design freedom. It can also be used together with reinforcing steel or fiber. (A combination of concrete and reinforcing steel is so-called reinforced concrete. Concrete has high compression resistance and low tension resistance. Therefore, it is necessary to reinforce concrete with a material having high tension resistance. In general, reinforcing steel is used for this reason.) Materials used to produce concrete are easy to obtain and have high economic advantage. For this reason, a large volume of concrete is used as an important material in building construction. How is concrete produced, disposed of, and recycled?

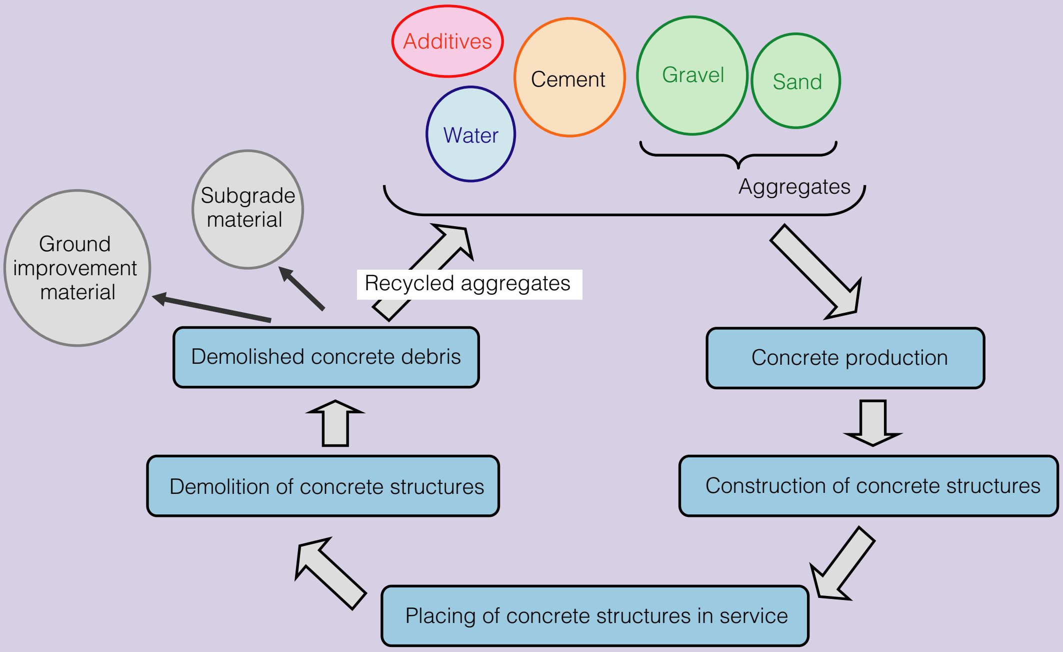
Figure 1 shows the life cycle of concrete (materials and manufacturing concrete production → construction of concrete structures → placing of concrete structures in service → demolition of concrete structures → disposal and recycling).

Concrete consists of cement, aggregates (gravel and sand), additives (blast furnace slag and fly ash), and water. These materials are seemingly simple and readily available. Recently, however, types of material have been highly diversified. For example, it has become difficult to collect quality fine aggregates in western Japan, and also, standards have been developed and implemented in order to promote use of slag.

During the manufacturing stage, in the case of a large scale construction project, a special concrete manufacturing plant is established at the construction site. However, in most cases, concrete is manufactured at a commercial ready-mixed concrete plant and is carried to the construction site. Although manufacturing of ready-mixed concrete at the plant is closely controlled, product (concrete) quality still varies more than other industrial products. Also, because of the nature of "ready-mixed" concrete, concrete hardens after a certain time period passes after manufacturing, and therefore, the distance between the manufacturing plant and the construction site is limited.

Due to the advancement of concrete pumping technology, power has been greatly saved in construction work using concrete. Note however, that the skill to work with concrete during the construction stage is still the key that determines concrete quality and performance.

Figure 1 Life cycle of concrete



After the construction stage is complete, concrete is used as a concrete structure. Except for the fact that the concrete structure requires maintenance and repair during its service period, not much change occurs in terms of LCA. Although it depends on the structure, a concrete structure in general serves for 30 to 60 years. This term is not determined based on life of concrete but instead seems to be determined based on the socially accepted building renewal cycle in Japan.

The concrete structure demolition stage requires a large amount of energy, and recycling of waste concrete is now a serious issue.

2. Material flow of concrete

Next, the material flow of concrete within its life cycle is examined. As shown in Table 1, environmental impacts such as CO_2 emission are large in the material and manufacturing as well as demolition stages[1). Here, from the material flow perspective, the material and manufacturing as well as demolition (disposal and reuse) stages are examined.

2.1 Material and manufacturing

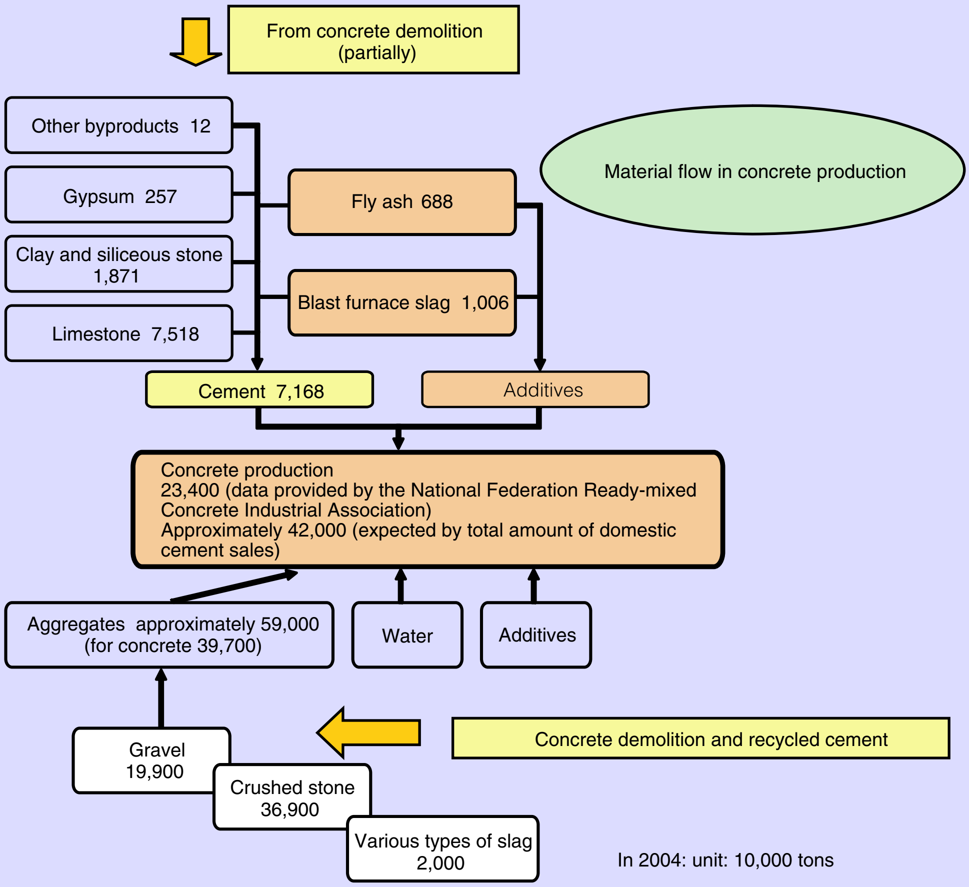
Figure 2 shows assessment result of concrete manufacturing starting from the material stage. The concrete manufacturing stage ends when a ready-mixed concrete plant ships the products. Values shown in the figure are based on the statistical figures obtained in 2004.

(1) Cement

Cement is in general produced by burning limestone (approximately 80%), clay (approximately 20%), slag, siliceous stone, and gypsum at a high temperature. Production of cement peaked in 1995 and is now decreasing. In 2004, 71.68 million tons (domestic sales: 56.74 million tons) of cement was produced.

As materials used in cement production, 75.18 million tons of limestone, and a total of 23.35 million tons of clay, siliceous stone, and gypsum were used. Also, a total of 28.78 million tons of blast furnace slag, fly ash, desulfurized gypsum, other waste, and byproducts were used as cement material or fuel[2). Recently, municipal solid waste has been actively reused as materials or fuel for cement production, and the ratio of use of alternative fuel is expected to grow further.

Figure 2 Material flow in concrete structure production (unit: 10,000 tons)



In 2004: unit: 10,000 tons

(2) Additives

Additives (blast furnace slag and fly ash) can be used not only to produce blended cement but also to be mixed with cement as concrete additives at a ready-mixed concrete plant. For the latter case, it is estimated that approximately 0.83 million tons of blast furnace slag and approximately 0.1 million tons of fly ash were used[3) 4)].

(3) Aggregates

A total of 590 million tons of aggregates were used. Of which, 397 million tons were used as concrete aggregates, and 193 million tons were used as road and ballast aggregates[5)].

(4) Chemical admixture

Only a small amount of chemical admixture were used; therefore, shipment result data has not been disclosed.

(5) Water

Industrial water, clean water, or recycled water is used ,and data on the total amount of use or its breakdown has not been disclosed.

(6) Concrete

According to the data disclosed by National Federation Ready-mixed Concrete Industrial Association, 106,280,000 m^3 of concrete was shipped in 2004[2)], which was about 234 million tons of concrete. Note however, that these values do not seem to include data of ready-mixed concrete plants which don't belong to the association or secondary product factories. The basic unit of quantity of cement is said to be about 13% of the weight of concrete. Therefore, if 56.74 million tons of cement was sold domestically, approximately 420 million tons of concrete was used.

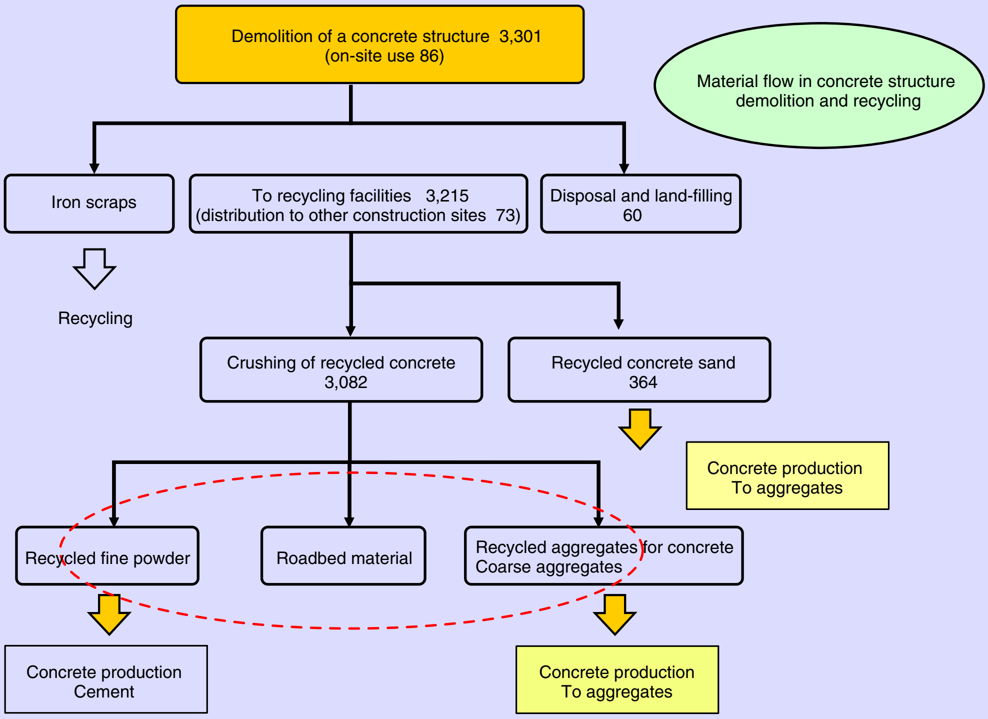
Table 1 Ratios of environmental burdens accounted for by each concrete life cycle process

Process	CO_2 emission (%)	SOx emission (%)	NOx emission (%)	Dust emission (%)
Material and manufacturing	84.9	63.2	40.6	27.9
Construction	4.9	9.5	16.0	19.2
Demolition	5.3	14.9	28.7	31.4
Disposal and recycling	1.2	1.9	1.6	2.1
Transportation	3.6	10.5	13.1	19.4

2.2 Demolition, disposal, and recycling

After being produced, concrete is used to construct a concrete structure and provided to its user. When the service period of the structure is finished, the structure is demolished and disposed of. Figure 3 shows the flow of demolition, disposal, and recycling of a concrete structure based on statistical values obtained in 2006.
of the age are required.

Figure 3 Material flow in concrete structure demolition and recycling (unit: 10,000 tons)



In 2006: unit: 10,000 tons

(1) Waste concrete

According to the latest data of 2006, 33.01 million tons of waste concrete was produced from demolition of concrete structures. Of which, approximately 98% was recycled or distributed to other construction sites to be used, and 600,000 tons of waste concrete was used in land-filling[6]. This recycling rate of 98% is a national average; compared to the recycling rate obtained in the previous survey which was 5 years ago, the recycling rate in both large cities and suburban cities has not changed much. Values for the elements surrounded by a red dotted line need to be estimated as there is no statistical data for them, but a large part of waste concrete was recycled into crushed stones to be used as roadbeds. Only a small part was recycled into concrete sand or coarse concrete aggregates or used as cement alternative, and the amount is considered to be very small.

(2) Iron scraps

The amount of iron scraps generated at the time of concrete demolition is considered to be proportional to the amount of waste concrete produced. However, specific statistical value is not available. Concrete structures in general are reinforced concrete structures. As for reinforcing steel, according to the Policy Bureau of the Ministry of Land, Infrastructure, Transport and Tourism (estimates based on the data provided by the Japan Iron and Steel Federation), approximately 10.7 million tons of small steel bars were produced for construction work in 2003[7]. At the time of concrete structure demolition and disposal, reinforcing steel inside the concrete can be collected as scrap and recycled.

3. Characteristics and issues for LCA in the concrete industry

Based on the statistical data presented above, the characteristics and issues for LCA in the concrete industry are as follows:

1) Concrete materials (cement and aggregates (gravel and sand) in particular) account for a large part of materials used in construction activities (it is said to be approximately 90%). For this reason, examination of LCA results for the concrete industry is highly important in examination of LCA results for the construction industry. The ideal concrete industry is a closed material input-and-output system wherein input means materials and manufacturing and output means demolition, disposal, and recycling; however, in the current state, it is extremely difficult to create a cycle in which the flow goes back to input from output.

2) As for comparison of CO_2 emission basic units among the materials (cement, aggregates (gravel and sand), and additives) used in concrete production, as seen in Table 1, although a large amount such as 400 million tons of gravel and sand are used, since their CO_2 emission basic unit is small, they only have a small impact on the total CO_2 emission of concrete compared to other materials. Also, though the CO_2 emission basic unit associated with aggregate collection is small, the environmental impact of collection of a large volume of natural aggregates from mountains and the sea on the surrounding environment has yet to be assessed. Therefore, LCA needs to be performed based on careful consideration of the abovementioned environmental impact.

3) A large volume of waste materials are accepted and used in the concrete material production stage. These waste materials must be used in land-filling if not used for concrete material production. How this waste material use should be incorporated into LCA is one of the future issues.

4) Improvement of concrete material quality (strength and durability improvement) and extension of concrete structure service period seem to be effective ways of reducing the overall environmental burdens of the life cycle. In reality, however, not only life extension of skeletal structures, but also comprehensive life extension of facilities and the living environment created by building structures and establishment of renewability of these facilities and the living environment in accordance with the needs of the age are required.

4. Conclusion

This article has discussed the issues related to LCA in the concrete industry. Simply by looking at the figures, it is easy to recognize that the concrete and cement industry is a highly influential industry that involves other industries. As discussed in this article, the ideal concrete industry is a closed material input-and-output system wherein input means materials and manufacturing and output means demolition, disposal, and recycling; however, in the current state, it is extremely difficult to create a cycle in which the flow goes back to input from output. The basic requirement in reduction of environmental burdens is a well-balanced object circulation as is widely known. For this, use of nonrenewable resources must be minimized and a recyclable system must be established.

Therefore, development of technologies that can create a material flow from output to input is sincerely desired. Also, it may be possible to find the solution to these issues by performing LCA of the concrete and cement industry in relation to production activities of other industries.

References

1) Japan Society of Civil Engineers: Environmental burdens of Concrete (Vol. 2), Concrete Technology Series 62, September, 2004
2) Japan Cement Association: Cement Handbook, 2005
3) Nippon Slag Association: Annual Slag Statistics, 2006
4) Japan Coal Energy Center: National Coal Ash Survey Report, 2006
5) Estimation by the Housing Industry Ceramics and Construction Materials Division of the Ministry of Economy, Trade and Industry
6) Ministry of Land, Infrastructure, Transport and Tourism: 2005 Construction By-Product Survey, 2006
7) Construction Promotion Division, Policy Bureau of the Ministry of Land, Infrastructure, Transport and Tourism: 2004 Forecast of Demand for Major Building Materials
8) Yoshitaka Ishikawa: LCA of Concrete Materials, Collection of Papers for the 1st Institute of Life Cycle Assessment of Japan Presentation Meeting, pp. 145 - 146, 2005
9) Yoshitaka Ishikawa: LCA of Concrete Materials (Part. 2), Collection of Papers for the 2nd Institute of Life Cycle Assessment of Japan Presentation Meeting, pp. 200 - 201, 2007

LCA in Large Pump Production Activities

- Creation of a Supply Chain LCA Database -

Hiroshi Kozuka
and
Yasuko Eto
Environmental Management Group
Haneda District, Ebara Corporation

1. Introduction

Environmental load are the negative result of economic activities. The level of economic activities is expressed and assessed in currency, and the level of environmental load is expressed and assessed in environmental potential. Goods receive additional value through economic activities and are traded at their prices. Therefore, definition of environmental load in accordance with the input-output table and calculation of environmental load of goods are useful activities. The input-output table however lists macroscopic values of the entire Japanese economy, and it seems too macroscopic to be used to calculate environmental load of goods manufactured by individual companies.

Now that goods prices are defined based on the internal manufacturing cost, their environmental load should probably be calculated based on emissions of each company.

For this reason, we decided to create an LCA database in order to understand the nature of environmental load of the supply chain consisting of our company and its suppliers and to calculate environmental load of products. From the factory LCA point of view, it is first necessary to define for each company the basic unit of environmental load that are appropriate for product specifications, and then create a supply chain basic environmental load unit database for calculating environmental load of goods.

This article reports on the database creation, results of calculation of large pump environmental load using the database, incorporation of the results into environmental management activities at the factory, and the future issues to be addressed.

2. Creation of a basic unit data base

The major processes listed below were analyzed for large pumps, which were the leading products manufactured at the Haneda plant, as follows:

(1) Processes at the Haneda plant (machine operation, assembly, testing, painting, and so on)
(2) Casting process
(3) Fabrication process (for large and small parts)
(4) Forging process (for large and small parts)
(5) Heat treatment process
(6)Machining process using subcontractor's machines (long parts, medium parts, and small parts)
(7) Transportation of formed materials
(8)Transportation between the Haneda plant and subcontracted processors
(9) Transportation to customers

Background data was used to obtain environmental load of materials and utilities, such as electricity, fuel, and water, for the formed material manufacturing stage and later stages. Note that purchased products were excluded from the analysis because they accounted only for a very small share of the products.

For the stages where suppliers were involved, suppliers to which a large number of orders were usually placed were selected. For each stage, suppliers of different sizes were selected in order to identify differences between suppliers of different sizes.

Annual environmental data (volume of resource and energy use, emission into the air or water, and the amount of waste materials) of individual companies was used in the analysis as input and output data. Actual measurement values were used as much as possible, but calculated values, estimated values, and background data were used for the amount of chemicals and emission into the air or water.

As a basic unit calculation index, production control data (work time, weight, surface area, and the number of units) was used.

Types of environmental potential analyzed were: global warming potential (GWP), acidification potential (AP), eutrophication potential (EP), primary energy consumption, photochemical ozone creation potential (POCP), human toxicity potential (HTP), and aquatic eco-toxicity potential (AETP). Annual environmental potentials for each process were calculated using Gabi4, which is summation method-based LCA software.

Then, the annual environmental potentials obtained were divided as follows to calculate the basic units of each type of environmental load. Environmental potentials were divided by work time for the development and design, machining, assembly, testing (pre-arrangement), and the processing by subcontractor's machines processes. For the testing (mechanical performance) process, they were divided by electricity used in testing. For the painting process, they were divided by surface area. For the distribution and other processes, they were divided by the number of units shipped. For the casting, fabrication, forging, and heat treatment processes, they were divided by weight produced or shipped by each company. Through the calculations above, the basic environmental load unit database for the supply chain in accordance with the product specifications (materials, weight, surface area, work time, and so on) was created.

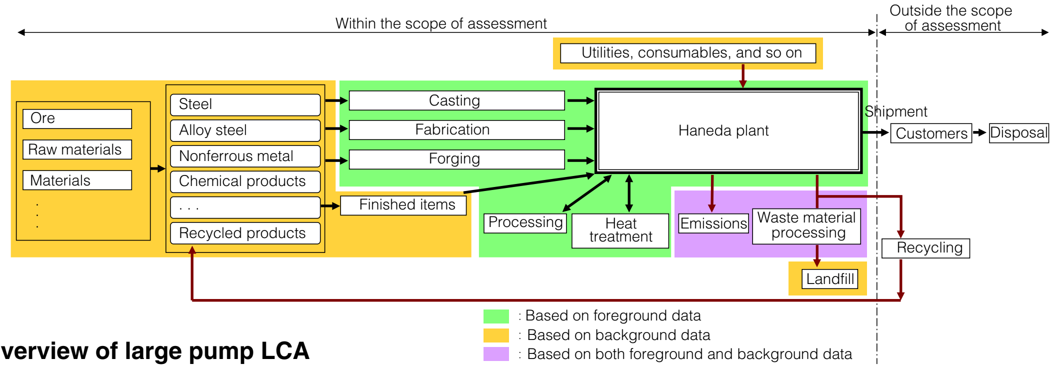


Figure 1 Overview of large pump LCA

Case Example

	Haneda plant					Large fabrication can manufacturing	Processing using subcontractor's machines
	Design	Machining	Assembly	Painting	Transportation Distribution		
GMP100 (kg-CO_2/**)	404	1,495	499	403	134	497	339
AP (kg-SO_2/**)	0.58	2.43	0.72	0.74	0.82	0.86	0.51
EP (kg-ph/**)	0.04	0.21	0.06	0.08	0.13	0.25	0.04
POCP (kg-Et/**)	0.15	0.70	0.35	17.7	0.28	0.20	0.18
HTP (kg-DCB/**)	12.3	43.2	13.5	18.0	2.2	17.4	9.5
AETP (sea salt water)	23.3	79.7	24.6	24.9	0.8	53.5	17.3
Primary energy consumption	9.0	32.6	10.5	9.6	1.8	9.3	7.6
Basic unit index (** = unit)	Work time (100 h)	Work time (100 h)	Work time (100 h)	Painted area (100 m^2)	Number of units shipped (units)	Work time (100 h)	Work time (100 h)

Table 1 Basic unit data (example)

3.Environmental load of the product (1200VZM calculation example)

Using the supply chain basic environmental load unit data, environmental load of a 1200 mm vertical mixed flow pump was calculated based on the product specifications for making estimates (casing: FC250, impeller: SCS13, and so on). Figure 2 shows the result.

Even for a made-to-order product like a large pump, it is possible to use data for cost calculation and easily calculate the product price and environmental load simultaneously by having the basic unit data created based on the product specifications as indices. Therefore, it is possible to present to customers data on environmental load of the product when submitting a quotation to suggest purchase of products with lower environmental load.

Also, by having a basic environmental load unit ready for each material, it is possible to calculate environmental load of a wide variety of products by combining material-specific and process-specific environmental load.

Figure 3 shows environmental load per one ton of shipment of cast products and fabrication products.

By obtaining the basic units using the product specifications as indices in advance, it is possible to easily calculate environmental load of other products that are manufactured within the same supply chain.

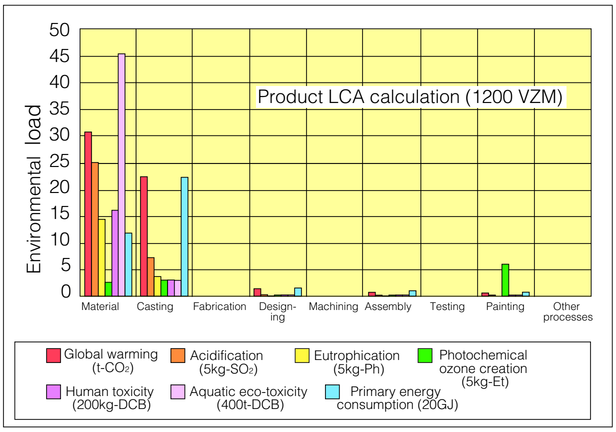


Figure 2 Environmental load of the product (1200 mm VZM)

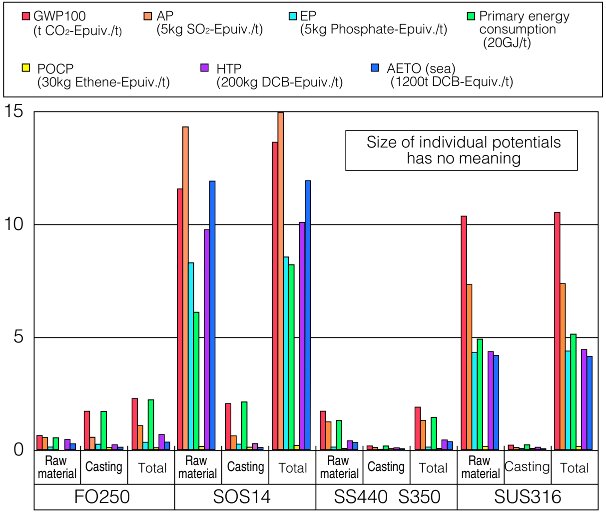


Figure 3 Environmental load per one ton of cast products and Fabrication products

4.Environmental load of each process and process improvement

Figure 4 shows environmental load of each large pump manufacturing process for a specific shipment weight.

Within the manufacturing processes, the casting process causes

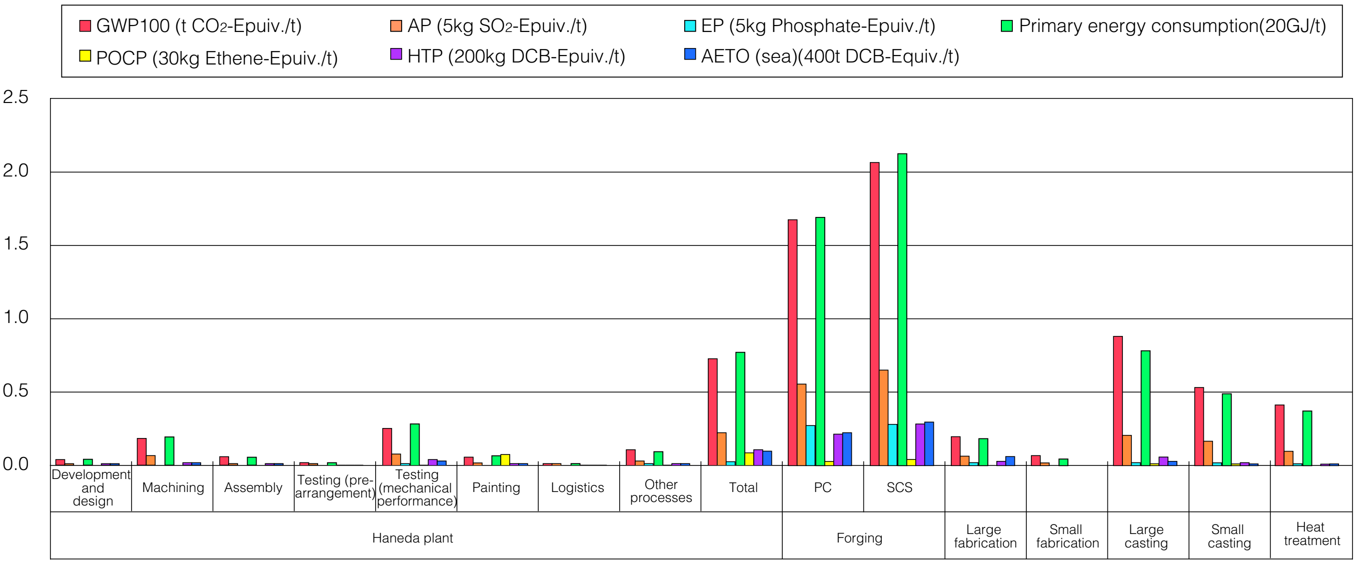


Figure 4 Environmental load of each process per one ton of production

the GWP and primary energy consumption to be high because of the level of electricity required to melt steel. The GWP and the primary energy consumption are also high in the forging and heat treatment processes because of the amount of fuel required for heating. It is also possible to quantitatively compare environmental load of other processes with other companies or other processes to identify issues. The comparison results will then serve as useful data to be used in promotion of environmental management activities.

The following sections provide examples of effective use of LCA data

4.1 Comparison of plant size

Figure 5 shows environmental load per 200 man-hours (working time by one worker in a month) for the fabrication, forging, and machining processes.

The figure indicates that environmental impacts associated with the use of energy are larger for larger plants. This seems to be because size of machines and equipment, rate of operation, available capacity of energy consumption equipment, and size of fixed equipment such as buildings and lighting are different between large plants and small plants.

As described above, analysis using environmental and production data provided by companies allows identification of differences in environmental load resulting from differences in company size. Analysis with the input-output table could not produce the same result, and therefore, this result is the achievement of the analysis method used in this report. From the green procurement point of view, it is important to use plants with a size appropriate for the size of products or parts.

4.2 Environmental load of each process at a large pump manufacturing plant

Figure 6 shows environmental load of each process at the Haneda plant, which is a large pump manufacturing factory.

The GWP and primary energy consumption are high in the machining and testing (mechanical and performance test) processes due to the use of power. In both processes, CO_2 is indirectly emitted through power generation. In the painting process, VOC contained in paint, solvent, and cleanser results in the generation of the POCP. Direct emission through paint work accounts for 62% of the POCP, and indirect emission caused by paint production and power generation accounts for the rest. The graph also shows that office work such as designing results in the same level of environmental load as onsite work such as assembly. Therefore, analysis of process-specific environmental data allows quantitative understanding of environmental issues, and LCA is effective in upgrading of environmental management systems.

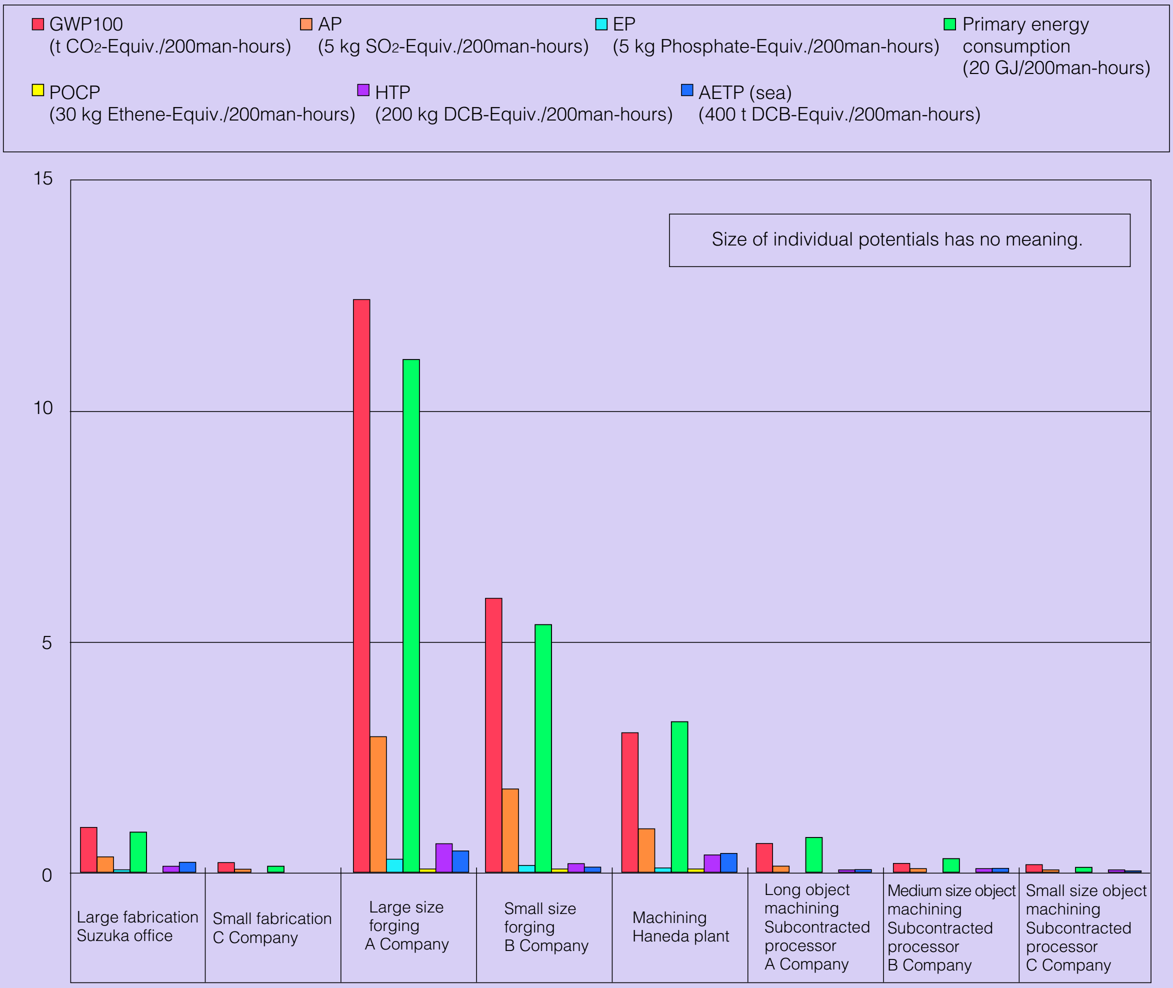


Figure 5 Environmental load per 200 man-hours for different processes at different companies

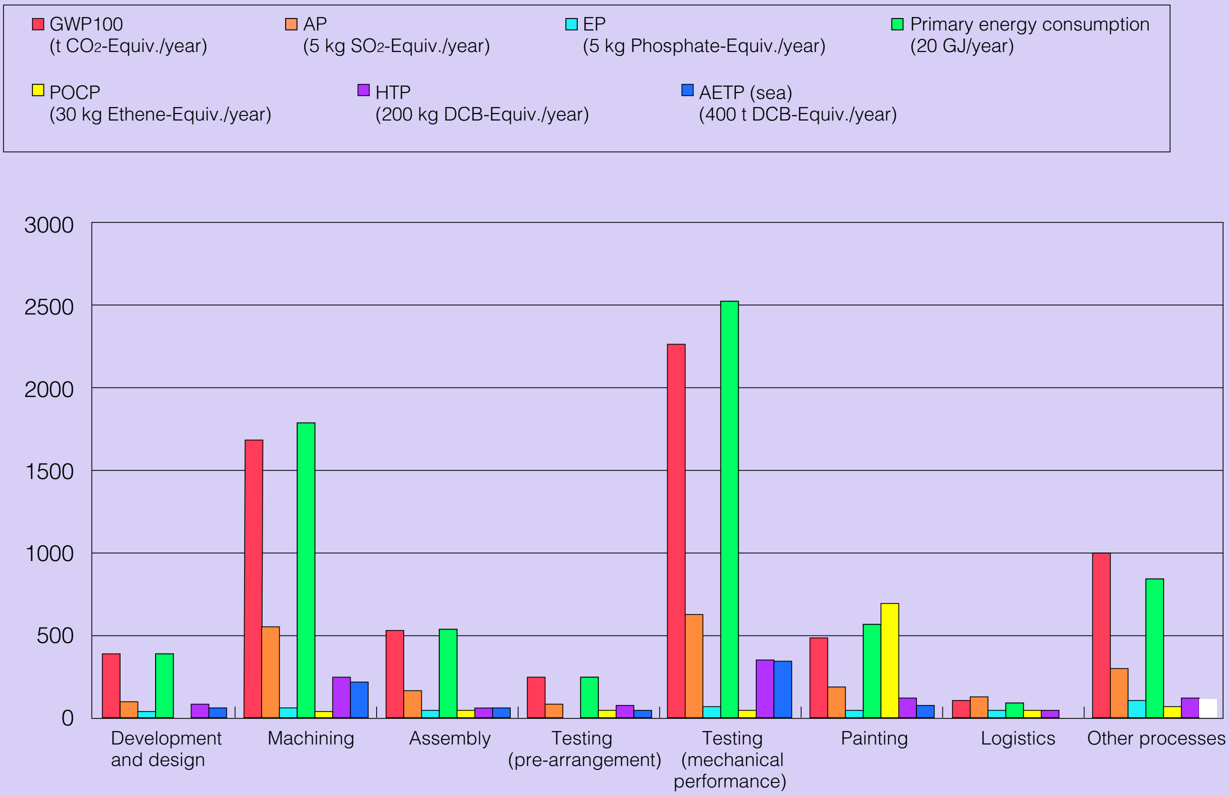


Figure 6 Environmental load of each process at the Haneda plant

5. Summary

Our findings from using the LCA basic unit calculation method for our supply chain are as follows:
1) It is easy to calculate product LCA results. Environmental load and costs can be obtained simultaneously; therefore, it is possible to quantitatively recommend products with low environmental load to customers.
2) The calculation method can be applied to other products as long as they are manufactured within the same supply chain.
3) Environmental management activities can be carried out quantitatively, and it is possible to express activity achievements as numerical values.
4) Compared to small factories, environmental load per specific work hour as well as specific produced weight are higher for large factories. Therefore, more active eco-friendly activities are required for larger factories.
5) Environmental load are high for material forming such as casting and forging. Reduction of product weight can greatly contribute to reduction of environmental load.
6) Alloy steel such as stainless steel has excellent electrochemical properties such as corrosion resistance; however, it has high environmental load and thus needs to be used properly.
7) Compared to cast products, can products can reduce environmental load during manufacturing.

6. Conclusion

In this project, we obtained environmental data and production control data from our cooperating companies on the processes of large pump manufacturing at our Haneda plant, and created a database of basic environmental load units for the supply chain.
In the automobile, IT, and home appliance industries, a supply chain has the shape of a pyramid, and a manufacturer that develops and sells finished products sits at the top of the pyramid.

In the industrial machinery industry, formed materials and parts are procured from a large number of independent manufacturers, and therefore, a set supply chain is not necessarily formed. For this reason, information that can be provided by individual companies is limited and purchased finished items are not included in analysis. Therefore, it is desirable that industrial machinery manufacturers cooperate with each other, and publish and share their achievement data so that a highly accurate database can be created and LCA techniques can be upgraded. Also, it is our belief that using LCA data as one of the tools to promote environmental management activities is beneficial. We welcome any comments to this report.

7. Acknowledgment

We would like to express our gratitude to the companies that provided data to us and to PE-Asia who analyzed data for this project.

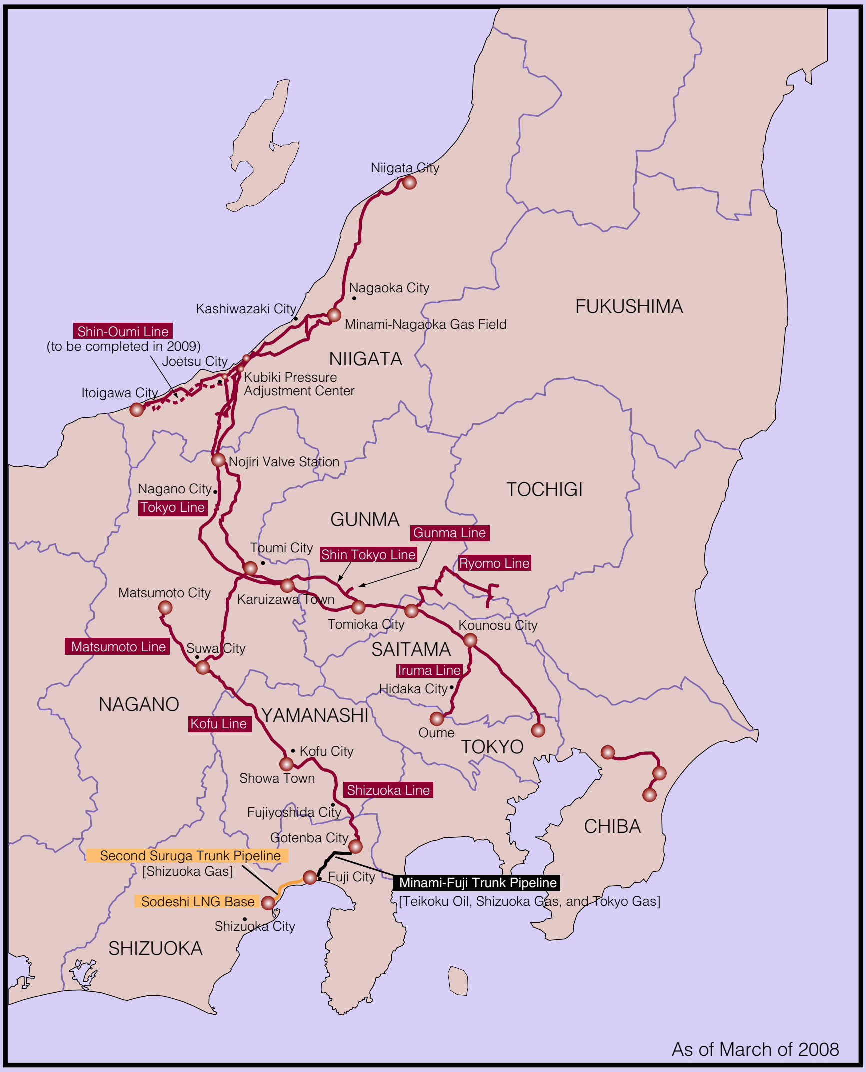
Life Cycle Inventory Analysis of Domestic Natural Gas

Hidenori Kaneta
Environmental Safety Department
Teikoku Oil Co., Ltd.

1. Natural gas with low environmental burdens

Natural gas has been attracting attention as a low environmental burden gas because of its low SOx and NOx emission at the time of combustion compared to coal or oil. In particular, changeover from heavy oil or kerosene to natural gas can reduce CO_2 emission by approximately 30%; therefore, the use of natural gas can be an effective environmental protection measure. Also, while more than 99% of oil is imported from overseas, 4% to 5% of natural gas can be self-supplied domestically. The Minami-Nagaoka Gas Field, which is our leading gas field located outside Nagaoka City, supplies natural gas to Niigata-pref, Nagano-pref., and the Northern Kanto area through pipelines, and the self-sufficiency ratio of domestic natural gas in these areas is high (Figure 1, as of March of 2008).

Although energy is one of the basic fields for which LCA should be conducted, there have only been a few LCA case examples since most energy resources are imported. One of the examples is an LCI survey on CO_2 emission of fossil fuels (coal, oil, liquefied natural gas (LNG), and liquefied petroleum gas (LPG)) conducted by the Institute of Energy Economics, Japan, in 1999. In this study, the LCI analysis of LNG was made based on the assumption that LNG would be imported from four South-East Asian countries and Alaska. The result showed that much energy was spent on the liquefaction process and LNG transportation by vessels. It was estimated that the natural gas in Minami-Nagaoka supplied through the abovementioned pipeline is lower in environmental burdens because liquefaction and transportation factors are eliminated. For this reason, in 2002, we conducted LCI analysis of CO_2 emission jointly with the Research Center for Life Cycle Assessment of the Advanced Industrial Science and Technology based on the business operation data of the previous year. This article describes the specific supplies and input energy that was assessed, the assessment results, and measures to reduce future CO_2 emission.



As of March of 2008

Figure 1 Natural gas pipelines

2. Objectives and scope of LCI analysis

The objectives of the LCI analysis conducted in 2002 were as follows:
(A)Creation of domestic natural gas data as the basic data essential for examination of energy systems
(B)Close examination of the impacts of natural gas search, development, production, and transportation on global warming, understanding of the reality of emission, and effective use of the information obtained in process improvement
The scope of analysis was emission of GHG (greenhouse gases) such as CO$_2$ and methane, with the amount of natural gas per MJ as a functional unit. Data obtained from January to December of 2001 was used in the analysis.

3. Input energy, supplies, and equipment that were analyzed in the LCI analysis

To extract natural gas, exploration activities are first carried out and then, when a potential gas field is found, test drilling is performed. When a particular gas field is determined as being economically viable, an online plant appropriate for that gas field is constructed, pipelines are installed, and natural gas is transported to destinations. Details of input energy, supplies, and equipment in each stage are described below.

(A)Exploration stage

Dynamite that was used in the Nagaoka Plain seismic exploration was analyzed. This seismic exploration was a basic geophysical exploration conducted in 1979 and was also how the Minami-Nagaoka Gas Field was found. Fuel used by seismic exploration vehicles could be the target of analysis, but it was not included in the analysis since no records on them were kept and the amount of fuel used was minimal.

(B)Drilling stage

In the Minami-Nagaoka area, a total of 36 wells were drilled including failed and abandoned wells between 1976 and 2001. In addition to these 36 wells, six wells used in well maintenance work (such as oil well tubular replacement work) and four wells used in massive hydraulic fracturing (MHF) work to increase oil availability were analyzed. As for supplies, light oil as power generator fuel, mud conditioning materials used in mud water for drilling, and cement were analyzed. As for durable equipment, drilling rigs, bits, pipes (drill pipes and casings), and pumps were analyzed. The equipment was calculated as iron mass; however, how much of the individual equipment was used in the Minami-Nagaoka area was calculated while taking into account the years of durability of individual equipment. Note also that untreated gas that was burnt in gas production tests was included in CO$_2$ emission.

(C)Production stage

The Minami-Nagaoka Gas Field has two gas processing plants. At these plants, gas and oil are separated, and water and CO$_2$ contained in natural gas are removed. Water and CO$_2$ must be removed in order to protect pipelines from corrosion and to adjust the heat quantity of gas. In the LCI analysis, the stainless steel, cement, and asphalt that were used when building the two plants, the well base, and the administration office were calculated as the facilities elements to be analyzed. The amount of electricity, gas, and city water used in a year was also calculated. Both the facilities and energy elements were divided in the ratio consistent with the heat quantity ratio between natural gas and oil to obtain the values associated with natural gas.
The CO$_2$ described above accounted for approximately 6% of the natural gas volume. This CO$_2$ is separated from the gas and emitted into the air. Since the emitted gas also includes methane, in this analysis, methane emission was also calculated based on the analysis value for the gas. Although the plants carry out gas turbine power generation using the natural gas produced at the plants as fuel and use the power generated at the plants, only the CO$_2$ generated when the gas was used as fuel was used in the analysis to prevent overlapping.

(D)Transportation stage

Iron, cement, and pipe exterior materials used when constructing pipelines, truss bridges, valve stations, and supply stations were analyzed as the facilities elements. As for the operational aspects associated with maintenance and management, natural gas emission in pipe replacement work, gasoline and light oil consumption in patrolling, electricity used in electrolytic protection, and natural gas emitted into the air at the time of pressure control (called "bleed gas") were calculated. Since gas produced in Minami-Nagaoka accounted for 88% of the total sales of gas transported through pipelines, 88% of the input energy and supplies were registered as an analysis target.

4. Result of the inventory analysis and measures to reduce GHG

For every 1 MJ of natural gas produced, 5.2 g of CO$_2$ or GHG was emitted. Of which, emission in the production stage accounted for 83% (4.4 g), the transportation stage accounted for 13% (0.66 g), and the drilling stage accounted for 4% (0.2 g). Emission in the exploration stage was extremely low at 0.0001% (0.63 x 10-6 g).
Breakdown of the emission among the stages are as follows. The production and transportation departments accounted for 70% of all emissions due to a large amount of emission from gas. Then, emission due to energy consumption in the production stage accounted for 22%. Non-durable supplies accounted only for 0.28% (see Figure 2).

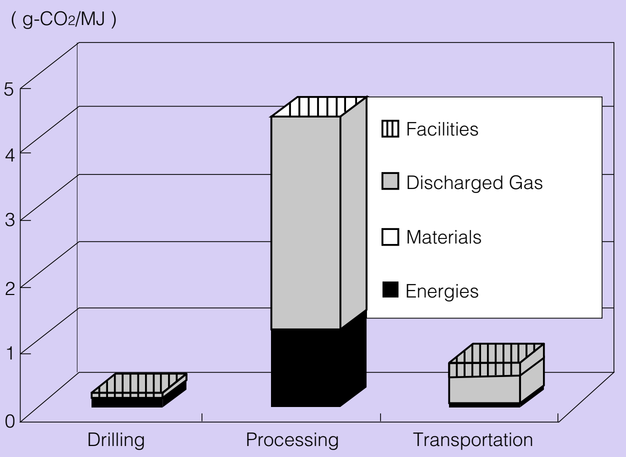


Figure 2 GHG emission in each process
(cited from the Journal of the Japan Institute of Energy 83-4, pp. 285 - 290)

95% of gas emitted from gas in the production stage was CO_2 originally contained in the fluid produced, and the remaining 5% was methane that was discharged with CO_2 when it was separated from the gas. CO_2 must be removed from gas at a gas processing plant since it is a corrosive fluid. A removal technique using a circulating amine solution has been adopted. Since small amounts of methane and VOC components (hydrocarbon over C_2) dissolved in the amine solution are discharged, discharged gas combustion devices have been operating since 2002. With the operation of these devices, the amount of methane emission has been decreasing.

A large part of emission in the transportation stage occurs during pipe replacement work and pressure control (bleed gas generation). Pipe replacement work is usually carried out in response to pipe relocation requests of local governments, the Ministry of Land, Infrastructure, Transport and Tourism, or landowners. Every time pipe replacement work is carried out, natural gas containing 90% methane is inevitably emitted. Traditionally, natural gas was emitted into the air while its pressure was still high (2 MPa to 5 MPa) in order to prioritize convenience of supply destinations. However, in response to the LCI analysis, attempts have been made to lower the operational pressure as much as possible prior to replacement work, and the amount of emission has been reduced by 30% to 40%. As for bleed gas emission, there are approximately 50 pressure controllers in total that use the pressure of the gas itself at pressure controlling centers. In the LCI analysis, calculations were performed using the maximum values provided in the equipment specifications, but the actual measurement values were one-third to quarter of the maximum values. Furthermore, although a few pressure controllers that do not emit gas have been installed, it has not reached the point where all pressure controllers shift to this zero-emission type due to financial restrictions.

5. Effects of the LCI analysis

As described above, LCI analysis was conducted with natural gas in Minami-Nagaoka using the operation data of 2001. The result indicated as hypothesized earlier that GHG emission throughout the life cycle of domestic natural gas was lower than that of imported LNG. In the end, the analysis allowed us to understand the reality of emissions, implement detailed process improvement measures in the production and transportation stages, and to reduce GHG emission.

Furthermore, the LCI analysis helped to expand sales of natural gas. At the same time, awareness of GHG emission was raised in the production and transportation-related departments, and the environmental protection measures described above were actively implemented. Afterwards, the Japan Petroleum Development Association, the industrial group we belong to, established and implemented a voluntary action plan to reduce GHG emission.

The revised Law Concerning the Promotion of the Measures to Cope with Global Warming was implemented in April, 2006 to require relevant companies to calculate and report the amount of CO_2 emission caused by combustion of fossil fuels. The data obtained from the LCI analysis of fuel is important as the basic data to be used in that calculation. As a natural gas supplier, we hope to minimize non-essential GHG emission in our operation.

We extended our natural gas pipelines from Nagano to Shizuoka through Yamanashi and completed the Shizuoka Line at the end of 2006. With this new line, we are able to secure sources of two types of gas: domestic natural gas mainly from Minami-Nagaoka on the Sea of Japan side; and vaporized LNG from the Pacific Ocean side. This will dramatically improve supply stability to allow us to sustain a stable supply of gas even when gas demand increases. The role played by natural gas is increasing in importance, and it is our goal to further spread the use of natural gas through city gas providers, and commercial and industrial customers.

Report

Reality of LCA Education

Nobuhiko Narita
Professor
Environmental Information Business Department
Nagoya Sangyo University

1. Introduction

For the few decades that I worked in private enterprise in production activities or as a researcher, improvement of product quality and cost reduction were two of my critical missions, and I believed that sulfur oxide must be removed (eliminated) for product quality reasons. However, for the last half of my career, I was in environment-related business operations. There, I participated in international dissemination of environmentally-friendly equipments and LCA studies. Also, I discussed the LCA methods based on the ISO specifications or interpretation of data with industry people. I was then transferred to a university two years ago, and since then, I have been teaching students environmental improvement through LCA. Based on the experience of LCA studies both with companies and students, I would like to summarize the issues with and improvement of LCA education at my university.

2. LCA education at companies

Companies have factories, and the products of these factories are the target of analysis. From the cost and environmental point of view, what to be improved is always clear. Needless to say, materials procured by their own factories are well known. Even though there is no knowledge of how particular parts are processed in other industries, people at companies still understand quite well that finished products cannot be completed unless various industries link with each other. On the other hand, when the objective or motivation is not clear, the necessity of LCA is questioned and analysis cannot be performed. Therefore, in order to perform and disseminate LCA at companies, clarification of the objective must be prioritized. Once the objective is clearly stated and it is determined that LCA will be performed, analysis can be carried out smoothly. What LCA advisors must do is support the processes from the very first step to report.

3. LCA education at Nagoya Sangyo University

Nagoya Sangyo University aims to develop comprehensive human resources who have organically integrated knowledge in the environment, information, and business fields. The name of the department that I belong to contains the word "environment," but the department has no choices of physics or chemistry although there is a conventional biology elective course in general science. As clearly indicated above, Nagoya Sangyo University is basically a small "arts" university. This section describes difficulties in teaching LCA to students and improvements to be made at my university.

(1) Interest in LCA

When conducting LCA, it is necessary to investigate the validity of the technology under review and to clarify the positioning of that technology within the target product or service. At the same time, discussion of whether or not the features of the technology can be advertised based only on its impact on global warming can serve as material for learning environmental issues in general through understanding of the LCA method.

Meanwhile, LCA education at the university is different from LCA education at companies. At university, students do not have much real world experience, and therefore, they do not know how goods are manufactured. This fact often makes LCA education difficult. As described earlier, my university has no engineering-related departments, and also, students have few opportunities to tour plants and thus do not have clear ideas about manufacturing. For this reason, the university encourages the students to learn the basics and the importance of manufacturing while emphasizing the necessity of life cycle thinking. For example, since one of the most common environmental issues for the students who have almost no practical experience at factories would be garbage disposal, they often have interest in disposal of general waste materials and recycling of used PET bottles. The reason why the students develop their interest in waste disposal is that the disposal flow is something visible and that they are able to follow what happens to garbage that they dispose of. In particular, there is a shortage in final disposal sites in Nagoya City and the "declaration of waste emergency" has been issued. For this reason, Nagoya City has been implementing one of the most advanced waste sorting systems in the country, and it is necessary to clearly identify the benefit of these systems.

Also, types of part-time jobs for students have been diversified, and an increasing number of students are experiencing the working world by working in the service industry such as at a convenience store or restaurant. For the students to be able to use this working experience to develop the LCA point of view, it may be effective if they learn the concept of a life cycle by learning the material chain flow in the food industry. In fact, one of the students who worked in the food-service industry became strongly interested in how tuna fish was caught and that a particular label could be obtained for tuna fish depending on how it was caught. This student then started to voluntarily collect information and developed the ability to think from the LCA point of view. As described above, it is possible to make the students interested in LCA through their own experience of working in the service industry.

(2) Building of the basic academic skills

Recently, senior high school students can decide not to take physics or chemistry. Therefore, many of the students who take the environmental assessment course or the LCA course, which is an undergraduate course specialized in the environment, have not taken senior high school chemistry. As a result, some students have difficulty calculating emissions, which is the minimum calculation requirement for understanding of environmental issues. For example, students often do not understand the basic chemical formulas for obtaining the amount of CO_2 emission due to gasoline combustion or the amount of sulfur oxidized during the combustion, and this has created a situation where I must teach basic chemistry in the specialized course. I finally consulted with the instructors in the instruction department and created a chemistry course to teach the basics of senior high school chemistry and environmental chemistry. From this April, it is my hope that the students will learn the basics of LCA and also material balance and energy balance, which are the basic concepts of manufacturing, in this chemistry course targeting students of all school years.

(3) Internship programs

I use environmental reports to let my students understand the concept of manufacturing at their imaginary, virtual factories. Environmental reports summarize material and energy balances of the company and show whether or not the manufactured products can be beneficial to society. However, as the saying "seeing is believing" goes, visits to production sites or experiencing production processes will surely help the students understand what manufacturing is. Internship programs allow students to experience not only service activities but also manufacturing, and are also a very effective way for students to learn how goods are produced. I would like to ask manufacturing companies for cooperation, even though having students present may generate extra work for them.

4. Conclusion

Since I never specialized in environmental studies, I was not very environmentally friendly when I was a student or a young researcher. Now, it has been almost two years since I started teaching environmental studies through teaching the LCA method. LCA is an important area of study for seeing the whole picture while specializations are increasingly diversified. Since LCA is only a methodology, in discussions with the students, I am hoping to suggest environmental improvement measures using the LCA method. My university has many issues that are unique to an "arts" university specialized in environmental studies. Although solutions for these issues are now being explored, I have introduced in this article some of the possible ways to solve these issues.

I hope to continue teaching in this field to develop young human resources who can use the knowledge they acquired in LCA education to contribute to development of future environmentally-friendly corporate management.

Information

2008 IEEE International Symposium on Industrial Electronics	June 30-July 2,2008 Cambridge, UK	ISIE http://www.fastconf.com/isie2008/
2008 Design Engineering Technical Conferences & Computers and Information in Engineering Conference (IDETC/CIE)	August 3-6,2008 New York City, USA	ASME http://asmeconferences.org/idetc08/
8th Asia Pacific Roundtable for Sustainable Consumption and Production	September 18-20,2008 Cebu, PHILIPPINES	APRSCP http://www.aprscp.org/roundtables/8th.htm
Life Cycle Assessment VIII	September 30-Octber 2,2008 Seattle, USA	American Center for Life Cycle Assessment http://www.lcacenter.org/
Sustainable Innovation 08	Octber 27-28,2008 Malmo, SWEDEN	The Centre for Sustainable Design http://www.cfsd.org.uk/
SETAC North America 29th Annual Meeting	November 16-20,2008 Tampa, Florida, USA	SETAC http://tampa.setac.org/default.asp
JSWME 19th Annual Conference	November 19-21, 2008 Kyoto University Clock Tower Centennial Hall, JAPAN	JSWME http://www.jswme.gr.jp/international/
8th International Conference EcoBalance	December 10-12,2008 Tokyo, JAPAN	JLCAJ http://www.sntt.or.jp/ecobalance8/
The 10th Eco Products 2008 - Eco Style Fair	December 11-13,2008 Tokyo, JAPAN	http://www.eco-pro.info/eco2008/english/index.html
2008 International Conference on Environment (ICENV 2008)	December 15-17, 2008 Penang, MALAYSIA	ICENV http://chemical.eng.usm.my/ICENV2008/
Eco-products International Fair 2009	March 19-22, 2009 Manila, PHILIPPINES	APO http://www.apo-tokyo.org/index.htm

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Editor's Address

Life Cycle Assessment Society of Japan (JLCA)
LCA Development Office, JEMAI
(Japan Environmental Management Association for Industry)
2-1, Kajicho 2-chome, Chiyoda-ku, Tokyo, 101-0044
tel: +81-3-5209-7708
fax: +81-3-5209-7716
E-mail: jlca@jemai.or.jp
http://www.jemai.or.jp/english/