早稲田大学大学院 環境・エネルギー研究科

博士学位論文

Environmental improvement methods for Printing Service by utilizing multilateral LCA approaches

印刷サービスにおける LCA を活用した環境配慮手法の構築に関する研究

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CHAPTER 1

INTRODUCTORY CHAPTER

ABSTRACT

As an introductory chapter, purpose of the study is described in detail at first to insist the importance of this research. Printing Service is degraded by bottomless price war in recent years, but should be upgraded by promoting environmental conscious manufacturing, namely Eco-design concept. It must be developed to create new added value as environmental strategic plan. Printing industry consists of many small printers which are relatively not so strong and big in terms of organizational size and operating fund, so originality and ingenuity are key characteristics for them to differentiate from big printers. In order to shift Printing Service from price oriented to Eco-design oriented, Life cycle assessment (LCA) method should be established as Printing Service LCA for all sizes of printers to focus on quantitative assessment by avoiding sensuous qualitative assessment such as preferable vegetable oil ink and recycled paper without clear reasons. Necessity of establishments of Recycling-based and Low-carbon Societies as national objectives, technological transition of LCA studies, domestic/overseas CFP practices and previous LCA case studies in printing industry are explained for background of the research. At the end of the chapter, overall framework of the research is illustrated precisely to show the stream of the research.

1.1 PURPOSE OF THE STUDY

Printing industry is deemed to be one of the decaying industries in most of advanced countries in late years. In many circumstances, strict price competition is only a scale to measure if Printing Service has its value or not. It spreads out without making a valuation about additional something extra. It is a disaster for many of small printers which have poor financial abilities to shut down the operations since they are caught in price oriented competition against big printers.

It is an urgent matter for small printers to tackle forming the basis of high-value added Printing Service when considering survival strategic plans. Values of commodity are usually thought to be price and quality, but environment conscious manufacturing is added as new precious value nowadays. For small printers, corporate investment on factories and equipments to improve cost performance and quality in hardware side is not easy to do, but shifting to environment conscious manufacturing in software side could be possible to do, so adopting Eco-design in Printing Service is a new departure to proceed for the future.

Previous Eco-design used to depend on qualitative assessment believing that vegetable oil based ink is better than normal solvent based ink and recycled paper can reduce environmental load than virgin paper for instance. All of Eco-design concepts can show touchy-feely superiority, but cannot show corroborating evidence by numerical numbers. Therefore, quantitative assessment method is strongly required to indicate that numerical conversion of environmental load reduction in the practices.

Quantitative assessment method has not been standardized in printing industry though some of big companies already worked on it. Now, it is the time for variety kinds of printed matters in Printing Service to be schematized as quantitative assessment method by utilizing LCA approach. It should be organized to promote Eco-design as Printing Service LCA.

Currently, environmental impact assessment is considered synonymously with global warming potential, namely CO_2e emission, but newly developed Printing Service LCA should cover not only global warming potential, but also include other impact categories such as energy depletion, ozone layer destruction, acid precipitation, natural resource consumption, air pollution, water resource pollution, waste treatment problem, ecosystem effect and so forth. Global warming potential is only one of impact categories, so well balanced way of viewing is important and needed.

After Printing Service LCA covering different impact categories assessment is schematized for domestic use, it should be expanded to emerging countries and be localized to contribute for promoting Eco-design concept in printing industry there. Especially in Asian countries, Japan has been having pleasure of assisting many emerging countries to construct LCA related projects by government for long time, so there are basic elements of LCA concepts there and no difficulties to transfer Japanese way of thinking about Printing Service. In the course of developing from emerging stage to advanced stage, Eco-design concept must be learned on ahead to pursue real environment conscious manufacturing.

On the other hand, Printing Service LCA should be compared with different LCA methods in European advanced countries to be polished up by accepting new ideas of environmental impact assessment methods. Many of European countries have long history of environmental impact assessment and its actual achievements in the industries, there might be a matter of great interest. In European printing industry, France and Germany set a precedent for carbon calculation; hundreds of printing companies already started working on it within recent years.

Final deliverable of the research is Printing Service LCA with simple operation handling quantitative calculation not only for different impact categories but also for integrated assessment of all impact categories for small printers which are usually troubled by shortage of workers. For Integrated LCA approach, several different approaches in Japan and in Europe are compared thoroughly to find appropriate one for Printing Service to fulfill its needs.

Additionally, economical assessment could be added to balance the evaluation. Even though environmental performance can meet specific requirement, it has no value if cost performance cannot hit the target. Thereafter, Printing Service LCA and Life cycle costing (LCC) should be standardized as uniformed evaluation system based on product life cycle. This system can spur creativity and innovation for Printing Service in the standpoint of Eco-design.

1.2 BACKGROUND AND NECESSITY OF THE STUDY

Promoting environment conscious manufacturing, namely Eco-design in Printing Service should conform to “Establishment of Recycling-based Society” and “Construction of Low-carbon Society” which are the national environmental strategic policies. Both policies are core elements for priority issues of environmental strategic plans, so explanations should be provided for better understanding of those.

1.2.1 Establishment of Recycling-based Society

We live in flourishing life for long time thanks to social system based on mass production, mass consumption and mass discharge. Whereas our lives become affluent, huge amount of waste disposal have been discharged and caused waste treatment problems. In the fiscal year of 2000, it was set as first year of the challenge to establish Recycling-based Society, “The Basic Law for Establishing Recycling-based Society” was enacted to try not to produce wastes, use produced wastes as resources and waste final disposal when it cannot be used by any means. The concept of the Basic Law is summarized in Figure 1.1.

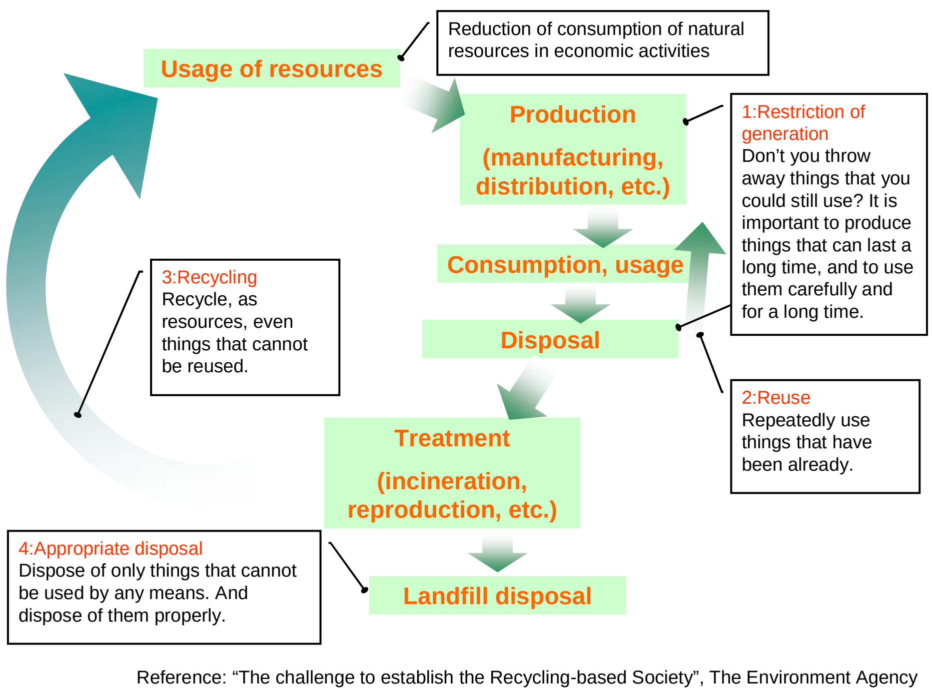


Figure 1.1 The concept of Basic Law for Establishing Recycling-based Society

What we have to do right now is reviewing our lifestyles and economic activities by utilizing limited natural resources with minimum environmental load.

Key points of the Basic Law are summarized as five pillars and indicated in Table 1.1.

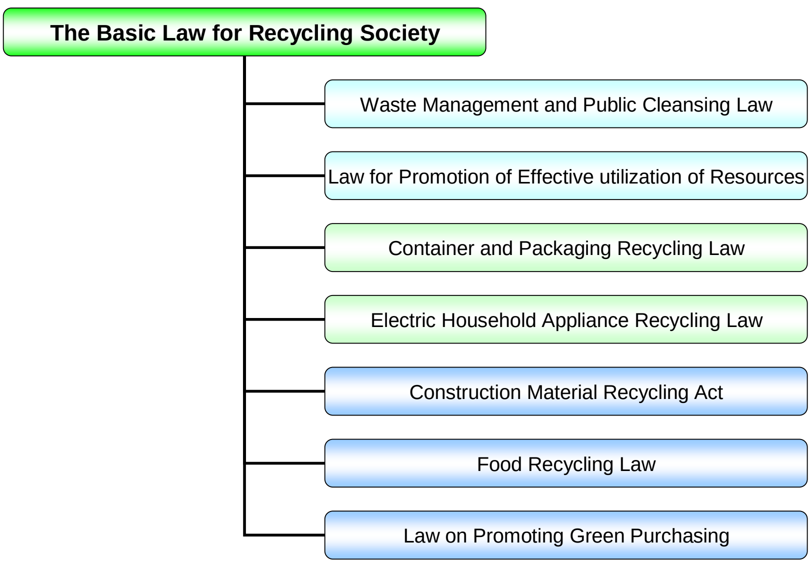
Table 1.1 Key points in the Basic Law for Establishing Recycling-based Society

①	The first effort is to reduce production of wastes as much as possible. Examples: To produce strong products and use them as long as possible. To choose and purchase products with simpler and less packaging.
②	The second effort is to re-use, as many as possible, things that are no longer needed. Examples: To return empty beer bottles to a liquor store. To recycle old clothes at a flea market.
③	The third effort is to recycle, as resources, things that cannot be used repeatedly. Examples: To sort wastes before disposal. To take TVs and refrigerators that are no longer being used, to an electronic appliance store.
④	The fourth effort is to burn things that canot be used as resources, and use the heat produced from their incineration. Examples: To use the heat generated from burning wastes for power generation or a warm-water pool.
⑤	The last effort is to appropriately dispose of things that cannot be re-used or recycled and that must be disposed of, in a manner that does not contaminate the environment Examples: To appropriately burn wastes so as not to generate dioxins, etc. To bury wastes so as not to influence the surrounding environment.

Reference: "The challenge to establish Recycling-based Society", The Environment Agency

Additionally, two major frames of the minds are set as keywords, one is "Discharging person's responsibility" and the other is "Extended Producer Responsibility". Here in the Basic Law, the responsibilities of persons who discharge waste disposal and of persons who manufacture things are clearly articulated.

The Basic Law does not function by stand-alone, so integrated operation by individual laws must support it to work properly. It is visualized in Figure 1.2.

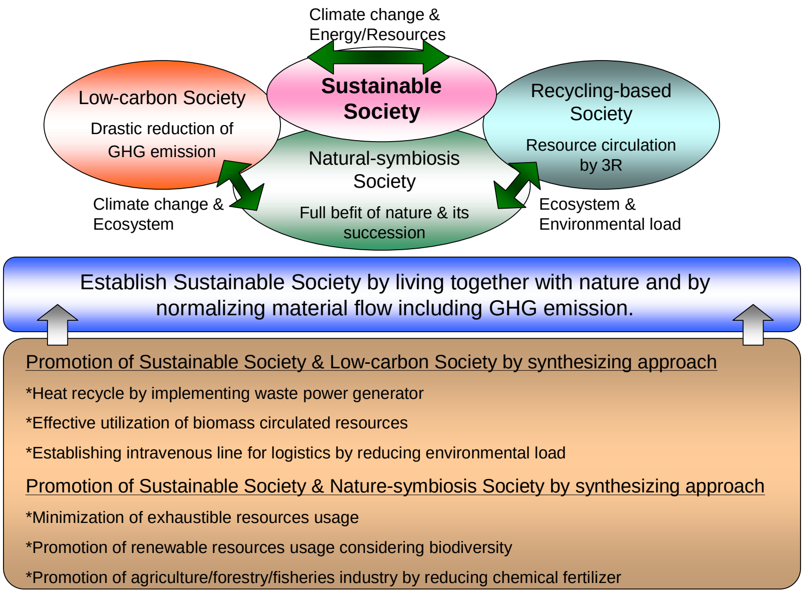


Reference: "The challenge to establish the Recycling-based Society", The Environment Agency

Figure 1.2 Individual laws supporting the Basic Law for Establishing Recycling-based Society

Eight years after the Basic Law was enacted, environmental conservation is reviewed in the viewpoints of newly emerged issues regarding developing Sustainable Society.

Firstly, Recycling-based Society becomes reality now by integrating the concept of Low-carbon Society and Natural-symbiosis Society. Minimized usage of depleted natural resources and recycled materials promotions considering biodiversity conservation are considered as important approaches. In order to develop Sustainable Society, material flow in nature and material flow in social economy should be reviewed; waste power generation and effective utilization of biomass are actual practices for instance. It is summarized as conceptual diagram in Figure 1.3.



Reference: "The 2nd version of the Basic Law for Recycling-based Society Plan ", Ministry of Environment

Figure 1.3 Synthesizing approach for establishing Sustainable Society

Secondly, formulation of local circulating zone with consideration for characteristics of the region and circulated resources is promoted to utilize biomass circulated resources and drive local production for local consumption. Additionally, promotion for people's movement to work on Reuse/Reduce/Recycle (3R) is strongly propelled.

Thirdly, installing quantitative assessment method to promote Recycling-based Society by implementing supplementary indicators and monitoring system to catch periodical transition is set forward. For example, in material flow indicators, proportion of resource production and proportion of circulated material usage are set by association with Low-carbon Society related indicators. In behavioral indicator, garbage discharge amount per person and avoidance of plastic bag at supermarket are set as individual indicators.

Fourthly, from international viewpoints, Japan's leading role to promote 3R and resource circulation in Eastern Asia should be defined. For Eastern Asian area, Japan can plot actual image of Circulated-based Society in Eastern Asia and organize Asian 3R research network to be developed in the future. For international activities, Japan can assist to develop 3R initiative movement in G8, international research projects in OECD and the United Nations Environment Programme (UNEP).

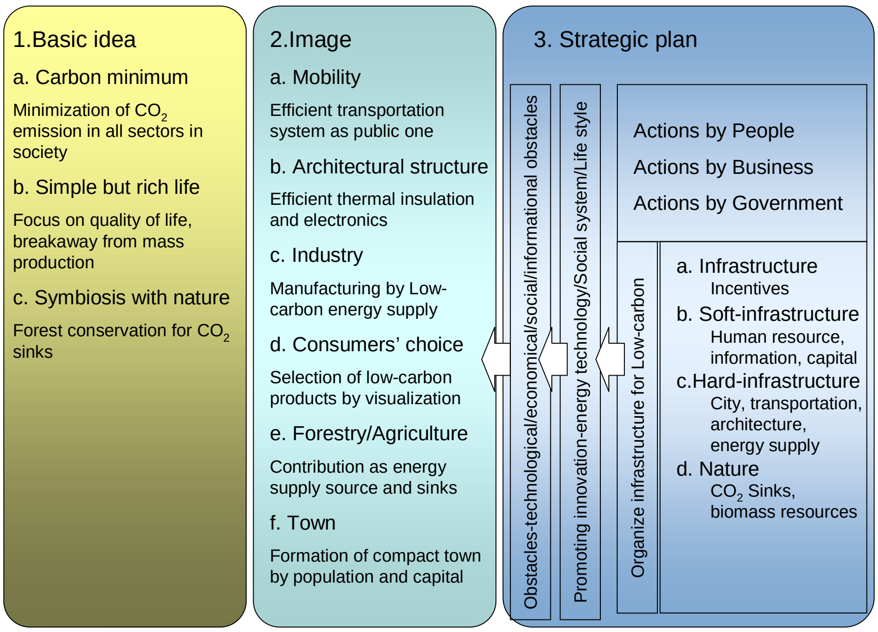
Printing Service can contribute a great deal to establishing of Recycling-based Society through the standpoint of Eco-design. Concrete ideas for Eco-design are strengthening of material tolerability, utilization of recycled materials, compromise of appearance when using recycled materials, minimization of material waste, and developing recyclable structure.

Today, there is increased need to correspond worldwide resource limitation and global warming problem, so establishing of Recycling-based Society should be promoted much further for home and abroad.

1.2.2 Construction of Low-carbon Society

Japan shares long term commitment for 60%-80% CO_2 emission reduction by 2050 with other advanced countries to contribute more than emerging countries can do. In order to reach to the top of Low-carbon Society, drastic CO_2e emission reduction is expected by drawing on all of environment related technologies. Within a decade or two decades, peak out of CO_2e emission is anticipated, so it is urgent for international society to work on fair and equitable consensus formation about global warming problem right now.

The concept of Low-carbon Society is indicated in Figure 1.4.



Reference: Construction of Low-carbon Society, Ministry of Environment

Figure 1.4 Basic idea, Image and Strategic plan to construct Low-carbon Society

For Basic idea, three concepts are characterized as the pillars of Low-carbon Society. Ultimately, CO_2e emission should be suppressed at certain level that nature can tolerate, so all sectors mainly consist of industry/government/citizen are supposed to promote energy saving and 3R to minimize CO_2e emission.

At the same time, people grow out of current lifestyle which is based on mass production and mass consumption to modify their value to new ones which is based on spiritual richness. Newly developed values on people having new mentality will bring innovative changes and deliver low-carbon and rich society.

Not only advanced technologies for environment, but also forces of natural are precious to maintain Low-carbon Society. Woodland and ocean absorbing CO_2e emission should be conserved and recovered to adopt unavoidable global warming problem. In each local society, the plans for construction of symbiotic and harmonized society go forward by utilizing nature-harmonized technologies.

As tangible images of Low-carbon Society, six of specific ones are characterized. Modalities of Transportation, Architectural structures, primary industries such as Forestry/Agriculture and Ideal town which are not directly linked with Printing Service are organized in terms of behavior, technology and field of activities. Among six tangible images, Consumers' choice and Industry are closely related to Printing Service, so each one of those should be verified to concentrate thoughts on actual contribution to Low-carbon Society by Printing Service.

For Consumers' choice as one of the concrete images for Low-carbon Society, six behaviors are recommended as follows;

- Reject unnecessary packaging and additional accessory
- Purchase re-used good or rented service
- Select a good which has low CO_2e emission
- Select a local product for local consumption
- Select a good produced by environment-conscious company
- Pay for activities reducing CO_2e emission

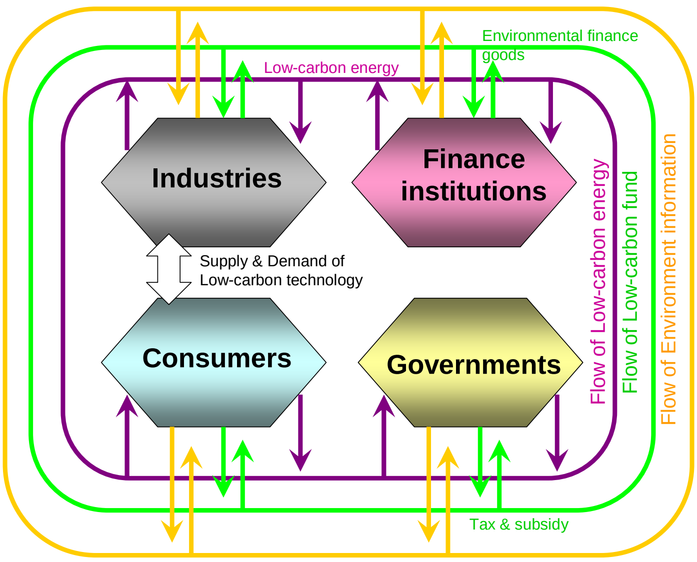
In order to promote six behaviors, visualization of environmental load holds the key to succeed. For clothing/food/housing, environmental load from production life cycle of all elements could be visualized numerically by LCA method, so Printing Service as adjunct substance should work on numerical conversion in a same manner to follow. For instance, information tag is attached on food to show food mileage, real estate shows CO_2e emission when it is constructed and used, home electronic appliance shows CO_2e emission when it is produced and used, overseas travel shows CO_2e emission to be compensated financially as carbon offsetting and so on. Printing Service can assist conveying product's information about visualization of environmental load.

Printing Service can assist Consumers' choice by weight saving of packaging material or cancellation of unnecessary packaging material in hardware side; on the other hand, by utilizing LCA method to support visualization of the load in software side. Printing industry should not hesitate to invest for infrastructure improvements to develop quantitative assessment method to prop up variety kinds of goods and services requiring printing matters.

For Industry, as one of the concrete images for Low-carbon Society, five behaviors are recommended as follows;

- Tackle global warming problem in positive way considering climate change is one of the business opportunities and contribute to Low-carbon Society by technology development, promotion of production efficiency, promotion of circulated resources utilization by LCA approach, corporate education and technology transition to emerging countries
- Publicize detailed information about environmental loads and environmental problems by corporate activities
- Innovate business model by avoiding to be damaged for Low-carbon Society
- Ensure spare time for employees to improve flexibility about their working hours, working place and extra career.
- Promote Low-carbon production by whole supply chain

In order to support low-carbon production system, more funds should be entrenched in advanced companies possessing environment related technology. The stream of funds, technology and information are summarized in Figure 1.5.

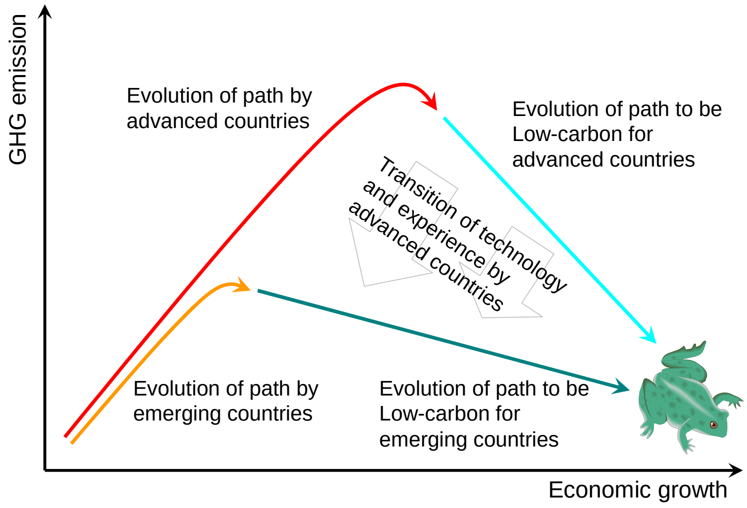


Reference: Construction of Low-carbon Society, Ministry of Environment

Figure 1.5 The stream of funds/technology/information supporting low-carbon production system

Printing Service can support Industry by promotion of circulated material utilization backed up by LCA approach, information disclosure about environment related issues and shift to low-carbon energy usage.

In Low-carbon Society concept, important thought for international society is transition of “Japanese model” to emerging countries as “leapflogging” approach. It is visually summarized as in Figure 1.6.



Reference: Construction of Low-carbon Society, Ministry of Environment

Figure 1.6 Leapflogging by emerging countries to avoid evolution of path by advanced countries

It is very effective procedure for Japan to transit Japanese model overcoming deterioration of environment and scarcity of energy in the past especially to Asian countries among emerging countries. Most of advanced countries construct High-carbon Society, but many of emerging countries can avoid same path by learning and utilizing Japanese technology and experience from now on. When working on action plans for global warming, byproduct can be provided pretty well as co-benefit advantages.

On another front, international research hub should be organized to collect/analyze/provide updated information about environmental technology and related activities by cumulative achievement as manufacturing oriented nation. In order to pragmatize, existing international, domestic research institution and universities should be shaped in networked for the future.

Printing Service can transform Japanese model for Asian emerging countries and transfer it as Eco-design concept supported by LCA approach. With the assistant of joint research projects by universities in Japan and Asian emerging countries, environment conscious manufacturing as Eco-design can be familiarized in printing industries in developing areas.

1.2.3 Utilization of LCA approach

It has been an action assignment for us to specify the solution about energy efficiency of technologies. To be provided an answer, the effort has been done to know what the best solution of energy supply method is.

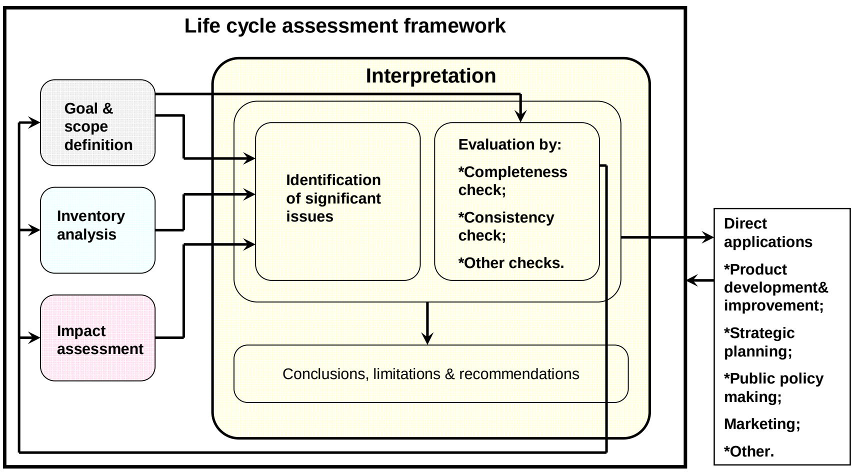
After world war two eras, a question for energy balance has been asked about new generation of energy, so the predecessor of LCA was already organized as systematic process-oriented approach to identify best energy solution.

In the late 1960s, the first Resource Environmental Profile Analyses (REPAs) were conducted and became original study of modern LCA. Coca Cola in The United States is considered as first company to work on investigating the resources and environmental profile of various packaging materials for their products. Oil crisis in 1970s drove LCA practitioners to focus on energy analysis. By the mid 1980s, multiphase systematic research was commonly utilized in the fields of beverages, appliances, automobiles and housing. In these days, newly developed terms such as eco-balances, cradle-to-grave analysis and life cycle analysis were used as common. In 1990, the term “life cycle assessment” was firmly fixed by the Society of Environmental Toxicology and Chemistry (SETAC). From this time, LCA was utilized in different industries by the help of best practice guide which was published by SETAC.

In 2002, UNEP and SETAC started UNEP/SETAC Life Cycle Initiative to support expanding use of LCA. The Unites State, European countries and Japan tried to generalize LCA concept in different industries and put it into practice, then LCA got sophisticated in advanced countries.

In ISO 14040, LCA was defined as “The increased awareness of the importance of environmental protection, and the possible impacts associated with products, both manufactured and consumed, has increased interest in the development of methods to better understand and address these impacts. One of the techniques being developed for this purpose is life cycle assessment.”

LCA usually follows four phases illustrated in Figure 1.7.

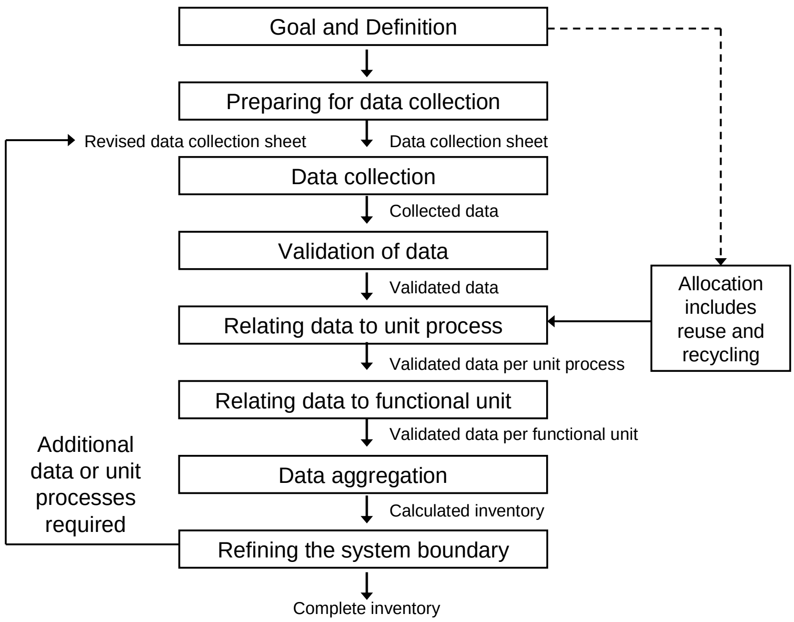


Reference: ISO14044 Environmental Management-Life cycle assessment-Requirements and guidelines

Figure 1.7 Four phases of LCA studies

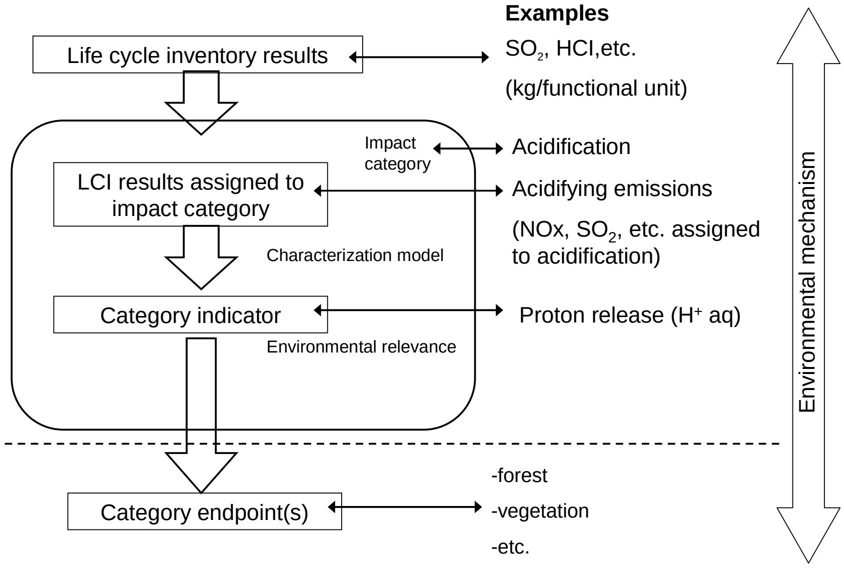
LCA consists of different phases;

- For Goal, a reason to carry out the study should be defined, then utilization of result and intended audience to whom the results of the study are intended to be disclosed are decided
- For Scope, it should be well clarified to secure in full measure that the breadth, depth, and detail of the study are compatible and sufficient to address the stated goal
- For Inventory analysis (operational step is shown in Figure 1.8), data collection and calculation procedures to quantify relevant inputs and outputs of a product system should be involved, primary data collection at work site and secondary data collection from database are considered as critical factors
- For Impact assessment (concept is shown in Figure 1.9), evaluating the significance of potential environmental impacts using the LCI results, a stream of classification/characterization/normalization could be done for different impact categories to lead to Integrated LCA approach
- For Interpretation, it is the phase of LCA in which the findings from inventory analysis and the impact assessment are evaluated together or, in the case of LCI studies, the findings of the inventory analysis only



Reference: ISO 14044 Environmental management –Life cycle assessment-Requirements and guidel

Figure 1.8 Operational procedure of inventory analysis



Reference: ISO 14044 Environmental management –Life cycle assessment-Requirements and guidelines

Figure 1.9 Concept of category indicators

Key feature of LCA is that covering five stages from raw material acquisition to waste disposal in consistent with scope and goal of the study. It is summarized in Figure 1.10.

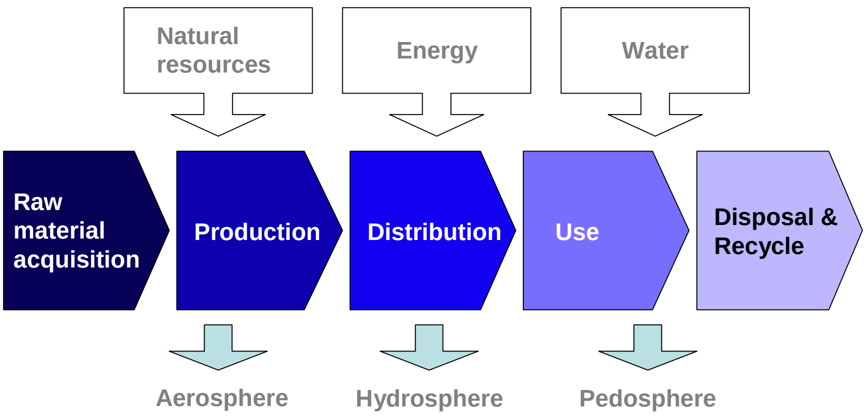


Figure 1.10 Five stages from cradle to grave of LCA studies

Human beings have use of variety kinds of goods and services, at the same time consume mineral resources and fossil fuels and discharge wide-ranging of waste disposals which are under environmental loads.

LCA considers not only raw material acquisition/production/distribution, but also use/disposal/recycle to evaluate environmental impact assessment by weighing resource consumption and discharges.

In order to minimize resource consumption and waste disposal, total amount of input and output for product or service should be investigated carefully to understand environmental impact in correct manner. The result from analysis is usually utilized for decision making for variety kinds of situations, so LCA is thought to be decision-making supporting tool.

1.2.4 Popularization of Carbon Footprint of Products in overseas

During late years, focusing on global warming potential, namely Life cycle CO_2e (LC CO_2e) has mass appeal in many industries. As a result of it, Carbon Footprint of Products (CFP) was launched in some of advanced and emerging countries, so brief overview is described below.

In UK, the Carbon Trust which was originally started by the fund of government but is private entity now takes lead role for widespread utilization of CFP. Today, total amount of products and services with CFP logo reached three billion USD per year. For printing related products and services, newspaper company named Trinity Miller is certified and the paper with CFP is distributed. Among all, CFP logo applications by TESCO networking distribution channels all over the world are increasing. More than 500 products are calculated as CFP and more than 100 of products are on the shelves in the supermarkets now. Carbon reduction labels by the Carbon Trust are certified. Their products are distributed not only in UK but also in Australia, New Zealand and Korea.

Distinctive trend in UK is that carbon calculation and certification is not based on Product Category Rule (PCR). Generally speaking, PCR is organized for each products or services, but it is believed that consistency of carbon calculation and uniformity of ISO 14025 (environmental label) can guarantee CFP without creating different kinds of PCR in UK. Besides PCR, PAS 2050 which is a the Holy Bible for carbon calculation is edited by the Carbon Trust and applied for CFP, so there is no increased needs for PCR so far. Other trend shows that carbon reduction labels without CO_2e emissions are seeable by the reason why some of organizations hesitate to disclose CO_2e numerical number or there is no enough space for CO_2e numerical number when products are not big ones.

Carbon reduction labels have beneficial effect for two years and are renewed by showing the evidence that CO_2e emissions are reduced by two years effort. If organizations cannot prove that they could reduce environmental load in two years, carbon reduction labels never ever are certified for continuous use. CFP in UK is developing for both external purpose of products and service competition and internal purpose of environmental load reduction.

In France, environmental labeling law named “Grenelle2: the bill on the national commitment to the environment” is set to start in 2011 as trial run. This label aims to promote sustainable methods of production and is estimated to cost as much as 5% of the price for French consumer/producers to accept this additional cost.

The Casino Group, big retailer in France, started environmental labeling projects and 200 products are already calculated and indicate CO_2e emissions by following the method of the Agency for Environment and Energy Management (ADEME). Another retailer, E.Lectlerc started their original approach showing carbon balance of each shopping. But, consumer cannot link the carbon information and shopping, namely relationship of carbon reduction and shopping behavior is not fully understood and is soon dissatisfied.

As method of showing environmental label, not only CO_2e emissions but also resource depletion and eutrophication are added as environmental indicators. PCRs which are under the process of developing in 16 divisions can specify which indicator should be selected for specific products.

When the Grenelle 2 law is passed, there will be anxiety since it can create significant barriers for processed, intermediate and bulk products by other countries. The pressure to demand environmental labeling including CFP and other impact categories might influence the retailers/suppliers relationship in ways it can cause anti-competitive concerns. There are still certain level of suspicions about consistency, compatibility and reliability of a specific CFP numerical numbers for products, so achieving final goal for CFP is thought to be time consuming one since more testing of different kinds of methodologies should be experimented on an ongoing basis

In Germany, The Product Carbon Footprint (PCF) project was promoted to develop systematic assessing and communicating procedure for CO_2e emissions, additionally provide platforms for sharing practical experiences. Ten of business organizations, such as BASF, dm-drogerie market, DSM, FRoSTA, Henkel, REWE Group, Tchibo, Tetra Pak, T-Home and Unternehmensgruppe Tengelmann, participated the project and start calculating CO_2e emissions for their products and services.

Government related institutions comment that indicating only CO_2e emissions has no demonstrated value, so implementing new CFP logo should be suspended and one sort of Blue Angel focusing on climate change which is current environment label can be utilized for CFP purpose if necessary. Blue Angel for climate change is applied for highly energy efficient products in each product category and is scheduled to be issued for 100 of products in three years starting from 2009.

In Korea, promoting diffusion of CFP is very speedy, 342 products and services are listed in three years operation. Among all products, non-durable goods are 200, energy-non-using durable goods are 16, energy-using durable goods are 64, production goods are 50 and services are 12, breakout is summarized by categories. Energetic activities by government are propelled to achieve carbon calculation education for producer/retailers and CFP education of certification criteria for evaluators continuously.

Particularly notable characteristic in Korean CFP label is that there are two different kinds of labels, one is carbon emission certificate showing simply CO_2e emissions and the other is low-carbon products certificate showing achievement of target which is set by government.

In Taiwan, carbon calculation guideline was organized and disclosed in 2010 and seven products by five companies are certified. By 2011, 35 products such as food, liquid display

TV and LED light bulb are certified. Pilot project just started, but currently offsets slow start-up by speedy action plans.

In Thailand, Thailand Greenhouse Gas Management Organization (TGO) and National Metal and Materials Technology Center (MTEC) are national bodies to promote CFP in order to support Thai industries in implementing low-carbon products and services in recent years to strengthen Thai products when competing in the world market.

TGO launched 20 pilot projects in 2009 (26 projects in 2011); all producers participated in training course to understand basic knowledge about data collection and calculation. TGO organized Carbon Footprint Design Contest to encourage university students and the public to think about CFP logo for real use.

Today, national database for local utility, natural resources and basic activities are organized in a hurried manner. Special task force by CFP professionals are formed to check PCRs for different products/services and calculating result evaluation manual.

In China, carbon labeling system is still in process. There is a lack of examples by government initiatives to promote low-carbon products and services. One case study by private sector is CFP label for scallop by a fishery company in 2010. Another trial is not CFP but low-carbon product certification which covers four different areas such as digital copier, printer, refrigerator and washing machine by collaborating with British Standards Institutions.

In New Zealand, CFP for primary industries are still under the way, but promoting low-carbon life style is commonly accepted by most of people there. One of carbon calculator program focuses on CO_2e emissions reductions by making careful low-carbon choice for building materials. Additionally, a wine producer is certified to issue two of CFP labels for their white wines and conducts test marketing for future utilization.

In The United States, CO_2e emission reduction plan was set in California by providing three different kinds of labels.

First one is “Low-carbon seal”; it is awarded to manufacturers who can create most carbon efficient products in the category. But, this seal can show only approval, so actual numerical number of CO_2e emission cannot be seen in practice. Second one is “Carbon score”; it is utilized to compare products and brands to be differentiated, but requires tremendous amount of investigation work to handle actual data. Third one is “Carbon rating”; it is almost same as Energy Rating which was launched in Europe. The rating is indicated by number of stars from one-star which is high-carbon product to five-star which is low-carbon product. In order to understand rating in a correct manner, rating/average/reference of product score must be clarified and evidenced.

In Japan, government prepared to label consumer goods to show CFP to raise public awareness about global warming problem and shift people’s lifestyles to low-carbon ones. General principle of CFP, PCR registration/approval rule, CFP verification rule and CFP labeling/displaying information rule are organized in great haste to promote national CFP project since 2009. Once, CFP system run about in confusion because of strict calculation rule and strict verification which are thought to be only for LCA professionals, but relaxed its grip on it to promote more CFP products from wide range of industries.

Currently, almost 60 PCRs and more than 300 products are organized and listed, so Japan is at the edge in the viewpoints of CFP popularization.

Major CFP logos are collected in Figure 1.11.

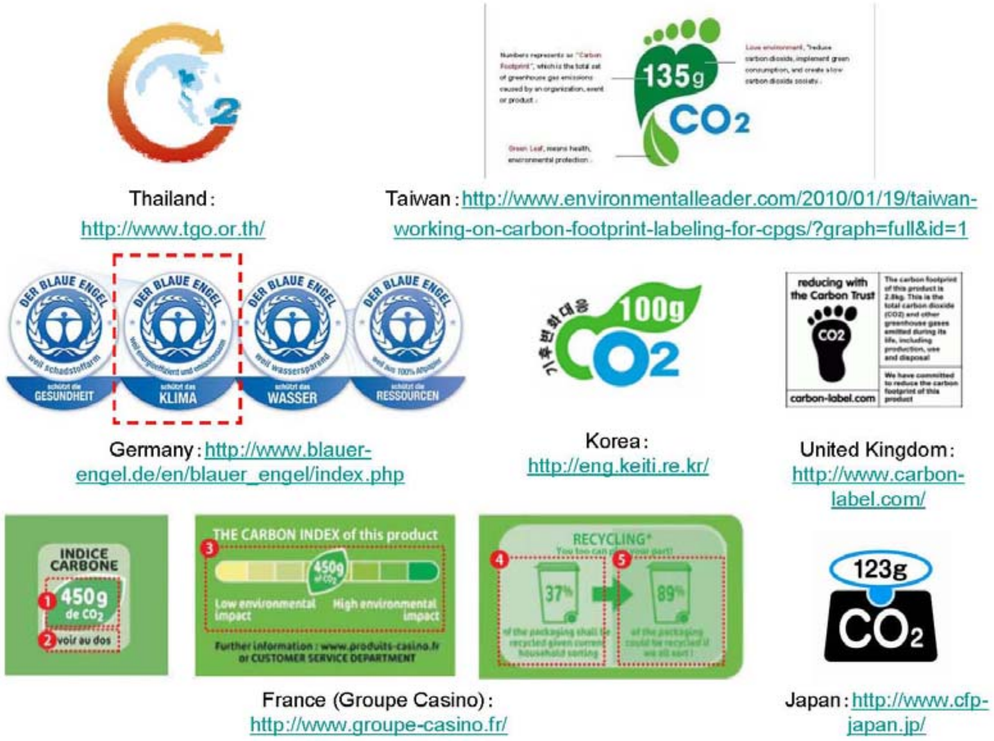


Figure 1.11 CFP logos worldwide

TC207 (Environmental management)/SC7 (Greenhouse gas management and related activities) set working group to start standardization for CFP in 2008 and schedule to be fixed in 2013 if all participating countries can achieve a settlement. As a result of it, TC130 (Graphic technology) started discussion about CFP by creating working group in 2010, tries to coordinate participating countries' interests. After CFP will be organized as international standard, it might walk alone and leave other impact assessments behind. It is important to take warning to our hearts all the time that CFP is just a part of LCA and is not all-purpose assessment method.

Magnificent CFP pilot programs are in execution in all over the world now in selected advanced and emerging countries, so the result will be available if CFP can take root in social system to shift peoples' lifestyles to low-carbon ones sooner or later.

1.2.5 Actual achievements of LCA studies in Printing industry

There are not so many case studies and conference presentations about Printing Service in terms of LCA studies, so it is very difficult to search previous LCA case studies. And yet, recent researches are summarized in Table 1.2.

Table 1.2 Previous printing related LCA researches

Year	Title of research	Researcher	Content of research
2004-2007	Paper pack for beverages	Nihon Tetra Pak	Paper pack for beverages LCA by different kinds of printing methods. Many of those are listed on "Ecoleaf" which is categorized eco labeling type Ⅲ. There are 15 projects to be listed.
2007	Paper cup LCI	Shikoku Pak, Dainippon Printing, Tokan Kogyo, Toppan Printing, Dixie Japan	Paper cup LCA mainly consists of paper, LDPE, gravure ink covering from production to first delivery to client's warehouse. This work is aggregated one, so depends heavily on background data unfortunately.
2009	Paper package LCA	Shimizu Printing	Shimizu Printing participated in "Green Performance Program" which is supported by government fund to educate LCA for SMEs. Carbon calculation scheme for printing production was proposed and checked as critical review by Japan Environment Management Association for Industry (JEMAI).
2009	Printing Service LCA and Carbon-offsetting	Shimizu Printing	Shimizu printing schematized LCA method for printing and created carbon calculator named "Printing Goes Green (PGG)". It was awarded Chairman's prize (2nd best) by LCA Japan Forum.
2009	Printing Service LCA and Carbon-offsetting	Shimizu Printing, Japan Waterless Printing Association (JWPA)	JWPA employed carbon calculation tool created by Shimizu Printing, then more than 50 members started utilizing it for proposing carbon-offseting as added value for their clients.
2010	Environmental Performance Assessment by utilizing LIME	Toppan Printing	Not only corporate activities, but also products are evaluated by LIME method which is Integrated LCA approach developed as government project. Reductions of environmental load by shifting from using natural wood to artificial forest, utilizing thinned wood, VOC reduction and energy efficient activities are introduced as a scale of LIME.
2011	Localizing of Printing Service $LCCO_2$ and Integrated LCA methods in Thailand	Shimizu Printing	Thanks to joint research project by Shimizu Printing and Chulalongkorn University, carbon calculation scheme was localized for Thai printing manners to be recognized by Carbon Footprint certified factory by national evaluation body. Additionally, Environmental Load Point (ELP) which is developed by Nagata Laboratory at Waseda University was also localized for well-balanced environmental impact assessment to avoid focusing only on GHG emission.

LCA studies in printing industry are left behind compared with other industries since printed matter is though to be faceless and collateral.

During recent years, variety kinds of paper packs for beverages by Nihon Tetra Pak were the targets for LCA studies and certified by Ecoleaf labeling system which is Environmental label type Ⅲ in Japan. Those paper packs were categorized by substrates and printing methods, 15 different kinds were certified by Ecoleaf from 2004 to 2007.

For paper cup LCI, there were so many companies participating in the project to work together, so specific data could not become evident and only generic data could become visible based on background data. It was unfortunate that real live data was obscured by many participants because of their sense of secrecy.

For environmental performance assessment by Life cycle Impact assessment Method based on Endpoint modeling (LIME), Toppan Printing tried to evaluate both of corporate activities and product by classifying environmental load into three impact categories such as biological resources, photochemical oxidant and global warming. Environmental loads for corporate activities and products are reduced by cutting down usage of solvent (volatile organic compounds), shifting from natural forest to artificial forest for paper usage, shifting from plastic to paper for beverage can substrate and shifting from artificial forest to thinned wood for printed matter. This presentation could be worth listening, but explanation about assessment process is not enough and only result is disclosed, so full understanding is difficult even for LCA practitioners especially main study theme was LIME oriented one.

For Printing Service LCA such as paper package LCA and localizing $LCCO_2e$/Integrated LCA for Thailand, Shimizu Printing left impressions of its feet in terms of LCA studies in printing industry. Thanks to Green Performance program which was funded by government for small and medium enterprises to learn basic of LCA studies, many printers applied and got opportunities to learn. Among nine printing companies, only one calculation scheme by Shimizu Printing was selected to be examined as critical review by Japan Environment Management Association for Industry (JEMAI), and then it was admitted as Printing Service LCA at first time and opened to the public.

This calculation scheme was developed as carbon calculation tool named "Printing Goes Green" and shared with more than 50 printing companies belonging to Japan Waterless Printing Association without charge to propose carbon offsetting service for print-buyers. Showing only result without explaining halfway process was reformed to be easily understandable one by pulling back the curtain on detailed calculation scheme in each printing process by Shimizu Printing.

Abroad, Printing Service LCA was localized and transferred to Thailand through joint research project by Shimizu Printing and Chulalongkorn University. No printed matter applied for CFP logo at that time, so carbon calculation of textbook was done and admitted as CFP certified book. Printing factory at Chulalongkorn University also applied for CFP certified printer and also admitted as CFP certified printing factory.

In every single country, even in emerging countries, Integrated LCA is required after $LCCO_2e$ practices since focusing only on one impact category is not satisfactory to see real environmental load. Therefore, Environmental Load Point developed by Nagata Laboratory at Waseda University was selected among several Integrated LCA methods and localized just for Thailand. CO_2e emission sounds familiar in Thailand as reported in mass media, but people in Thai Printing industry would like to know more about other issues such as the influence of VOC problems inside and outside of the factory. Printing Service LCA will be transformed into second stage in both advanced countries and emerging countries from now on.

When switching the viewpoint to overseas past studies, there are some printing related ones in recent years. It is summarized in Table 1.3 and Table 1.4.

Table 1.3 Previous printing related original LCA researches overseas

Goal	Year	Author	Boundaries	Impact categories	Not included
The relative distribution of environmental impact of generic printed matter by sheetfed offset	2004	Institute of Product Development (Denmark)	All stages of the life are covered as regards the use of raw materials/energy (from material extract to disposal when possible) but for the potential environmental impacts, the main focus is on the production stage.	Global warming, Ozone depletion, Acidification, Nutrient enrichment, Photochemical Ozone formation, Chronic human toxicity via water and soil, Chronic ecotoxicity in water and soil, Acute human toxicity via air, Acute ecotoxicity via in water, Hazardous waste, Nuclear waste, Slag and ashes, Bulk waste, Resource consumption	Transpors of raw materials from procedures to the printing industry, Transports in the production/use/disposal stages
The difference between conventional and waterless offset printing	2002	FRAMKOM (Sweden)	From cradle to printed paper sheet from the press	Resource depletion, Acidification, Eutrophication potential, Global warming, Photochemical Ozone creation	Energy use at postpress, Transports to customers, Recycling
To perform an ecological evaluation of a typical newspaper and magazine	1998	Axel Springer Verlag AG Stora Canfor (Germany)	All direct inputs and outputs, the materials and energy which flow directly into the production process along the entire life cycle of primary and preliminary products or are emitted during cycle.	Climate change, Ozone depletion, Acidification, Eutrophication, Ecotoxicity effects of effluents	The material and energy flows involved in the manufacture of transport vehicles and production installations (including buildings)
Information of environmental impact of various printed matter	1995	The institute for Media Technology (Sweden)	Start when the oil is pumped from the ground and trees are planted. Finished when the paper has been deposit and turned to methane gas and the waste has decomposed and turned to CO2 and methane gas	Global warming, Ozone depletion, Acidification, Nutrient enrichment, Photochemical Ozone formation, Toxic emission, COD and BOD, Hazardous waste, Deposit of waste, Resource consumption, Electricity use	The forming of the oil, Production capital as paper machines, printing presses and lorries
Illustrate the difference between petroleum based and vegetable oil based ink for newspaper	1998	The institute for Media Technology (Sweden)	For the oil in ink: whole process starting with the cultivation of oil-plants and the extraction of the petroleum.	Global warming, Acidification, Eutrophication	The degree of recycling of newspaper, printing process

Reference: European Commission

The study of the origin of printing related LCA was started in Europe in 90s. Goal of those studies vary from specific printing process comparison to generic printed matters comparison. Additionally, many of major impact categories are included for most of them, but are excluded for others.

For system boundaries, all studies do not include whole necessary stages which are supposed to be included as LCA for printed matters. For example, transportation of raw materials/production/disposal, energy use for production, recycling process of printed matters and printing process are occasionally not included. Those are forward-thinking studies, but important materials and processes are sometimes excluded to be investigated.

In recent years, there are so many researches by foreign researchers, not like Japan, so some of those are summarized below.

Table 1.4 Previous printing related recent LCA researches overseas

Year	Title of research	Researcher	Content of research
2010	Carbon footprint and environmental impacts of print products from cradle to grave	Hanna Pihkola and et al.	The aim of the research is to study environmental impacts occurring during the life-cycle of print products such as newspaper, magazine, book and advertisement. Two research methods are applied; one is carbon footprint and the other is LCIA. The research provides calculation methodology and principles for fibrebased print products.
2010	Communicating environmental impacts of print products	Hanna Pihkola Maija Federley and Minna Nors	To increase the usability of the environmental analysis results among the industrial stakeholders and funding parties, communication was selected as one of the focused area for the research. One of the main areas is how to convey environmental information to to non-expert stakeholders. Case-specific presentation material is proposed for stakeholders to comprehend.
2010	Printed and tablet e-paper newspaper from an environmental perspective - A screening life cycle assessment	Asa Moberg, Martin Johansson, Goran Finnveden and Alex Jonsson	It has been suggested that environmental impact of e-paper can be lower than physical newspaper, but it should be screened carefully by life cycle perspective. Highest environmental loads are production of substrate for analog and platform for digital; both key aspects are compared by multilateral points of views.
2010	Life cycle carbon footprint of the National Geographic magazine	Terrie K. Boguski	The life cycle carbon footprint of a product can provide the publisher and material suppliers with information to reduce GHG emission. The study shows that carbon footprint of the magazine about 0.82kg-CO2e per magazine. Conclusion is indicated that opportunities for improving carbon footprint are likely to be found within manufacturing and printing of paper.
2010	Product environmental metrics for printers	Jason Ord, Ellen Chappell, Scott Canonico and Tim Strecker	Hewlett-Packard's Imaging and Printing Group (IPG) is charting a course towards environmental leadership in its market. This research describes development process to construct the initial metrics focusing on carbon footprint.
2010	Uncertainty and Sensitivity in the Carbon Footprint of Shopping Bags	Tuoma Mattila and et al.	Carbon footprints for several shopping bag alternatives (polyethylene, paper, cotton, biodegradable modified starch and recycled polyethylene) are compared by life cycle assessment method. In each analyzed waste treatment scenario, few parameters dominate the uncertainty within the scenario. Most of those are downstream of bag manufacturing including consumer behaviors, landfill conditions, method of waste combustion, etc. The result highlights the importance of including several scenarios in comparative life cycle.
2011	Moving Forward of Thai Printing Industry to Environmental Issue	Aran Hansuebsai, Hirokazu Shimizu	This research is performed as case study, calculating Carbon Footprint of a book production and Total Volatile Organic Compounds (TVOC) emission content produced by Chulalongkorn University Printing House. The result shows that Carbon Footprint of a book depends on the choice of purchased materials and TVOC values give high-level influence on people living near printing facilities.

For basic CFP calculation, Hanna Pihkola tries to schematize calculation methodology for printed products by carbon calculation and wide-range environmental impact assessment based on fibrebased printed products.

For communicating environmental impacts of print products, Hanna Pihkola describes the demand for usability of the environmental analysis results among industrial stakeholders and funding parties. Major study area here is how to convey environmental information to non-expert stakeholders.

For comparison of paper media and electronic media in newspaper, Asa Moberg avoids to believe stereotype many think the load of digital media can be lower than digital media sensuously. Key factor for paper media is paper production and the one for digital media is device production. Both are compared from various perspectives.

For CFP of a magazine, Terrie K. Boguski picks up actual magazine production to calculate CFP and concluded 0.82kg-CO_2e each. This research suggests that potential improvements are found in manufacturing process and procurement of substrate.

For CFP of shopping bags, Tuoma Mattila compares CFP by different substrates such as polyethylene, paper, cotton, biodegradable modified starch and recycled polyethylene. Calculation results are influenced by consumer behaviors, landfill conditions, methods of waste combustions and so on. Necessity of different scenarios for uncertain parameters to be compared is emphasized.

For moving Thai printing industry toward eco-friendly direction, Aran Hansuebsai calculates CFP and Total Volatile Organic Compound (TVOC) to evaluate environmental impact from products and printing facilities.

Recent studies are much more accurate in terms of system boundary, but detailed calculation scheme is not released to the public for other printers to follow. On the contrary, this research here is opened to the public with aim of spread enlightenment of LCA concept.

Nowadays, many of printed products related researches are found. This fact indicates that print buyers and consumers are interested in environmental issues much more than before.

1.3 FRAMEWORK OF THE STUDY

This research paper consists of eight chapters.

In second chapter, 47 major countries in Asia, North America, Europe and Middle East/Africa are investigated in terms of entities/employees/sales volumes in a couple of years to understand recent trend in both Printing industry and Paper industry. For domestic market, detailed research is conducted to catch the trend in seven years to analyze drastic decrease of entities/employees/sales volumes compared with other advanced countries worldwide. Additionally, SMEs ratio of Printing industry is checked to know the fact most of printers here are relatively small by the scale of physical size and operational budget. Future agendas for Printing Service to work on quantitative assessment by LCA method are understanding if digital media is superior or not in advanced countries and reducing environmental loads from materials and production in emerging countries.

In third chapter, establishment of Printing Service LCA is concreted as industry standard to shift from qualitative assessment to quantitative assessment for visualization of the load by numerical numbers. Procedures of technical approaches for primary data collection at working site and secondary data collection are shown for other printers to follow easily.

Specification of Printing Service is improved by utilizing Eco-design concept changing paper weight or structural design based on LCA results. This LCA results can be applied not only for product and service improvements as direct carbon reduction method, but also for carbon offsetting and CFP as indirect carbon reduction method. Future agenda for $LCCO_2e$ for paper oriented printing matters is remained since reduction of paper usage is limited, so new evaluation method should be considered as Integrated LCA method.

In fourth chapter, five different Integrated LCA methods are tested for Packaging Printing Service which is paper-oriented one and cannot be replaced by digital media. Best Integrated LCA method is selected as the most ideal one considering different impact categories in well-balanced manner. Printing Service LCA depends heavily on $LCCO_2e$ since LCA studies attract a lot of attention because of CFP spread out in several advanced and emerging countries. But, $LCCO_2e$ can provide solution focusing on reduction or replacement of paper usage, so is not effective when evaluating Packaging Printing Service which requires paper usage unconditionally. Future agenda for Integrated LCA, what one thinks in thoughts about the method should be practiced in the real world. Real on-going jobs are targeted for case study to confirm if Integrated LCA can work or not to improve products performance.

In fifth chapter, present progressive jobs are selected to verify if Environmental Load Point (ELP) which is selected as best Integrated LCA because of its well-balanced views for different kinds of impact categories can effectively function or not. When utilizing $LCCO_2e$ and ELP, $LCCO_2e$ concludes that paper reduction is the priority even for package production, but ELP suggests recycle-oriented package design promoting easy-dismantled package for people to recycle without burden of package breakdown. Practical Eco-design for Packaging Printing Service often receives favors from ELP since it can evaluate wide range of environmental issues. On the other hand, Information Printing Service is verified only by $LCCO_2e$ because replacement from paper media to digital media can be done without stress most of the time. Many believe that digital media can save tremendous amount of CO_2e emission compared with paper media, so sensitive analysis is done to understand if digitalization favor belief is correct or not.

In sixth chapter, Printing Service LCA consisting of $LCCO_2e$ and ELP is localized and transferred to Thailand through joint research project by Shimizu Printing and Chulalongkorn University for CFP projects there. Textbook at the university and printing factory operated by the university are certified as CFP products and factory as successful achievements from the project by utilizing $LCCO_2e$ method. Meanwhile, in order to create ELP for Thailand, AHP questionnaires deciding category importance by people are conducted to know people's awareness about different impact categories, and then annual consumption and emission of selected items from natural resources and polluted discharges are investigated. ELP is completely customized for Thailand and is ready to be used for LCA practitioners to grasp broad range of environmental loads not to focus only on global warming. Printing Service

LCA is also established in Malaysia, it shows quantification model which is transferrable to any other countries. Future agenda for Integrated LCA, complicated evaluation procedure should be described in easily understandable way for business related people at first and common people in the future.

In seventh chapter, the way of looking things is changed, Printing Service LCA in European countries are surveilled as different evaluation models. International confederation for printing and allied industries (INTERGRAF) publicizes 13 recommended parameters for carbon calculation and many carbon calculator developers in Europe follow it basically. Most of calculation tools are operated by allocation method, calculation is easy and fast though time-consuming annual input and output is cumbersome. Carbon calculation and data disclosure to print buyers are usually free of charge, so this quick calculation method is imitable one since it is difficult for each production facility to be monitored for cumulative calculation method and for small printers to staff up for extra activities. But, after working on case studies, constrained condition about distributional basis is found for allocation method. It is clearly identified as calculation method with limited condition for practical use.

In eighth chapter, conclusion of the study and actual achievements in our organization/printing association/emerging countries are summarized. As a result of continuous research, newly developed Printing Service LCA is utilized in Japan/ Thailand/Malaysia in practice and increases the impact for printed matters in terms of Eco-design. Environmental strategic plan based on Printing Service LCA supported by LCCO$_2$e for CFP and ELP for multilateral evaluation is summed up from actual practices.

Correlative relationships of chapters are visualized as framework in Figure 1.12.

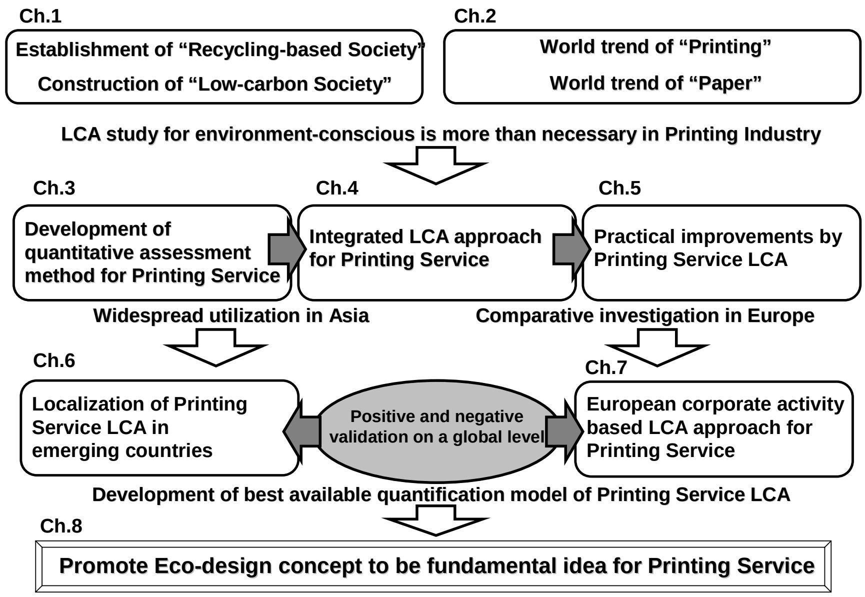


Figure 1.12 Framework of the study

CHAPTER 2

WORLDWIDE TREND ANALYSIS

FOR PRINTING AND PAPER INDUSTRIES

FROM THE ASPECT OF ENVIRONMENT-CONSCIOUS

ABSTRACT

It is important to work on industry trend research at first to take careful note of the fact about printing and paper industries on a world scale and a domestic scale. In order to know characteristics features for both industries in recent years, number of establishments/number of employees/sales volumes are selected to be investigated for short-term trend analysis. In printing industry, emerging countries represented by BRICs are definitely on rising trend, but most of advanced countries in Europe and North America grow stagnant. One such downward market is Japan, it is much worse than other advanced countries since the range of drop especially in sales volume in the past seven years is more than double digits. In paper industry, movement of upward and downward trends for emerging countries and advanced countries are exactly the same as printing industry, digital shift becomes clear in most of advanced countries. But, when turning eyes to domestic paper market, seven years survey can provide further understanding that it is completely different from domestic printing market since sales volume remains flat while downsizing the organization. Further research is conducted for domestic printing related business from observing point of small medium-sized enterprises (SMEs) to know relation nature to organizational size compared with other industries.

2.1 INTRODUCTION

Before considering about practical environment conscious action plans for Printing Service, printing and paper industries outlooks should be surveyed at first to understand the trend of whole printing related industries.

In order to know key statistics of printing and paper, such as number of establishments/ number of employees/sales volumes, the current researches of leading 47 countries are indicated by dividing worldwide data into four different areas (Asia & Pacific, North/South America, Europe and Middle East & Africa) to grasp essentials in geographical way.

Additionally, more detailed researches are conducted for Japanese market; not only main industries, but also other industries which are closely related to main industries are scrutinized in detail from the viewpoint of SMEs.

2.2 PURPOSE OF THE STUDY

In the manufacturing industries in a broad sense, especially printing and paper industries are not assumed to be booming ones because of up-to-date drastic media shift of mass communication media. Especially in advanced countries in western worlds, digitalization gets ahead in expeditious way; it definitely promotes paperless information propagation methods.

In order to consider the presence of Printing Service in the future, qualitative and quantitative trends for both printing and paper industries should be investigated on a world scale. Further more, detailed research especially for printing industry in Japan is conducted to get an insight into the true nature of the industry through the standpoint of SMEs.

2.3 PRINTING INDUSTRY PERFORMANCE

2.3.1 Key statistics worldwide

2.3.1.1 Establishments, employments and sales volumes in major countries

Worldwide Printing Industry Outlook (establishments, employments and sales volumes) is segmented into four different areas, and then summarized in Table 2.1 and Table 2.2 for different purposes.

Table 2.1 Worldwide Printing Industry Outlook in 2009-2010

Nation	2009			2010			% change (2010/2009)		
	Establishments	Employments	Sales (million USD)	Establishments	Employments	Sales (million USD)	Establishments	Employments	Sales (million USD)
<Asia & Oceania>									
Australia	1,937	43,914	6,032	1,947	44,129	6,117	100.5%	100.5%	101.4%
China	126,097	2,858,146	35,920	125,532	2,845,275	38,295	99.6%	99.5%	106.6%
India	91,924	2,083,569	7,850	92,817	2,103,778	8,222	101.0%	101.0%	104.7%
Indonesia	23,127	524,203	4,176	23,256	527,115	4,332	100.6%	100.6%	103.7%
Japan	11,726	265,795	33,549	11,581	262,487	32,584	98.8%	98.8%	97.1%
Malaysia	3,059	69,336	1,507	3,114	70,571	1,507	101.8%	101.8%	100.0%
New Zealand	363	8,233	748	366	8,303	747	100.8%	100.9%	99.9%
Pakistan	13,647	309,324	972	14,015	317,672	970	102.7%	102.7%	99.8%
Phillipines	7,514	170,316	1,011	7,686	174,212	1,048	102.3%	102.3%	103.7%
Singapore	476	10,792	1,275	485	10,987	1,338	101.9%	101.8%	104.9%
South Korea	5,051	114,493	6,153	5,009	113,525	6,087	99.2%	99.2%	98.9%
Taiwan	2,400	54,394	3,519	2,454	55,629	3,497	102.3%	102.3%	99.4%
Thailand	7,249	164,313	2,012	7,287	165,165	2,019	100.5%	100.5%	100.3%
<North and South America>									
Argentina	3,350	75,936	2,006	3,357	76,095	2,099	100.2%	100.2%	104.6%
Brazil	17,008	385,510	10,620	17,179	389,369	10,915	101.0%	101.0%	102.8%
Canada	3,059	69,333	8,977	3,062	69,413	8,815	100.1%	100.1%	98.2%
Chile	1,660	37,625	1,200	1,673	37,917	1,210	100.8%	100.8%	100.8%
Colombia	3,692	83,680	1,477	3,686	83,536	1,481	99.8%	99.8%	100.3%
Mexico	9,816	222,486	5,690	9,795	222,016	5,823	99.8%	99.8%	102.3%
United States	29,414	592,265	84,797	29,425	592,478	86,570	100.0%	100.0%	102.1%
Venezuela	2,435	55,199	2,244	2,479	56,193	2,301	101.8%	101.8%	102.5%
<Europe>									
Austria	768	17,404	2,610	763	17,292	2,599	99.3%	99.4%	99.6%
Belgium	918	20,818	3,007	914	20,711	2,973	99.6%	99.5%	98.9%
Czech Republic	913	20,701	1,278	904	20,486	1,290	99.0%	99.0%	100.9%
Denmark	480	10,874	1,989	475	10,767	1,924	99.0%	99.0%	96.7%
Finland	474	10,737	1,597	470	10,643	1,576	99.2%	99.1%	98.7%
France	5,105	115,714	16,495	5,062	114,736	16,198	99.2%	99.2%	98.2%
Germany	7,187	162,894	22,528	7,087	160,633	22,321	98.6%	98.6%	99.1%
Greece	912	20,681	2,052	906	20,527	2,065	99.3%	99.3%	100.6%
Hungary	845	19,144	801	830	18,819	788	98.2%	98.3%	98.4%
Ireland	490	11,114	1,759	500	11,338	1,681	102.0%	102.0%	95.6%
Italy	5,371	121,735	14,157	5,337	120,975	13,708	99.4%	99.4%	96.8%
Netherlands	1,437	32,580	5,078	1,424	32,282	5,055	99.1%	99.1%	99.5%
Norway	498	11,298	2,850	498	11,285	2,743	100.0%	99.9%	96.2%
Poland	3,021	68,485	2,935	2,972	67,367	3,153	98.4%	98.4%	107.4%
Portugal	955	21,643	1,502	948	21,488	1,525	99.3%	99.3%	101.5%
Russia	13,494	305,851	8,853	13,239	300,081	9,075	98.1%	98.1%	102.5%
Spain	4,013	90,966	9,820	4,046	91,696	9,899	100.8%	100.8%	100.8%
Sweden	847	19,198	2,698	843	19,097	2,671	99.5%	99.5%	99.0%
Switzerland	750	17,001	3,361	748	16,965	3,281	99.7%	99.8%	97.6%
United Kingdom	5,416	122,755	13,847	5,370	121,720	13,638	99.2%	99.2%	98.5%
<Middle East & Africa>									
Egypt	6,993	158,516	1,222	7,238	164,048	1,280	103.5%	103.5%	104.7%
Iran	6,549	148,438	2,285	6,634	150,355	2,360	101.3%	101.3%	103.3%
Israel	665	15,074	1,336	672	15,240	1,361	101.1%	101.1%	101.9%
Saudi Arabia	2,789	63,208	2,979	2,853	64,673	2,914	102.3%	102.3%	97.8%
South Africa	3,258	73,856	1,761	3,305	74,913	1,794	101.4%	101.4%	101.9%
Turkey	6,012	136,264	3,781	6,017	136,378	3,837	100.1%	100.1%	101.5%

Reference: "Barnes Report: Worldwide printing Industry", C.Barnes & Co.

Table 2.2 Worldwide Printing Industry Outlook compared with Japan in 2011 (forecasted)

Nation	2011 (forecasted)					
	Establishments	compared with Japan	Employments	compared with Japan	Sales (million USD)	compared with Japan
<Asia & Oceania>						
Australia	1,907	17.1%	43,227	17.1%	6,129	18.9%
China	121,815	1092.7%	2,760,987	1092.7%	40,999	126.1%
India	91,354	819.5%	2,070,580	819.5%	8,863	27.3%
Indonesia	22,795	204.5%	516,667	204.5%	4,401	13.5%
Japan	11,148	–	252,678	–	32,501	–
Malaysia	3,089	27.7%	70,015	27.7%	1,573	4.8%
New Zealand	360	3.2%	8,161	3.2%	762	2.3%
Pakistan	14,031	125.9%	318,012	125.9%	974	3.0%
Phillipines	7,664	68.7%	173,700	68.7%	1,091	3.4%
Singapore	481	4.3%	10,904	4.3%	1,433	4.4%
South Korea	4,841	43.4%	109,725	43.4%	6,200	19.1%
Taiwan	2,447	22.0%	55,457	21.9%	3,729	11.5%
Thailand	7,140	64.0%	161,833	64.0%	2,160	6.6%
<North and South America>						
Argentina	3,279	29.4%	74,330	29.4%	2,213	6.8%
Brazil	16,913	151.7%	383,343	151.7%	11,181	34.4%
Canada	2,989	26.8%	67,739	26.8%	8,861	27.3%
Chile	1,643	14.7%	37,248	14.7%	1,247	3.8%
Colombia	3,586	32.2%	81,287	32.2%	1,570	4.8%
Mexico	9,528	85.5%	215,956	85.5%	5,254	16.2%
United States	28,693	257.4%	577,734	228.6%	85,897	264.3%
Venezuela	2,460	22.1%	55,760	22.1%	2,355	7.2%
<Europe>						
Austria	739	6.6%	16,747	6.6%	2,582	7.9%
Belgium	886	7.9%	20,085	7.9%	2,916	9.0%
Czech Republic	872	7.8%	19,762	7.8%	1,316	4.0%
Denmark	459	4.1%	10,393	4.1%	1,935	6.0%
Finland	454	4.1%	10,283	4.1%	1,600	4.9%
France	4,893	43.9%	110,895	43.9%	15,946	49.1%
Germany	6,812	61.1%	154,407	61.1%	22,156	68.2%
Greece	876	7.9%	19,861	7.9%	1,979	6.1%
Hungary	796	7.1%	18,033	7.1%	816	2.5%
Ireland	497	4.5%	11,274	4.5%	1,678	5.2%
Italy	5,170	46.4%	117,185	46.4%	13,151	40.5%
Netherlands	1,376	12.3%	31,180	12.3%	4,970	15.3%
Norway	485	4.4%	10,988	4.3%	2,755	8.5%
Poland	2,850	25.6%	64,596	25.6%	3,224	9.9%
Portugal	918	8.2%	20,796	8.2%	1,443	4.4%
Russia	12,662	113.6%	286,989	113.6%	9,402	28.9%
Spain	3,975	35.7%	90,100	35.7%	9,586	29.5%
Sweden	817	7.3%	18,518	7.3%	2,697	8.3%
Switzerland	728	6.5%	16,502	6.5%	3,277	10.1%
United Kingdom	5,191	46.6%	117,649	46.6%	13,912	42.8%
<Middle East & Africa>						
Egypt	7,301	65.5%	165,490	65.5%	1,351	4.2%
Iran	6,550	58.8%	148,454	58.8%	2,374	7.3%
Israel	663	5.9%	15,019	5.9%	1,447	4.5%
Saudi Arabia	2,846	25.5%	64,501	25.5%	3,108	9.6%
South Africa	3,268	29.3%	74,067	29.3%	1,794	5.5%
Turkey	5,870	52.7%	133,047	52.7%	3,892	12.0%

Reference: "Barnes Report Worldwide printing Industry", C.Barnes & Co.

There are 47 countries to be investigated for the research in total; 13 in Asia & Pacific, 8 in North & South America, 20 in Europe and 6 in Middle East & Africa. Each item is surveyed and forecasted from 2008 to 2012 for five years, but only two years are summarized to see actual trend in short term.

The explanation of research methodology should be given as to how to conduct it across the world. Original report provides estimates by appropriate economic model consisting of domestic industry overviews and overseas secondary sources, only substantive matters are extracted to confirm the trend. North American Classification System (NAICS) codes are applied not only for The United States but also for industry definitions for other countries to be defined and standardized. According to Barnes Reports Worldwide Printing Industry which is a basis of the research reference, the definition of printing industry is defined as “This industry comprises establishments primarily engaged in printing on apparel and textile products, paper, metal, glass, plastic and other materials except fabric (grey goods). The printing processes employed include, but are not limited to lithographic, gravure, screen, flexographic, digital and letterpress. Establishments in this industry do not manufacture the stock that they print but may perform postprinting activities, such as bending, cutting or laminating the materials they print and mailing.”

Printing industry is collective entity from;

- Commercial printing, lithographic
- Offset and photolithographic printing
- Offset printing
- Photo-offset printing
- Photolithographic printing
- Promotional printing, lithographic
- Business form and card printing, lithographic
- Calendar and card printing, lithographic
- Atlas and map printing, lithographic
- Poster and decal printing, lithographic
- Tag, ticket and schedule printing, lithographic
- Wrapper and seal printing, lithographic
- Publication printing, lithographic

There are 13 sub-industries which are included in printing industry.

In Table 2.1, actual figures and percent change from 2009 to 2010 in each country are indicated.

In Asia & Oceania, surprising figures emerge from attention to China and India showing robust economic growth and vitality in recent years. It is estimated that Chinese printing industry employs over 2.8 million people by over 125 thousand companies and results more than 38 million USD which is ranked second biggest volume all over the world in 2010. Indian printing industry employs over 2.1 million people, but sales volume is only 8.2 million USD accounting around one fifth of Chinese performance.

In North/South America, Brazil shows big industry size and steady increase even in one year. The United States indicates positive transition in two years comparison; it is particularly notable that all items are not in negative transition even though almost all advanced countries show subtraction sign.

In Europe, positive transitions are seen only in eastern part and Russia. All advanced countries are struggling; significant drop is confirmed even in one year comparison. Four major countries such as France, Germany, Italy and United Kingdom show no positive figures in all items.

In Middle East & Africa, many countries are in growth trend except for Saudi Arabia. Only six countries are investigated though there are many countries in Africa, so it is understood that collective data is limited and represented ones in this area.

In Table 2.2, all of investigated items in 47 countries in 2011 (forecasted) are compared by the figures of Japan to know their actual scale for instantaneous understanding.

China is more than ten times as big as Japan in terms of establishments and employees, but sales volume is less than 1.3 times. Key items show that substantial manpower strongly supports the industry there. India is more than eight times as big as Japan in terms of establishments and employees, but sales volume is only one forth. The United States is around 2.5 times as big as Japan in all items and four advanced countries (France, Germany, Italy and United Kingdom) in Europe are roughly half size of Japan.

Comparisons of printing industries in 47 countries are effective pointers to understand about the scale of printing industries, current economical transition and relative scale to Japan in whole entire world.

2.3.1.2 Establishments, employments and sales volume in advanced and emerging areas

Worldwide data can provide broad idea about the industry, but it should be checked in detail by focusing on selected countries. Table 2.3 indicates that chosen countries from Group of seven (G7) and Brazil/Russia/India/China (BRICs) are summarized by additional scales of employees per establishment, sales volume per establishment and sales volume per employee.

Table 2.3 Printing Industry Outlooks in G7 and BRICs

Nation	2010					
	Establishments	Employments	Sales (million USD)	Empl./Est.	Sales/Est. (million USD)	Sales/Empl. (million USD)
<Group of seven>						
Canada	3,062	69,413	8,815	22.669	2.879	0.127
France	5,062	114,736	16,198	22.666	3.200	0.141
Germany	7,087	160,633	22,321	22.666	3.150	0.139
Italy	5,337	120,975	13,708	22.667	2.568	0.113
Japan	11,581	262,487	32,584	22.665	2.814	0.124
United Kingdom	5,370	121,720	13,638	22.667	2.540	0.112
United States	29,425	592,478	86,570	20.135	2.942	0.146
Average:				22.305	2.870	0.129
<BRICs>						
Brazil	17,179	389,369	10,915	22.665	0.635	0.028
Russia	13,239	300,081	9,075	22.666	0.685	0.030
India	92,817	2,103,778	8,222	22.666	0.089	0.004
China	125,532	2,845,275	38,295	22.666	0.305	0.013
Average:				22.666	0.429	0.019

Reference: "Barnes Report Worldwide printing Industry", C.Barnes & Co.

It is anticipated that the economical model utilized for employment per establishment by the researcher is based on around 22 employees at an organization in the countries. Sales volume per establishment and per employment show similar trend since employment per establishment is almost the same in every single country.

Average sales volume per establishment in G7 is around 2.87 million USD and sales volume per employee is 0.13 million USD, which are almost seven times as high as BRICs. It concludes that advanced countries can perform higher production efficiency, but not outstandingly higher when considering the gap of technology.

The ratio compared employments and sales volume with national total is summarized in Table 2.4.

Table 2.4 G7 and BRICs Printing Industry Outlooks compared with national total

Nation	2009					
	Employments	Total labor	employment % to total	Sales (million USD)	GDP (million USD)	sales % to total
<Group of seven>						
Canada	69,333	19,096,475	0.363%	8,815	1,336,068	0.660%
France	115,714	28,664,716	0.404%	16,198	2,649,390	0.611%
Germany	162,894	42,342,913	0.385%	22,321	3,330,031	0.670%
Italy	121,735	25,377,206	0.480%	13,708	2,112,786	0.649%
Japan	265,795	65,787,019	0.404%	32,584	5,068,996	0.643%
United Kingdom	122,755	31,753,627	0.387%	13,638	2,174,530	0.627%
United States	592,265	158,995,068	0.373%	86,570	14,119,000	0.613%
<BRICs>						
Brazil	385,510	101,452,980	0.380%	10,915	1,594,490	0.685%
Russia	305,851	75,883,745	0.403%	9,075	1,231,892	0.737%
India	2,083,569	457,459,478	0.455%	8,222	1,377,264	0.597%
China	2,858,146	783,157,007	0.365%	38,295	4,985,461	0.768%

Reference: "Barnes Report Worldwide printing Industry", C.Barnes & Co.
Reference (total labor and GDP): The World Bank

The rate of employment per establishment is more or less same for all countries, so only employment and sales volume figures are left in the table to know the proportion of printing industry to the national total.

The ratios of industry employment compared to total labor ranges from 0.36% to 0.48%, on the other hand, the ones of sales volume compared to Gross Domestic Product ranges from 0.61 to 0.78%. BRICs show slightly higher dependence on printing industry in the viewpoint of sales volume.

Sales volume from printing industry which is categorized by NAICS generally captures 93% of commercial printing which is different category from printing industry and also not part of it.

Previous data is limited to primary 47 countries, does not cover whole regions all over the world. Figure 4.1 shows the portion of commercial printing compared with other printing related items such as newspapers, books and magazines.

Figure 4.2 indicates actual achievement and future forecast of sales volume from worldwide commercial printing from 2005 to 2014. There is weak demand for commercial printing only in 2009 because of Lehman shock, but dynamic growth is expected five years from now on. Most of advanced countries, especially Japan and European countries, seem like they cannot clear the dark clouds by the previous research, but emerging countries are expected to continue growing in the medium and long terms.

Figure 4.3 pinpoints that Asia is already the biggest region from the standpoint of global commercial printing; obviously China is driving force pushing this region to be a top region during recent years. It leads us to imagine that European countries are in delicate situation since they perform in distress to both Asia and America regions.

Item	Global market share (%)
General commercial	46.5%
Newspaper	29.3%
Book	9.1%
Others	7.9%
Magazine	7.2%

Reference: Global Commercial Printing, DATAMONITOR

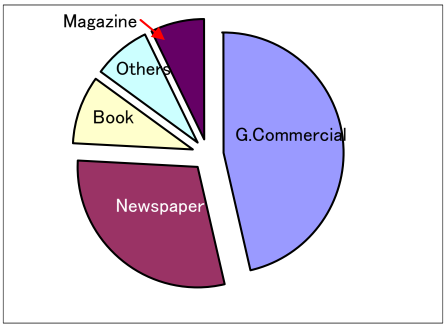


Figure 2.1 Global market shares by different printing items

Year	USD(billion)	vs previous yr.	vs 2005
2005	375.7		
2006	383.1	2.0%	2.0%
2007	391.7	2.2%	4.3%
2008	397.3	1.4%	5.7%
2009	393.7	−0.9%	4.8%
2010	405.6	3.0%	8.0%
2011	414.7	2.2%	10.4%
2012	424.9	2.5%	13.1%
2013	437.2	2.9%	16.4%
2014	449.6	2.8%	19.7%

Reference: Global Commercial Printing, DATAMONITOR

*Anticipated data is shown from 2010 to 2014
*Compound Annual Growth Rate is 1.2% from 2005 to 2009
*Compound Annual Growth Rate is expected to be 2.7% from 2009 to 2014

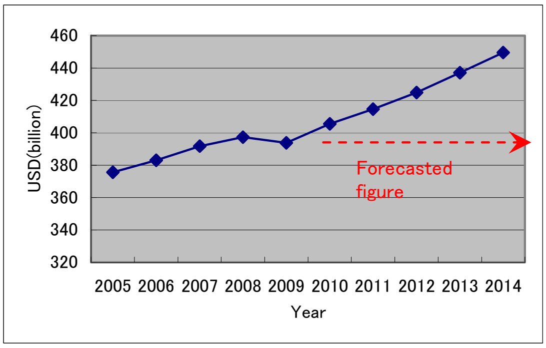


Figure 2.2 Global commercial printing from 2005 to 2014

Region	Global market share (%)
Asia	35.3%
America	34.8%
Europe	27.9%
Others	2.0%

Reference: Global Commercial Printing, DATAMONITOR

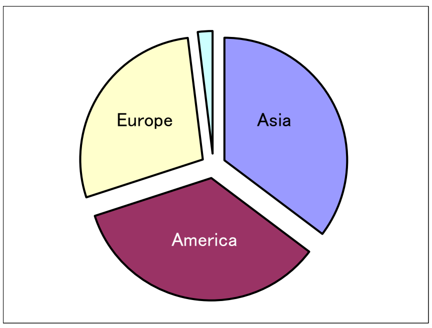


Figure 2.3 Global commercial printing by regions

2.3.2 Key statistics within the country

2.3.2.1 Establishments, employments and sales volumes in Japan

Printing related products including the goods from prepress, bookbinding, postpress, printing related service and paper related products are checked through to know the level in the viewpoint of financial scale. Table 2.5 shows general manufacturing data.

Table 2.5 Sales volume per establishments in manufacturing in 2009

Code	Industry	Establishments		Employees		Sales (million USD)		Sales/Est. (million USD)
170	Petrorium and Coal products	959	0.4%	25,455	0.3%	123,375	4.0%	128.6499
300	Information and communication electronics equipment	2,174	0.9%	217,348	2.8%	134,794	4.3%	62.0027
160	Chemical and allied products	4,831	2.0%	347,103	4.5%	285,596	9.2%	59.1174
310	Transportation equipment	11,501	4.9%	947,704	12.3%	555,137	17.8%	48.2686
220	Iron and Steel	4,588	1.9%	220,518	2.9%	188,098	6.0%	40.9979
280	Devices and electronic circuits	5,066	2.1%	462,543	6.0%	175,162	5.6%	34.5759
230	Non-ferrous metals products	3,010	1.3%	143,214	1.9%	81,647	2.6%	27.1251
100	Beverages,Tobacco and Feed	4,549	1.9%	104,328	1.3%	117,569	3.8%	25.8450
270	Business oriented machinery	4,871	2.1%	218,516	2.8%	83,155	2.7%	17.0714
290	Electrical machinery, Equipment and Supply	10,173	4.3%	476,765	6.2%	161,331	5.2%	15.8587
250	General-purpose machinery	8,107	3.4%	323,766	4.2%	115,875	3.7%	14.2932
140	Pulp, Paper and Paper products	6,949	2.9%	194,569	2.5%	83,154	2.7%	11.9663
190	Rubber products	2,891	1.2%	116,266	1.5%	31,164	1.0%	10.7795
90	Food	31,233	13.2%	1,125,413	14.5%	287,624	9.2%	9.2090
180	Plastic Products, except otherwise classified	14,590	6.2%	419,936	5.4%	118,317	3.8%	8.1095
210	Ceramic, Stone and Clay products	11,656	4.9%	255,159	3.3%	79,608	2.6%	6.8298
260	Production machinery	20,917	8.9%	536,630	6.9%	141,348	4.5%	6.7575
320	Miscellaneous	8,998	3.8%	164,403	2.1%	44,827	1.4%	4.9819
150	Printing related products	14,851	6.3%	308,878	4.0%	72,613	2.3%	4.8895
240	Fabricated metal products	30,611	13.0%	584,127	7.6%	146,196	4.7%	4.7759
120	Lumber and Wood products, except furniture	6,978	3.0%	99,891	1.3%	24,685	0.8%	3.5376
110	Textile mill	17,151	7.3%	311,264	4.0%	45,508	1.5%	2.6534
130	Furniture and Fixtures	7,282	3.1%	105,202	1.4%	19,300	0.6%	2.6503
200	Leather tanning, Leather products and Fur skins	1,881	0.8%	26,791	0.3%	4,613	0.1%	2.4523
	Total:	235,817		7,735,789		3,120,695		553.3981

Reference: 2009 Census Statistical Tables by Respective Industry for the Whole Country(more than 4-employee/establishment) / Ministry of Economy, Trade and Industry

Sales volume per establishment for printing related products is around 4.9 million USD; it is ranked one forth from the bottom among manufacturing sector. Additionally, it has just less than half value of paper related products when compared. Average sales volume per establishment of manufacturing is around 13 million USD, so is roughly one third of overall average in manufacturing sector.

Detailed data focusing on printing related industry in seven year transition is summarized in Table 2.6. Number of establishments in manufacturing was decreased from 293,311 to 235,817 (-19.8%) in seven years, on the other hand, printing industry was changed from 19,621 to 14,851 (-24.3%) in the same period. Both overall manufacturing and printing industry are on the decline, but the rate of decline is more than overall manufacturing.

Number of employees in manufacturing was decreased from 8.2 million to 7.7 million (-6.0%) in seven years, on another front, printing industry was changed from 360,614 to 308,878 (-14.3%) in the same period. The most important indicator is sales volume, the one in manufacturing slipped from 3.2 to 3.1 million USD (-3.1%), but the one in printing industry dropped from 85,030 to 72,613 million USD (-14.6%) from 2003 to 2009. This figure really reflects that printing industry is dragged into the pits in recent years.

Table 2.6 Establishments/Employees/Sales volume in Printing industry from 2003-2009

		2003		2004		2005		2006		2007		2008		2009		Estab. Comparison	
		Estab.	Emp./Est.	Estab.	Emp./Est.	Estab.	Emp./Est.	Estab.	Emp./Est.	Estab.	Emp./Est.	Estab.	Emp./Est.	Estab.	Emp./Est.	2009-2003	2009/2003
0000	National Total	293,911	28.0	270,906	30.0	276,716	29.5	258,543	31.8	258,232	33.0	263,061	31.8	235,817	32.8	-58,094	80.2%
	(vs 2003)	–	–	92.2%	107.0%	94.1%	105.3%	88.0%	113.6%	87.9%	117.8%	89.5%	113.6%	80.2%	117.2%		
1600	Printing related	19,621	18.4	17,954	19.3	17,919	19.0	16,466	20.0	16,320	20.5	16,484	19.8	14,851	20.8	-4,770	75.7%
	(vs 2003)	–	–	91.5%	104.9%	91.3%	103.5%	83.9%	109.0%	83.2%	111.6%	84.0%	107.8%	75.7%	113.2%		
1611	Printing	14,996	19.3	13,796	20.2	13,825	20.0	12,742	21.0	12,653	21.3	12,783	20.6	11,576	21.8	-3,420	77.2%
1621	Prepress	1,781	20.1	1,581	21.4	1,442	21.2	1,267	22.2	1,261	22.9	1,132	23.3	1,032	24.0	-749	57.9%
1631	Bookbinding	1,528	14.0	1,417	14.6	1,436	14.2	1,348	14.9	1,257	15.7	1,312	15.1	1,181	15.4	-347	77.3%
1632	Postpress	1,190	10.4	1,050	11.3	1,109	11.0	1,008	11.6	1,017	14.1	1,120	12.7	966	11.5	-224	81.2%
1691	Printing related service	126	14.0	110	14.4	107	16.8	101	17.8	132	17.2	137	18.2	96	21.8	-30	76.2%

		2003		2004		2005		2006		2007		2008		2009		Employees Comparison	
		Employees	Sales/Emp. (mil.USD)	Employees	Sales/Emp. (mil.USD)	Employees	Sales/Emp. (mil.USD)	Employees	Sales/Emp. (mil.USD)	Employees	Sales/Emp. (mil.USD)	Employees	Sales/Emp. (mil.USD)	Employees	Sales/Emp. (mil.USD)	2009-2003	2009/2003
0000	National Total	8,228,150	0.4	8,113,676	0.4	8,159,364	0.4	8,225,442	0.5	8,518,545	0.5	8,384,607	0.5	7,735,789	0.4	-492,361	94.0%
	(vs 2003)	–	–	98.6%	105.4%	99.2%	109.0%	100.0%	115.1%	103.5%	118.8%	101.7%	120.6%	94.0%	103.1%		
1600	Printing related	360,614	0.2	346,175	0.2	340,890	0.2	329,830	0.2	334,796	0.2	326,476	0.2	308,878	0.2	-51,736	85.7%
	(vs 2003)	–	–	96.0%	101.4%	94.5%	101.7%	91.5%	103.7%	92.8%	104.1%	90.5%	103.0%	85.7%	99.7%		
1611	Printing	289,208	0.3	278,212	0.3	275,835	0.3	268,151	0.3	269,640	0.3	263,571	0.3	252,799	0.3	-36,409	87.4%
1621	Prepress	35,860	0.2	33,801	0.2	30,628	0.2	28,119	0.2	28,829	0.2	26,405	0.2	24,731	0.2	-11,129	69.0%
1631	Bookbinding	21,377	0.1	20,661	0.1	20,426	0.1	20,086	0.1	19,707	0.1	19,763	0.1	18,184	0.1	-3,193	85.1%
1632	Postpress	12,407	0.1	11,915	0.1	12,203	0.1	11,680	0.1	14,347	0.1	14,250	0.1	11,074	0.1	-1,333	89.3%
1691	Printing related service	1,762	0.1	1,586	0.1	1,798	0.1	1,794	0.1	2,273	0.1	2,487	0.1	2,090	0.1	328	118.6%

		2003		2004		2005		2006		2007		2008		2009		Sales Comparison	
		Sales (mil.USD)	Sales/Est. (mil.USD)	Sales (mil.USD)	Sales/Est. (mil.USD)	Sales (mil.USD)	Sales/Est. (mil.USD)	Sales (mil.USD)	Sales/Est. (mil.USD)	Sales (mil.USD)	Sales/Est. (mil.USD)	Sales (mil.USD)	Sales/Est. (mil.USD)	Sales (mil.USD)	Sales/Est. (mil.USD)	2009-2003	2009/2003
0000	National Total	3,220,405	11.0	3,346,097	12.4	3,480,004	12.6	3,703,937	14.3	3,961,843	15.3	3,947,986	15.0	3,120,694	13.2	-99,711	96.9%
	(vs 2003)	–	–	103.9%	112.7%	108.1%	114.8%	115.0%	130.7%	123.0%	140.0%	122.6%	137.0%	96.9%	120.8%		
1600	Printing related	85,030	4.3	82,781	4.6	81,711	4.6	80,657	4.9	82,145	5.0	79,269	4.8	72,613	4.9	-12,417	85.4%
	(vs 2003)	–	–	97.4%	106.4%	96.1%	105.2%	94.9%	113.0%	96.6%	116.1%	93.2%	111.0%	85.4%	112.8%		
1611	Printing	74,678	5.0	72,602	5.3	71,821	5.2	70,590	5.5	71,511	5.7	69,499	5.4	64,486	5.6	-10,192	86.4%
1621	Prepress	6,206	3.5	6,136	3.9	5,884	4.1	6,060	4.8	5,947	4.7	5,153	4.6	4,591	4.4	-1,615	74.0%
1631	Bookbinding	2,545	1.7	2,494	1.8	2,435	1.7	2,484	1.8	2,452	2.0	2,404	1.8	2,096	1.8	-448	82.4%
1632	Postpress	1,364	1.1	1,331	1.3	1,383	1.2	1,326	1.3	1,938	1.9	1,942	1.7	1,224	1.3	-141	89.7%
1691	Printing related service	238	1.9	219	2.0	209	2.0	196	1.9	297	2.3	270	2.0	217	2.3	-21	91.3%

Reference: 2003-2009 Census Statistical Tables by Respective Industry for the Whole Country(more than 4-employee/establishment) / Ministry of Economy, Trade and Industry

2.4 PAPER INDUSTRY PERFORMANCE

2.4.1 Key statistics worldwide

2.4.1.1 Establishments, employments and sales volumes in major countries

Paper industry outlook is also segmented into four different areas just the same as printing industry. Data resource is exactly the same as printing industry, so number of countries in all, number of countries in four different regions, survey methodology, and future forecast based on researcher's economical model, segmentation for the industry by NAIC codes and surveyed period are all identified. It is summarized in Table 2.7 and 2.8.

Table 2.7 Worldwide Paper Industry Outlook in 2009-2010

Nation	2009			2010			% change (2010/2009)		
	Establishments	Employments	Sales (million USD)	Establishments	Employments	Sales (million USD)	Establishments	Employments	Sales (million USD)
<Asia & Oceania>									
Australia	9	2,520	1,334	9	2,506	1,295	100.0%	99.4%	97.1%
China	558	164,012	7,946	549	161,557	8,110	98.4%	98.5%	102.1%
India	407	119,564	1,737	406	119,454	1,741	99.8%	99.9%	100.2%
Indonesia	102	30,081	924	102	29,930	917	100.0%	99.5%	99.2%
Japan	52	15,252	7,421	51	14,904	6,900	98.1%	97.7%	93.0%
Malaysia	14	3,979	333	14	4,007	319	100.0%	100.7%	95.8%
New Zealand	2	472	165	2	471	158	100.0%	99.8%	95.8%
Pakistan	60	17,750	215	61	18,038	205	101.7%	101.6%	95.3%
Phillipines	33	9,773	224	34	9,892	222	103.0%	101.2%	99.1%
Singapore	2	619	282	2	624	283	100.0%	100.8%	100.4%
South Korea	22	6,570	1,361	22	6,446	1,289	100.0%	98.1%	94.7%
Taiwan	11	3,121	778	11	3,159	740	100.0%	101.2%	95.1%
Thailand	32	9,429	445	32	9,378	427	100.0%	99.5%	96.0%
<North and South America>									
Argentina	15	4,358	444	15	4,321	444	100.0%	99.2%	100.0%
Brazil	75	22,122	2,349	75	22,109	2,311	100.0%	99.9%	98.4%
Canada	27	7,957	3,972	27	7,883	3,734	100.0%	99.1%	94.0%
Chile	7	2,159	265	7	2,153	256	100.0%	99.7%	96.6%
Colombia	16	4,802	327	16	4,743	314	100.0%	98.8%	96.0%
Mexico	43	12,767	1,259	43	12,606	1,233	100.0%	98.7%	97.9%
United States	264	67,973	37,516	262	67,283	36,666	99.2%	99.0%	97.7%
Venezuela	11	3,168	496	11	3,191	487	100.0%	100.7%	98.2%
<Europe>									
Austria	3	999	577	3	982	550	100.0%	98.3%	95.3%
Belgium	4	1,195	665	4	1,176	630	100.0%	98.4%	94.7%
Czech Republic	4	1,188	283	4	1,163	273	100.0%	97.9%	96.5%
Denmark	2	624	440	2	611	407	100.0%	97.9%	92.5%
Finland	4	1,232	707	4	1,209	668	100.0%	98.1%	94.5%
France	23	6,640	3,649	22	6,515	3,430	95.7%	98.1%	94.0%
Germany	32	9,348	4,983	31	9,121	4,727	96.9%	97.6%	94.9%
Greece	4	1,187	454	4	1,166	437	100.0%	98.2%	96.3%
Hungary	4	1,099	177	4	1,069	167	100.0%	97.3%	94.4%
Ireland	2	638	389	2	644	356	100.0%	100.9%	91.5%
Italy	24	6,986	3,132	23	6,869	2,903	95.8%	98.3%	92.7%
Netherlands	6	1,870	1,123	6	1,833	1,070	100.0%	98.0%	95.3%
Norway	4	1,297	1,261	4	1,282	1,162	100.0%	98.8%	92.1%
Poland	13	3,930	649	13	3,825	668	100.0%	97.3%	102.9%
Portugal	4	1,242	332	4	1,220	323	100.0%	98.2%	97.3%
Russia	60	17,551	1,958	58	17,039	1,922	96.7%	97.1%	98.2%
Spain	18	5,220	2,172	18	5,207	2,096	100.0%	99.8%	96.5%
Sweden	7	2,203	1,194	7	2,169	1,131	100.0%	98.5%	94.7%
Switzerland	3	976	744	3	963	695	100.0%	98.7%	93.4%
United Kingdom	24	7,044	3,063	23	6,911	2,888	95.8%	98.1%	94.3%
<Middle East & Africa>									
Egypt	31	9,096	270	32	9,315	271	103.2%	102.4%	100.4%
Iran	29	8,518	506	29	8,537	500	100.0%	100.2%	98.8%
Israel	3	865	296	3	865	288	100.0%	100.0%	97.3%
Saudi Arabia	12	3,627	659	12	3,672	617	100.0%	101.2%	93.6%
South Africa	14	4,238	390	14	4,254	380	100.0%	100.4%	97.4%
Turkey	27	7,819	836	26	7,744	813	96.3%	99.0%	97.2%

Reference: "Barnes Report Worldwide Paper Industry", C.Barnes & Co.

Table 2.8 Worldwide Paper Industry compared with Japan in 2011 (forecasted)

Nation	2011 (forecasted)					
	Establishments	Compared with Japan	Employments	Compared with Japan	Sales (million USD)	Compared with Japan
<Asia & Oceania>						
Australia	8	16.3%	2,459	17.1%	1,243	18.9%
China	534	1089.8%	157,062	1092.7%	8,313	126.1%
India	400	816.3%	117,787	819.4%	1,797	27.3%
Indonesia	100	204.1%	29,391	204.5%	892	13.5%
Japan	49	−	14,374	−	6,590	−
Malaysia	14	28.6%	3,983	27.7%	319	4.8%
New Zealand	2	4.1%	464	3.2%	154	2.3%
Pakistan	61	124.5%	18,091	125.9%	197	3.0%
Phillipines	34	69.4%	9,881	68.7%	221	3.4%
Singapore	2	4.1%	620	4.3%	291	4.4%
South Korea	21	42.9%	6,242	43.4%	1,257	19.1%
Taiwan	11	22.4%	3,155	21.9%	756	11.5%
Thailand	31	63.3%	9,206	64.0%	438	6.6%
<North and South America>						
Argentina	14	28.6%	4,228	29.4%	449	6.8%
Brazil	74	151.0%	21,807	151.7%	2,267	34.4%
Canada	26	53.1%	7,707	53.6%	3,593	54.5%
Chile	7	14.3%	2,119	14.7%	253	3.8%
Colombia	16	32.7%	4,624	32.2%	318	4.8%
Mexico	42	85.7%	12,285	85.5%	1,065	16.2%
United States	256	522.4%	65,730	457.3%	34,833	528.6%
Venezuela	11	22.4%	3,172	22.1%	477	7.2%
<Europe>						
Austria	3	6.1%	953	6.6%	524	8.0%
Belgium	4	8.2%	1,143	8.0%	591	9.0%
Czech Republic	4	8.2%	1,124	7.8%	267	4.1%
Denmark	2	4.1%	591	4.1%	392	5.9%
Finland	4	8.2%	1,170	8.1%	649	9.8%
France	21	42.9%	6,308	43.9%	3,233	49.1%
Germany	30	61.2%	8,784	61.1%	4,492	68.2%
Greece	4	8.2%	1,130	7.9%	401	6.1%
Hungary	3	6.1%	1,026	7.1%	165	2.5%
Ireland	2	4.1%	641	4.5%	340	5.2%
Italy	23	46.9%	6,666	46.4%	2,666	40.5%
Netherlands	6	12.2%	1,774	12.3%	1,008	15.3%
Norway	4	8.2%	1,250	8.7%	1,117	16.9%
Poland	12	24.5%	3,675	25.6%	654	9.9%
Portugal	4	8.2%	1,183	8.2%	293	4.4%
Russia	55	112.2%	16,326	113.6%	1,906	28.9%
Spain	17	34.7%	5,125	35.7%	1,944	29.5%
Sweden	7	14.3%	2,107	14.7%	1,094	16.6%
Switzerland	3	6.1%	939	6.5%	664	10.1%
United Kingdom	23	46.9%	6,693	46.6%	2,821	42.8%
<Middle East & Africa>						
Egypt	32	65.3%	9,414	65.5%	274	4.2%
Iran	29	59.2%	8,445	58.8%	481	7.3%
Israel	3	6.1%	854	5.9%	293	4.4%
Saudi Arabia	12	24.5%	3,669	25.5%	630	9.6%
South Africa	14	28.6%	4,213	29.3%	364	5.5%
Turkey	26	53.1%	7,569	52.7%	789	12.0%

Reference: "Barnes Report Worldwide Paper Industry", C.Barnes & Co.

The definition of paper industry should be clarified; according to Barnes Reports Worldwide Paper Industry which is fundamental of the research reference, it is defined as "This industry comprises establishments primarily engaged in manufacturing paper from pulp. These establishments may manufacturer or purchase pulp. In addition, the establishments may convert the paper they make. The activity of making paper classifies an establishment into this industry regardless of the output."

Paper industry is collective entity from;

- Paper mills

- Towels, tissues and napkins; paper and stock
- Cleansing paper
- Facial tissue stock
- Napkin stock, paper
- Pattern tissue
- Sanitary tissue paper
- Tissue paper
- Toilet tissue stock
- Toweling tissue (paper)
- Parchment, securities and bank note papers
- Bank note paper
- Parchment paper
- Securities paper
- Specialty or chemically treated papers
- Absorbent paper
- Capacitor paper
- Cigarette paper
- Filter paper
- Milk filter disks
- Specialty papers
- Book, bond and printing papers
- Bond paper
- Book paper
- Lithograph paper
- Offset paper
- Printing paper
- Text paper
- Poster and art papers
- Art paper
- Construction paper
- Stationary, envelope and tablet papers

There are 32 sub-industries which are included in paper industry.

Table 2.7 indicates that the size of paper industry is relatively smaller compared with printing industry by NAIC codes.

In Asia & Oceania, China has strong presence exceptionally; establishments and employments are outstandingly ranked first among all countries. When looking at percent change of sales volume in this area, the rate of increase underperforms compared with the one of printing industry.

In North/South America, The United States outstrips others especially in terms of sales volume which heads the ranking list all over the world, but is in downward trend now. Brazil is indispensable country in the standpoint of the scale of establishments and employments not only in this area, but is also on decline just the same as others.

In Europe, major country is Russia; Germany/Italy/United Kingdom/France are almost same scales. Significant drops in sales volumes in second group range from 5% to 7% and have surely negative impacts on those countries.

In Middle East and Africa, no major companies have places in the area by the viewpoint of sales volumes which have one digit less than major countries in other areas.

In Table 2.8, all researched items are compared by actual achievements of Japan to have ideas easily how bigger or smaller compared with Japan by the scale of performance in Japan. Basic method of comparison is the same as the one for printing industry.

China and India are eight to ten times bigger by the measurement of establishments and employees, but sales volume is only 26% more compared with China and four times as big as India. The United States is five times as big as Japan in terms of all items; it is notable that employment is 4.5 times as big as Japan, but sales volume is 5.3 times as high as Japan. It indicates much higher efficiency in their production system, namely much smaller number of staff can outperform Japan by their system. The scales of paper industries in European countries show around half size of Japan, it is exactly the same tendency as printing industry.

2.4.1.2 Establishments, employments and sales volumes in advanced and emerging areas

Likewise printing industry, paper industry in G7 and BRICs is summarized in Table 2.9.

Table 2.9 Paper Industry Outlooks in G7 and BRICs

Nation	2010					
	Establishments	Employments	Sales (million USD)	Empl./Est.	Sales/Est. (million USD)	Sales/Empl. (million USD)
<Group of seven>						
Canada	27	7,883	3,734	291.963	138.296	0.474
France	22	6,515	3,430	296.136	155.909	0.526
Germany	31	9,121	4,727	294.226	152.484	0.518
Italy	23	6,869	2,903	298.652	126.217	0.423
Japan	51	14,904	6,900	292.235	135.294	0.463
United Kingdom	23	6,911	2,888	300.478	125.565	0.418
United States	262	67,283	36,666	256.805	139.947	0.545
Average:				290.071	139.102	0.481
<BRICs>						
Brazil	75	22,109	2,311	294.787	30.813	0.105
Russia	58	17,039	1,922	293.776	33.138	0.113
India	406	119,454	1,741	294.222	4.288	0.015
China	549	161,557	8,110	294.275	14.772	0.050
Average:				294.265	20.753	0.071

Reference: "Barnes Report Worldwide Paper Industry", C.Barnes & Co.

It is speculated that researcher applies economical model estimating around 290 employees for employment per establishment in each organization for both advanced and emerging countries with no difference.

Average sales volume per establishment in G7 is around 139 million USD and sales volume per employee is 0.48 million USD, which are about seven times as high as BRICs, just all the same as the tendency of printing industry.

Employments in the industry are compared with total labor and sales volumes are compared with GDP in each country of G7 and BRICS. It is summarized in Table 2.10.

Table 2.10 G7 and BRICs Printing Industry Outlooks compared with national total

Nation	2009					
	Employments	Total labor	employment % to total	Sales (million USD)	GDP (million USD)	sales % to total
<Group of seven>						
Canada	7,883	19,096,475	0.041%	3,734	1,336,068	0.279%
France	6,515	28,664,716	0.023%	3,430	2,649,390	0.129%
Germany	9,121	42,342,913	0.022%	4,727	3,330,031	0.142%
Italy	6,869	25,377,206	0.027%	2,903	2,112,786	0.137%
Japan	14,904	65,787,019	0.023%	6,900	5,068,996	0.136%
United Kingdom	6,911	31,753,627	0.022%	2,888	2,174,530	0.133%
United States	67,283	158,995,068	0.042%	36,666	14,119,000	0.260%
<BRICs>						
Brazil	22,109	101,452,980	0.022%	2,311	1,594,490	0.145%
Russia	17,039	75,883,745	0.022%	1,922	1,231,892	0.156%
India	119,454	457,459,478	0.026%	1,741	1,377,264	0.126%
China	161,557	783,157,007	0.021%	8,110	4,985,461	0.163%

Reference: "Barnes Report Worldwide printing Industry", C.Barnes & Co.
Reference (total labor and GDP): The World Bank

Employment percentage to total labor in Canada and The United States is much higher than other countries, so sales volume goes hand-in-hand with it. When comparing above figures with the ones of printing industry, it leads to the understanding of the fact that printing industry is about nine times bigger by the measure of employments and more than double size by the measure of sale volume to be compared with paper industry.

2.4.2 Key statistics within the country

2.4.2.1 Establishments, employments and sales volumes in Japan

Overall manufacturing data is already reviewed in previous clause, so fix eyes on only paper industry data. Specific data in seven-year performance is summarized in Table 2.11

In the same manner as printing industry, paper industry consists of five sub-industries such as Pulp, Paper, Carton paper, Carton box & packages and others. Paper and Carton paper are paper mills; they are core part of the industry.

Number of establishments was drastically decreased from 8,394 to 6,949 (-17.2%) and number of employees was also declined, but not as bad as establishments, from 220,084 to 194,569 (-11.6%) respectively.

The indicator getting all the attention is sales volume, it remained unchanged from 83,396 to 83,154 million USD (-0.3%). In printing industry, it slipped almost 15%, but paper industry worked on restructuring by promoting merger & acquisition and by cutting in workforce. The reason why paper industry could drive forward was that sales volume each organization was not small one like the one in printing industry. Sale volume per employee in paper industry is 0.4 million USD which is double of printing industry, and sales volume per establishment in paper industry is 12.0 million USD which is triple of printing industry, so these figures could be used as evidence.

Table 2.11 Establishments/Employees/Sales volume in Paper industry from 2003-2009

		2003		2004		2005		2006		2007		2008		2009		Estab. Comparison	
		Estab.	Emp./Est.	Estab.	Emp./Est.	Estab.	Emp./Est.	Estab.	Emp./Est.	Estab.	Emp./Est.	Estab.	Emp./Est.	Establishment	Emp./Est.	2009-2003	2009/2003
0000	National Total	293,911	28.0	270,908	30.0	276,718	29.5	258,543	31.8	258,232	33.0	283,061	31.8	235,817	32.8	-58,094	80.2%
		-	-	92.2%	107.0%	94.1%	105.3%	88.0%	113.6%	87.9%	117.8%	89.5%	113.6%	80.2%	117.2%		
1400	Paper related	8,394	26.2	7,851	27.2	7,894	26.7	7,457	28.0	7,414	28.3	7,391	27.7	6,949	28.0	-1,445	82.8%
		-	-	93.5%	103.9%	94.0%	101.7%	88.8%	106.7%	88.3%	108.0%	88.1%	105.8%	82.8%	106.8%		
1411	Pulp	24	48.6	23	45.7	22	45.6	24	58.1	26	66.9	26	61.3	26	60.6	2	108.3%
1421	Paper	302	105.8	288	105.6	282	103.0	277	101.2	284	95.0	266	98.3	256	94.7	-46	84.8%
1422	Carton paper	118	83.3	98	94.2	102	89.0	98	91.6	102	84.8	102	82.4	100	81.8	-18	84.7%
1456&1454	Carton box & package	4,547	20.0	4,272	20.8	4,310	20.6	4,069	21.5	3,997	22.0	4,044	21.7	3,808	22.1	-739	83.7%
1499+	others	3,403	25.3	3,170	26.5	3,178	25.9	2,989	27.7	3,005	28.1	2,953	27.5	2,759	27.7	-644	81.1%

		2003		2004		2005		2006		2007		2008		2009		Employees Comparison	
		Employees	Sales./Emp. (mil.USD)	Employees	Sales./Emp. (mil.USD)	Employees	Sales./Emp. (mil.USD)	Employees	Sales./Emp. (mil.USD)	Employees	Sales./Emp. (mil.USD)	Employees	Sales./Emp. (mil.USD)	Employees	Sales./Emp. (mil.USD)	2009-2003	2009/2003
0000	National Total	8,228,150	0.4	8,113,676	0.4	8,159,364	0.4	8,225,442	0.5	8,518,545	0.5	8,364,607	0.5	7,735,789	0.4	-492,361	94.0%
		-	-	98.6%	105.4%	99.2%	109.0%	100.0%	115.1%	103.5%	118.8%	101.7%	120.6%	94.0%	103.1%		
1400	Paper related	220,084	0.4	213,803	0.4	210,460	0.4	208,585	0.4	209,882	0.4	204,994	0.4	194,569	0.4	-25,515	88.4%
		-	-	97.1%	104.6%	95.6%	104.6%	94.8%	107.2%	95.4%	113.3%	93.1%	118.1%	88.4%	112.8%		
1411	Pulp	1,167	0.4	1,052	0.4	1,003	0.4	1,394	0.4	1,740	0.4	1,593	0.4	1,576	0.3	409	135.0%
1421	Paper	31,964	0.8	30,421	0.8	29,048	0.9	28,028	0.9	26,983	1.0	26,148	1.0	24,240	1.0	-7,724	75.8%
1422	Carton paper	9,826	0.8	9,233	0.9	9,079	0.9	8,976	1.0	8,647	1.1	8,408	1.1	8,181	1.1	-1,645	83.3%
1456&1454	Carton box & package	91,079	0.3	88,940	0.3	88,898	0.3	87,478	0.3	88,032	0.3	87,764	0.3	84,246	0.3	-6,833	92.5%
1499+	others	86,048	0.3	84,157	0.3	82,432	0.3	82,709	0.3	84,480	0.3	81,081	0.3	76,326	0.3	-9,722	88.7%

		2003		2004		2005		2006		2007		2008		2009		Sales Comparison	
		Sales (mil.USD)	Sales/Est. (mil.USD)	Sales (mil.USD)	Sales/Est. (mil.USD)	Sales (mil.USD)	Sales/Est. (mil.USD)	Sales (mil.USD)	Sales/Est. (mil.USD)	Sales (mil.USD)	Sales/Est. (mil.USD)	Sales (mil.USD)	Sales/Est. (mil.USD)	Sales (mil.USD)	Sales/Est. (mil.USD)	2009-2003	2009/2003
0000	National Total	3,220,405	11.0	3,346,097	12.4	3,480,004	12.6	3,703,937	14.3	3,961,843	15.3	3,947,986	15.0	3,120,694	13.2	-99,711	96.9%
		-	-	103.9%	112.7%	108.1%	114.8%	115.0%	130.7%	123.0%	140.0%	122.6%	137.0%	96.9%	120.8%		
1400	Paper related	83,396	9.9	84,731	10.8	83,402	10.6	84,723	11.4	90,118	12.2	91,704	12.4	83,154	12.0	-243	99.7%
		-	-	101.6%	108.6%	100.0%	106.3%	101.6%	114.4%	108.1%	122.3%	110.0%	124.9%	99.7%	120.4%		
1411	Pulp	419	17.4	417	18.1	444	20.2	496	20.7	623	23.9	575	22.1	534	20.6	116	127.7%
1421	Paper	25,013	82.8	24,936	86.6	24,777	87.9	24,539	88.6	25,910	91.2	27,195	102.2	23,439	91.6	-1,574	93.7%
1422	Carton paper	8,150	69.1	8,571	87.5	8,568	84.0	8,870	90.5	9,265	90.8	9,513	93.3	8,607	86.1	457	105.6%
1456&1454	Carton box & package	23,576	5.2	24,111	5.6	23,904	5.5	23,749	5.8	25,543	6.4	26,376	6.5	25,138	6.6	1,562	106.6%
1499+	others	26,239	7.7	26,696	8.4	25,709	8.1	27,069	9.1	28,777	9.6	28,045	9.5	25,435	9.2	-804	96.9%

Reference: 2003-2009 Census Statistical Tables by Respective Industry for the Whole Country(more than 4-employee/establishment) / Ministry of Economy, Trade and Industry

It is capable of learning about establishments/employees/sales volumes in paper industry, but not capable of learning about transition of production volume in Table 2.11. So on that point, total production of Paper and Paperboard is captured from 2003 to 2009 and summarized in Figure 2.4 and Figure 2.5. The term "Paper" here refers to the one for commonly-used, on the other hand, the term "Paperboard" refers to the one for packaging use.

Item	2003	2004		2005		2006		2007		2008		2009	
Paper	18,396,362	18,788,241	102.1%	18,901,072	102.7%	19,065,678	103.6%	19,192,208	104.3%	18,827,707	102.3%	15,831,919	86.1%
Paperboard	12,060,516	12,103,373	100.4%	12,051,254	99.9%	12,041,940	99.8%	12,073,546	100.1%	11,799,748	97.8%	10,436,033	86.5%
Total (t/year):	30,456,878	30,891,614	101.4%	30,952,326	101.6%	31,107,618	102.1%	31,265,754	102.7%	30,627,455	100.6%	26,267,952	86.2%

Refernce: Chronological Data by Commodity / Ministry of Economy, Trade and Industry

＊Percentage shown from 2004 to 2009 is the figure compared with 2003.

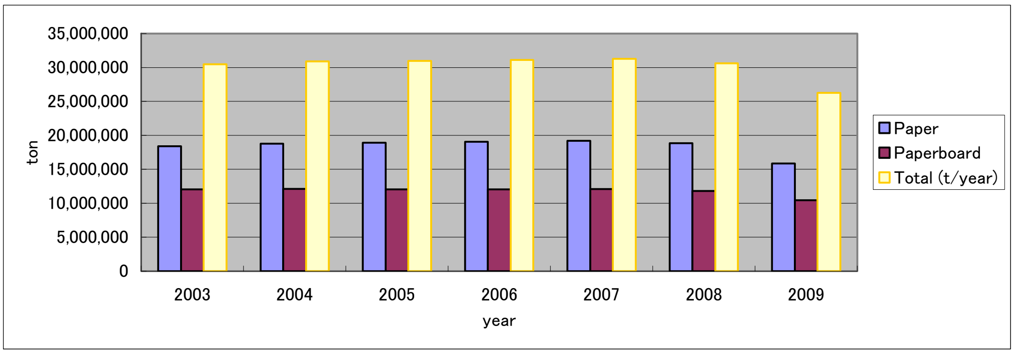


Figure 2.4　Total production volume of Paper and Paperboard from 2003-2009

Item	2008				2009			
	Production quantity		Shipments quantity	Inventory quantity	Production quantity		Shipments quantity	Inventory quantity
Newsprint paper in rolls	3,680,410	12.0%	3,715,725	261,391	3,454,589	13.2%	3,475,304	240,459
Printing & communication paper	11,501,422	37.6%	11,055,199	989,867	9,120,058	34.7%	8,964,401	886,768
Wrapping paper	1,010,144	3.3%	961,409	114,000	785,658	3.0%	795,287	89,752
Sanitary paper	1,804,878	5.9%	1,788,664	66,284	1,776,141	6.8%	1,775,132	67,714
Miscellaneous paper	830,853	2.7%	654,367	102,296	695,473	2.6%	573,316	86,333
Paper total(t/year):	18,827,707	61.5%	18,175,364	1,533,838	15,831,919	60.3%	15,583,440	1,371,026
Container board	9,219,039	30.1%	8,665,102	357,765	8,212,298	31.3%	7,686,079	337,874
Paperboard for paper container	1,818,775	5.9%	1,763,836	126,015	1,636,897	6.2%	1,578,770	136,542
Miscellaneous paperboard	761,934	2.5%	714,882	74,187	586,838	2.2%	564,344	62,666
Paperboard total(t/year):	11,799,748	38.5%	11,143,820	557,967	10,436,033	39.7%	9,829,193	537,082
Paper and Paperboard total(t/year):	30,627,455		29,319,184	2,091,805	26,267,952		25,412,633	1,908,108

Reference: Chronological table Commodity / Ministry of Economy, Trade and Industry

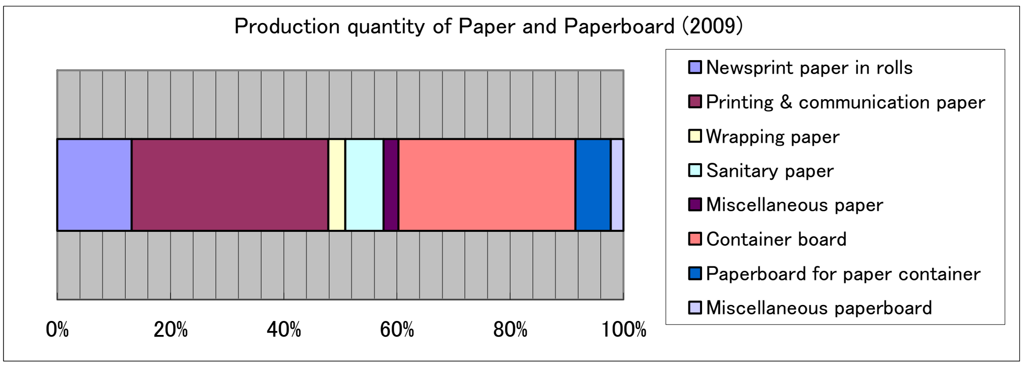


Figure 2.5　Total production volume of Paper and Paperboard in detail from 2008-2009

In Figure 2.4, Paper demonstrated upward trend slowly, but Paperboard remained same level in six years. In 2009, both Paper and Paperboard dropped sharply in consequence of financial crisis, almost 15% fell off compared with total production volume in 2003.

In Figure 2.5, it is apprehensible that the ratios of Paper and Paperboard are normally around 60 to 40 every year in Japan. Total production quantity went down from 30,627,455-t in 2008 to 26,267,952-t in 2009; it was almost 15% downslide. When examining Paper and Paperboard individually, production quantity of Paper went down from 18,827,707-t in 2008 to 15,831,919-t in 2009 (-15.9%) and of Paperboard went down from 11,799,748-t in 2008 to 10,436,033-t in 2009 (-11.5%) each. The further fact of Paper that "Printing & communication paper" decreased sharply, only one item could account 20.7% drop occupying one fifth of total Paper and Paperboard drawdown. It definitely has negative impact on printing business.

2.5 JAPANESE PRINTING INDUSTRY AS SMALL BUSINESS ENTERPRISES

2.5.1 The ratio of big enterprises and small business enterprises in manufacturing

SMEs are defined as the enterprise capitalized at 300 million yen (3.5 million USD) with no more than 300 employees in Japan. The ratios of big enterprises and SMEs in 24 industries in manufacturing are summarized in Table 2.12.

Table 2.12 The ratio of big enterprises and SMEs in manufacturing

Code	Industry	Establishments		Employees		Sales	
		Big enterprises	SMEs	Big enterprises	SMEs	Big enterprises	SMEs
0	Manufacturing	0.8	99.2	31.9	68.1	59.7	40.3
200	Leather tanning, Leather products and Fur skins	0.0	100.0	1.0	99.0	2.3	97.7
120	Lumber and Wood products, except furniture	0.1	99.9	4.6	95.4	9.9	90.1
110	Textile mill	0.1	99.9	5.3	94.7	11.9	88.1
130	Furniture and Fixtures	0.2	99.8	9.7	90.3	19.6	80.4
240	Fabricated metal products	0.3	99.7	12.6	87.4	24.1	75.9
150	Printing related products	0.2	99.8	11.2	88.8	27.2	72.8
90	Food	0.6	99.4	19.7	80.3	31.0	69.0
180	Plastic Products, except otherwise classified	0.8	99.2	19.3	80.7	33.6	66.4
210	Ceramic, Stone and Clay products	0.5	99.5	20.3	79.7	36.9	63.1
270	Business oriented machinery	1.2	98.8	32.4	67.6	40.5	59.5
260	Production machinery	0.7	99.3	22.5	77.5	43.6	56.4
320	Miscellaneous	0.3	99.7	17.4	82.6	44.1	55.9
140	Pulp, Paper and Paper products	0.8	99.2	23.2	76.8	49.5	50.5
250	General-purpose machinery	1.1	98.9	39.9	60.1	58.1	41.9
230	Non-ferrous metals products	2.4	97.6	44.2	55.8	60.1	39.9
290	Electrical machinery, Equipment and Supply	1.4	98.6	39.0	61.0	61.7	38.3
190	Rubber products	1.0	99.0	38.8	61.2	61.9	38.1
160	Chemical and allied products	4.8	95.2	47.9	52.1	62.6	37.4
100	Beverages,Tobacco and Feed	0.9	99.1	22.6	77.4	66.2	33.8
220	Iron and Steel	1.8	98.2	44.7	55.3	68.0	32.0
280	Devices and electronic circuits	3.4	96.6	53.0	47.0	74.6	25.4
300	Information and communication electronics equipment	4.2	95.8	57.8	42.2	77.1	22.9
310	Transportation equipment	2.4	97.6	62.8	37.2	84.1	15.9
170	Petrorium and Coal products	3.1	96.9	57.0	43.0	92.1	7.9

Reference: 2008 Census Statistical Tables by Respective Industry for the Whole Country (more than 4-employee/establishment) / Ministry of Economy, Trade and Industry

Each industry is ranked in descending order of sales volume percentage, SMEs establishments' percentage for the average of entire manufacturing is 99.2%, and it is out of doubt that almost all enterprises are SMEs in Japan in terms of establishments. The proportion of SMEs employees is 68.1% and of sales volume is just 40.3%, so these figures cannot show the presence since there are many SMEs as entity but their performance employing people and generating money is relatively not robust enough to compete against big enterprises.

Whereas the summary indicates that printing industry is ranked 6th (72.8%) from the viewpoint of SMEs ratio in sales volume, paper industry is ranked 13th which is midpoint among whole manufacturing industry. SMEs ratio in establishments is 99.8% attaining almost all, and the one in employees is 88.8%, all one can say that printing industry is labor-intensive business by small entities.

2.5.2 Distribution of printing enterprises by capital fund

Printing enterprises are categorized by the size of capital fund. Table 2.13 compares printing industry and overall manufacturing by the scale of establishments, employees and sales volume.

Table 2.13 Establishments, employees and sales by capital in printing industry and manufacturing

Segment	Manufacturing						Printing					
	Establishments		Employees		Sales (million¥) *Sales (million USD)*		Establishments		Employees		Sales (million¥) *Sales (million USD)*	
<¥3millions (<$35thousands)	2,058	0.8%	18,940	0.2%	157,317 *1,851*	0.0%	119	0.7%	902	0.3%	7,589 *89*	0.1%
¥3millions.–¥10millions ($35thousands–$117thousands)	71,175	27.1%	693,682	8.3%	6,866,166 *80,778*	2.0%	5,058	30.7%	38,869	11.9%	359,586 *4,230*	5.3%
¥10millions.–¥30millions ($117thousands–$353thousands)	101,361	38.5%	2,027,624	24.2%	36,111,719 *424,844*	10.8%	7,545	45.8%	129,181	39.6%	1,922,702 *22,620*	28.5%
¥30millions–¥50millions ($353thousands–$588thousands)	17,675	6.7%	743,711	8.9%	17,891,832 *210,492*	5.3%	923	5.6%	38,017	11.6%	786,225 *9,250*	11.7%
¥50millions.–¥100millions ($588thousand–$1.2millions)	14,628	5.6%	965,766	11.5%	27,875,439 *327,946*	8.3%	637	3.9%	41,210	12.6%	902,718 *10,620*	13.4%
¥100millions.–¥300millions ($1.2millions–$3.5millions)	5,761	2.2%	556,105	6.6%	19,578,631 *230,337*	5.8%	215	1.3%	21,357	6.5%	671,935 *7,905*	10.0%
¥300millions–¥1billions ($3.5millions–$11.8 millions)	4,752	1.8%	649,655	7.8%	27,567,688 *324,326*	8.2%	130	0.8%	20,454	6.3%	549,256 *6,462*	8.2%
¥1billions.–¥10billions ($11.8 millions–$118millions)	4,419	1.7%	926,578	11.1%	53,777,473 *632,676*	16.0%	79	0.5%	11,632	3.6%	453,265 *5,333*	6.7%
>¥10billions (>$118millions)	2,753	1.0%	1,500,847	17.9%	143,369,158 *1,686,696*	42.7%	41	0.2%	14,017	4.3%	1,020,081 *12,001*	15.1%
Union and others	2,442	0.9%	56,040	0.7%	1,193,380 *14,040*	0.4%	63	0.4%	1,806	0.6%	20,781 *244*	0.3%
Indivisual	36,037	13.7%	225,659	2.7%	1,190,022 *14,000*	0.4%	1,674	10.2%	9,031	2.8%	43,704 *514*	0.6%
Total:	263,061		8,364,607		335,578,825 *3,947,986*		16,484		326,476		6,737,842 *79,269*	

Reference: 2008 Census Statistical Tables by Respective Industry for the Whole Country (more than 4-employee/establishment) / Ministry of Economy, Trade and Industry

Number of establishments categorized in 3 millions yen to 30 millions yen of the capital fund in manufacturing is counted up to 65.6% dominating two thirds of the total. In printing industry, number of establishments in the same category is 76.5% occupying three fourth of the total. Number of employees categorized in the same range of the capital in manufacturing is summed up to 32.5% accounting one third of the total. In printing industry, number of employees in the same category is 51.5%; it is more than half of the total and much higher than the one in manufacturing. Sales volumes from SMEs are relatively small portion, only 12.8% in manufacturing, but in printing industry it captures 33.8%. It concludes that SMEs have major function especially in printing industry compared with entire manufacturing.

2.5.3 Tracing a path of Printing and Publishing of SMEs in half a century

Publishing industry and printing industry have been two sides of the same coin for long time. Figure 2.6 shows that the proportion of SMEs in terms of establishments and employees in both industries.

Year	Establishments			Employees		
	Total	SMEs	SMEs %	Total	SMEs	SMEs %
1951	17,843	17,628	98.8%	224,570	153,284	68.3%
1954	20,289	20,219	99.7%	288,508	227,593	78.9%
1957	20,915	20,846	99.7%	324,754	264,030	81.3%
1960	22,176	21,780	98.2%	368,759	296,752	80.5%
1963	26,956	26,840	99.6%	439,792	291,574	66.3%
1966	31,767	31,651	99.6%	498,274	407,364	81.8%
1969	37,641	37,517	99.7%	543,753	445,676	82.0%
1971	44,374	44,232	99.7%	591,675	480,483	81.2%
1974	49,370	49,222	99.7%	596,517	487,498	81.7%
1977	55,659	55,518	99.7%	629,104	521,468	82.9%
1980	61,993	61,852	99.8%	675,951	572,708	84.7%
1986	67,644	67,498	99.8%	729,579	628,759	86.2%
1991	70,148	69,963	99.7%	824,239	699,418	84.9%
1996	67,167	66,990	99.7%	793,836	681,736	85.9%
2001	57,383	57,230	99.7%	701,686	603,205	86.0%
2006	41,755	41,677	99.8%	466,986	423,047	90.6%

Reference: Establishments and Enterprises Census, Ministry of Internal Affairs and Communications

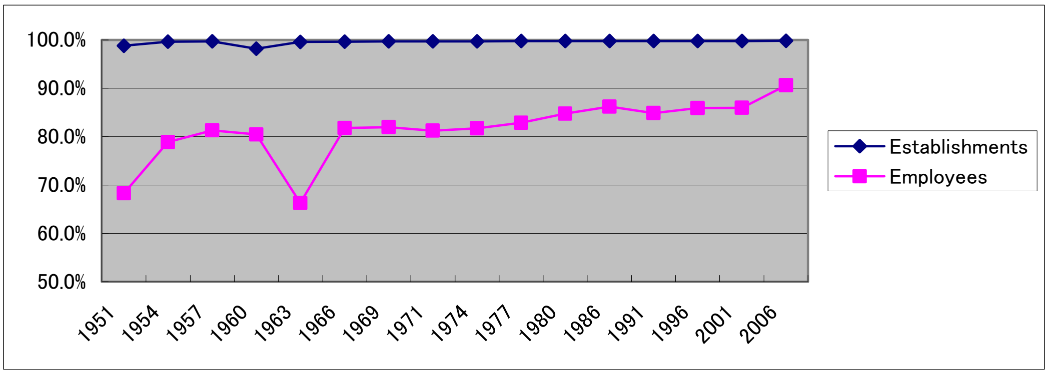


Figure 2.6 SMEs ratio of establishments and employees in printing and publishing industries

The ratio of SMEs in establishments remains the same at high percentage, but the one in employees gradually increases in 40 years, it spells out that both industries are downsizing at easy pace.

When looking at the number of establishments, it suffers a sharp decline from 70,148 in 1991 to 41,755 in 2006 with the rate of 40.5% drastic decline. On the other hand, the number of employees declines from 824,239 in 1991 to 699,418 in 2006 with the rate of 15.5% decline, percent decrease is not like the one of establishments. Two figures can indicate that big companies cease to exist to be downsized and part of its labor force is partly dispersed.

2.6 CONCLUSION

When the world is divided into developing and developed areas, upward momentum in emerging countries is affirmed and downward acceleration in advanced countries is confirmed in both printing and paper industries from worldwide and domestic research.

In Japanese market, in-depth research is conducted only for printing industry from a perspective of SMEs and shows higher proportion of SMEs compared with other industries. It is obvious that printing industry comes into existence mainly by SMEs supported by different statistics.

Many of print-buyers, especially government or local governments expect that printers including SME can adjust themselves to “Act on Promoting Green Purchasing”, but SME cannot respond to the expectations all the time since green materials are not the same as normal materials in terms of price. There are printing guidelines showing a list of green materials such as paper, ink and postpress materials, but changing to those eco-friendly materials by same contract price is not easy matter. Industry organization tries to show the way to reduce hazardous chemicals and energy use to be greener, but it sometimes go beyond its mental capacity because judgments is made only by top management of industry organization who are from only big printing companies. This research could give SMEs a route to be environment-conscious not only from hardware or material side but from software aide which is based on life-cycle approach.

Bio-polar situations in printing related industries are visible, but when emerging countries will go on to the next phase, the industry willl be totally different one in the future.

Current unstoppable digitalization in advanced countries will spread across emerging countries sooner or later, so the amount of physical printed matters is expected to be decreased gradually from now on because some physical printed matters will be certainly replaced to digitalized ones. It might have roots in the belief no paper consumption could promote environment promotion without concrete evidence.

From here on, environmental impact assessment method for Printing Service should be obtained from the studies based on multilateral points of views to know if digitalization without paper usage is the ideal selection for Printing Service or not in advanced countries. Additionally, submitting environmental information including evaluation by LCA could be prerequisite to get a contract for print-buyers to sort out current subcontractors. From different standpoint, information of environmental load is necessary for consumers since people are getting wiser in order to select environment-friendly products. Companies cannot ignore the demand from consumers, so LCA study is something they are going to face and tackle in the near future.

On the other hand, the aim to utilize environmental impact assessment method for Printing Service in emerging countries is different from the one in advanced countries; material usage reduction and production improvements are utmost priorities before being anxious about digital shift from paper media.

The past behavior to rely too much on qualitative assessment should be counteracted and newly developed quantitative assessment method based not only on environmental view but also on economical view is expected to be organized for practical use for printing industries in advanced and emerging countries.

CHAPTER 3

DEVELOPMENT OF QUANTITATIVE ASSESSMENT METHOD FOR PRINTING SERVICE

ABSTRACT

Environmental load for Printing Service has been evaluated by qualitative assessment, usage of recycled paper or vegetable oil ink is generally recommended. Nowadays, demand for quantitative assessment is requested by environment conscious companies at front edge, so method of Printing Service Life Cycle Assessment (LCA) should be formulated in a hurried manner. Purpose of Printing Service LCA consists of three subjects. Firstly, environmental load should be calculated as numerical number; it is so-called visualization. Secondary, original printing service specification should be shifted to Eco-design after assessing LCA result. Thirdly, calculated LCA result could be utilized for Carbon Offset or Carbon Footprint of Products which are expected to lead the way to Low-carbon society by indirect way. In this case study, one hundred thousand of paper box production is evaluated by LCI and LCIA to know what kind of environmental factor should be focused. There are findings what sort of printing factor combination is preferred in terms of environment and economy. In conclusion, Printing Service should not be based only on paper in the future since environmental load is dominated by paper usage only for information related business. Additionally, global warming potential accounts for the majority of environmental load, so Life Cycle CO_2e (LCCO_2e) method which is a part of LCA could be one of the significant indicators. Focusing on LCCO_2e method might be able to accelerate Carbon Offset or Carbon Footprint of Products expecting indirect influence changing current consumers' life styles to Low-carbon ones.

3.1 INTRODUCTION

Printing industry should have had head start of LCA study for environment conscious based design and production since Printing Service comes into usage for broad range of social life in variety aspects, but the study did not exercised and utilization of it caused delay more than a little. And on the other hand, other industries at leading-edge such as electronics, automotives and chemicals conducted LCA studies aggressively, and then printing industry lagged behind by the reason stemming from long term cumulative passive attitude as a matter of routine.

There had been no Printing Service guideline for environment conscious which is based solely on quantitative assessment not on qualitative assessment until "Product Category Rule for Carbon Footprint of Products (CFP)" was set at the end of 2009. It covers only procurement and production except for delivery/waste management/recycle for print buyers since Printing Service is considered as intermediate goods. It is graphically explained in Figure 3.1. As is well known, CFP is one of the key political policies to construct Low-carbon society and prevent global warming problem, so CFP pilot projects for all industries started by strong and consistent support from Ministry of Economy, Trade and Industry (METI).

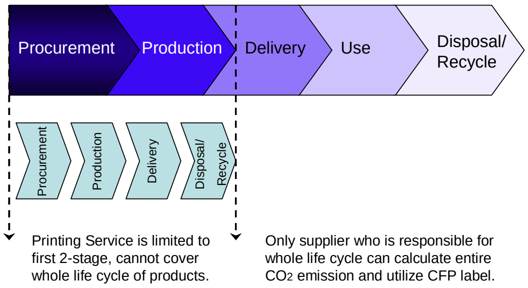


Figure 3.1 Relationship of CFP 5-stage and printing service 4-stage

Before that, “Offset Printing Service Guideline for Order Placement” which was set by Green Purchasing Network in 2001 was sole and exclusive guideline for environment conscious from viewpoint of printing service buyers. It mentions not only about environment-friendly materials and methods which are highly preferred to utilize, but also about organizational efforts to reduce environmental loads at printing sites extensively.

There was “Recycle-oriented Printing Guideline” which was promoted by Japan Federation of Printing Industries (JFPI) and Paper Recycling Promotion Center in 2009; it is shown in Table 3.1. It suggested that best combinations of paper/ink/material in the standpoints of recycle easiness, but still could not focus on the concept of LCA, namely could not concern about quantitative assessment and LCA approach was not established at this point.

Table 3.1 Recycle-oriented Printing Guideline by JFPI

Major classification	Minor classification	Material	Paper recycle adequacy
1:Paper	Normal	Coated	A
1:Paper	Normal	Fine paper	A
1:Paper	Processed	Polyethylene laminated paper	B
1:Paper	Processed	Glassine paper	B
1:Paper	Processed	Carbon paper	C
1:Paper	Processed	Thermal paper	C
1:Paper	Processed	Forming paper	D
1:Paper	Processed	Fragrant paper	D
2:Ink	Normal	General Sheetfed ink	A
2:Ink	Normal	Gravure ink(solvent-based)	A
2:Ink	Normal	Flexo ink(solvent-based)	A
2:Ink	Normal	Screen ink	A
2:Ink	Particular	UV ink(recycle-frindly)	A
2:Ink	Particular	UV ink	B
2:Ink	Particular	Electro Beam ink	B
2:Ink	Particular	Thermal ink	C
2:Ink	Particular	Magnetic ink	C
2:Ink	Particular	Forming ink	D
2:Ink	Particular	Fragrant ink	D
3:Post-press material	Bookbinding	Wire/staple	A
3:Post-press material	Bookbinding	EVA Hot-melt(easy-destructive)	A
3:Post-press material	Bookbinding	PUR Hot-melt	A
3:Post-press material	Bookbinding	Yarn	B
3:Post-press material	Bookbinding	EVA Hot-melt	B
3:Post-press material	Surface coating	Varnish coating	A
3:Post-press material	Surface coating	Plastic(PP) lamination	B
3:Post-press material	Surface coating	UV coating	B
3:Post-press material	Surface coating	Hot/cold stamp	B
4:Others	Extranerous material	Plastic	C
4:Others	Extranerous material	Fabric	C
4:Others	Extranerous material	Nonwoven fabric	C
4:Others	Extranerous material	Aromatic substance, perfume	D

Reference:”Recycled-oriented Printing Guideline”, Japan Federation of Printing Industries
(not listed all, selected randomly)

A:Good for recycling of paper and paperboard
B:Good for recycling of paperboard, but unsuitable for recycling of paper
C:Unsuitable for recycling of paper and paperboard
D:Unsuitable for recycling of paper and paperboard even small amount is mixed

3.2 PURPOSE OF THE STUDY

LCA study which is conducted in a comprehensive and rigorous manner has grown in usage because it could visualize environmental load for each process and reduce it by knowing numerical number, not by human sense. There are many different fields of LCA case studies in edgy industries for last decade, but the ones for Printing Service are restrictive to assessment for paper only for long time. So on that point, Printing Service LCA should be established to know not only the load from paper but also from all stages covering materials, production, disposal and recycle. It has been an urgent issue since printed matter is related to any kinds of products in all industries, so it is completed in this paper by citing general examples of case studies.

By accomplishing of Printing Service LCA, quantitative assessment can play very important role when trying to reduce certain amount of the load. Until now, many believe that using vegetable oil ink or using recycle paper without support by numerical numbers can make Printing Service better from the standpoint of environment, but from now on, only convincing quantitative assessment can reduce the environmental load.

Three purposes of the study are set forth to achieve.

Firstly, visualization of environmental load by Printing Service LCA which is newly established quantitative assessment without relying on current qualitative assessment should become operative. To begin with, the load should be figured out to know current actual state by numerical numbers.

Secondly, shifting to Eco-design should be accelerated. For instance, structural design should be reviewed through the standpoints of strength against weight and torsion in packaging field. It might be partly replaced by environmentally low impact ones based on visualization of environmental load.

Thirdly, utilizing Printing Service LCA by the results of visualization and Eco-design is effective for CFP and Carbon Offset which are indirect method for reduction of environmental load. Quantitative assessment could be fully applied as calculation basis, so it can help the nation promote low carbon related policies in the concrete.

3.3 ANALYSIS

3.3.1 Feature of primary and secondary data

Implementation of Printing Service LCA for paper-based DVD/CD package (paper package) covers from procurement to waste management; it is to say “from cradle to grave”. Calculation is mostly based on live primary data which are collected from real production in printing factory and on secondary data which is mainly provided by Advanced Industrial

Science & Technology (AIST) which is Japan's largest public research organization related closely with METI through LCA software named JEMAI-LCA Pro. Summary of primary data and secondary data is shown in Table 3.2.

Table 3.2 Summary of primary data and secondary data

Item	P/S	Collect method for activity amount/Creator	Last updated
Carton Paper	P	Actual number of used paper and make ready	2008/2/20
	S	Advanced Industrial Science & Technology(AIST)	2007/8/30
Polyurethane(ink)	P	Estimated ink usage by calculation	2008/2/20
	S	Advanced Industrial Science & Technology(AIST)	2005/3/28
Water	P	Estimated dampening water usage from ink usage	2008/2/20
	S	Advanced Industrial Science & Technology(AIST)	2005/9/2
Isopropyl alchohol(IPA)	P	Estimated IPA usage from dampening water usage	2008/2/20
	S	Advanced Industrial Science & Technology(AIST)	2008/9/30
Aluminum, sheet(plate)	P	Actual weight of plate used	2008/2/20
	S	Advanced Industrial Science & Technology(AIST)	2007/8/30
Delivery(2t truck)	P	Actual weight and distance for procurement and delivery	2008/2/20
	S	Advanced Industrial Science & Technology(AIST)	2007/8/30
Delivery(4t truck)	P	Actual weight and distance for procurement and delivery	2008/2/20
	S	Advanced Industrial Science & Technology(AIST)	2007/8/30
Press	P	Estimated electricity used from average data	2008/2/20
	S	Advanced Industrial Science & Technology(AIST)	2007/8/30
Die-cut	P	Estimated electricity used from average data	2008/2/20
	S	Advanced Industrial Science & Technology(AIST)	2007/8/30
Gluer	P	Estimated electricity used from average data	2008/2/20
	S	Advanced Industrial Science & Technology(AIST)	2007/8/30
Ethylene Vinyl Acetate(glue)	P	Actual weight of hot-melt used	2008/2/20
	S	Advanced Industrial Science & Technology(AIST)	2008/9/30
Steel sheet(cutting plate)	P	Estimated materials used by subcontractor	2008/2/20
	S	Advanced Industrial Science & Technology(AIST)	2005/3/25
Wood(cutting plate)	P	Estimated materials used by subcontractor	2008/2/20
	S	Advanced Industrial Science & Technology(AIST)	2007/8/30
Disposal(incination)	P	Actual weight of wasted paper	2008/2/20
	S	Advanced Industrial Science & Technology(AIST)	2008/9/30
Recycled pulp	P	Actual weight of recycled paper from press and post-press	2008/2/20
	S	Advanced Industrial Science & Technology(AIST)	2005/3/25
Aluminum, secondary	P	Actual weight of recycled plates from pre-press	2008/2/20
	S	Advanced Industrial Science & Technology(AIST)	2007/8/30

Reference:"JEMAI-LCA Pro"(LCA software), Japan Environmental Management Association for Industry

P:Primary data S:Secondary data

For Life Cycle Inventory analysis (LCI), input and output data such as raw material, product, and utility are first collected together as inventory chart. Then, important factors are grasped by consumption volume at each process.

For Life Cycle Impact Assessment (LCIA), each item in LCI is connected with each impact category at first, it is called classification. Secondary, a set of inventory results associated with impact categories such as global warming/human toxicity/aquatic ecotoxicity/terrestrial toxicity/acidification are shown by numerical numbers to know environmental influence for each category. In order to cite a case, global warming is influenced by CO_2/NH_4/N_2O/PFC/HFC/SF_6 which are all called greenhouse gases, those impacts are calculated employing Global Warming Potential of IPCC by the scale of CO_2 equivalent

(CO_2e) value.

Application of Printing Service LCA is designed to;

1. Reduce environmental load of current manufactured product and service
2. Develop environment conscious product and service supported by Eco-design
3. Evaluate advanced technology of printing related methods

Result of this study is for product designer to lessen the load by shifting to Eco-design, for product supplier and for product user to know environment conscious purchasing, namely it cause awareness of green procurement and purchasing.

3.3.1.1 Specification of case study

Detailed specification of paper package is summarized in Table 3.3.

Table 3.3 Specification of paper-based DVD/CD package

Dimension:	133mm×133mm×10mm	Water & Additives:	Water & Isopropyl alchohol
Weight:	18.6g	Pre-press:	Printing plate (Computer to Plate)
Paper:	Paperboard, 420g/㎡	Press:	UV 7-color+coating unit
Printing method:	Ultraviolet(UV) Offset		(4-color&varnish)
Ink & Varnish:	UV hybrid ink・UV overprint varnish	Post-press:	Diecut & glue

As function of product, package is usually used for product transportation to protect content and for sales promotion to exercise ability of eye-catching advertisement. For specific series of jobs as case study here, total production is millions of packages in a year, but functional unit here is set 100,000 copies since it is minimal batch based on actual achievement in the past. In order to avoid leading environmental load lower, the least production volume is selected for calculation basis.

3.3.1.2 Aspects of procurement, production, delivery and disposal/recycle

Printing service is divided into 4 stages; those are procurement, production, delivery and disposal/recycle. It is shown in Figure 3-2.

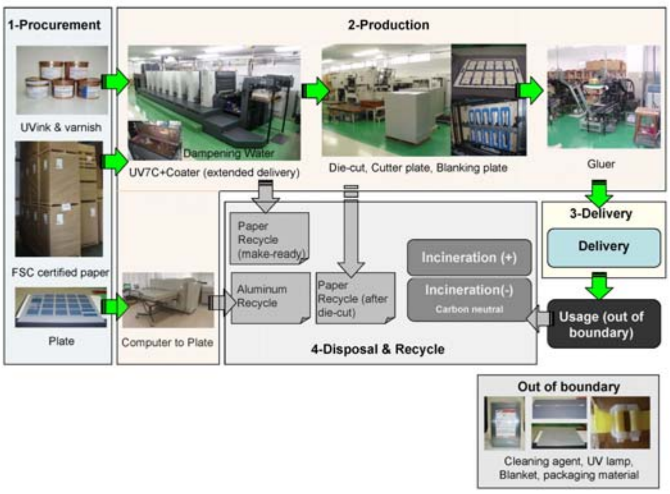


Figure 3.2 System boundary of paper package

At the onset, paper, ultraviolet (UV) ink/varnish, and printing plate are purchased at procurement stage. Next, printing plate output, printing ink/varnish on paper and die-cut/glue packages by using electricity are performed at the stage of production. And then completed products are delivered to designated place and shipped to retail stores. In this case study, a stage of usage is not included. Finally, packages are dumped into garbage box at home, collected by cleansing department of local government and burned by incinerator plant which is usually constructed by local government or recycled.

Items which are out of system boundary are cleaning agent, UV lamp, blanket and packaging materials such as polypropylene band binding printed stack. There are some more items such as back-office section/color proof/sales activity/employee commuting, but only typical items are listed in Figure 3.2.

3.3.1.3 Secondary data assessment

Quality, types and age of secondary data in JEMAI LCA Pro used for this case study is examined and summarized in Table 3.4.

Table 3.4 Quality, types and age of secondary data

<Type>

Stage	Measured	Interview	Literature	Calculated	Unknown	Total
Production	2	5	60	57	6	130
Usage	0	0	0	0	0	0
Disposal	1	2	20	20	1	44
Total:	3	7	80	77	7	174
proportion to total:	1.7%	4.0%	46.0%	44.3%	4.0%	

<Quality>

Stage	Very Good	Good	Average	Bad	Unknown	Total
Production	3	24	80	17	6	130
Usage	0	0	0	0	0	0
Disposal	2	2	33	6	1	44
Total:	5	26	113	23	7	174
proportion to total:	2.9%	14.9%	64.9%	13.2%	4.0%	

<Age>

Stage	Up to 1 year	Up to 3 years	Up to 5 years	Over 5 years	Unknown	Total
Production	0	0	0	124	6	130
Usage	0	0	0	0	0	0
Disposal	0	0	0	42	2	44
Total:	0	0	0	166	8	174
proportion to total:	0.0%	0.0%	0.0%	95.4%	4.6%	

Reference: "LCA Pro", JEMAI

Secondary data are categorized into 3 stages (production, usage and disposal), but substantially 2 stages because of excluding a stage of usage.

Type of secondary data consists mainly of literature and calculation basis evenly occupying around 90% and percentage of unknown is only 4%, so it is set to calculate with confidence. Quality of secondary data is said to be good enough since percentage of above average is 83%; it is also bold proof to be sufficient data. The only issue which matters is that age of secondary data. All data are set more than 5 years ago, almost no newly calculated data. There might be touch of uncertainty, but it cannot have profound influence on core elements.

3.3.1.4 Impact categories to be considered

There are 14 impact categories and 81 substances for this case study in JEMAI-LCA Pro (LCA software), but 6 major impact categories and 31 substances are selected as comparative targets to be compared. Selected impact categories, characterization models and substances are listed below.

1. Global Warming <IPCC 100-year (2001)>, 4 substances (CO_2, CH_4, HFC-134a, N_2O)
2. Human Toxicity (carcinogenicity) <HTP_cancer>, 6 substances, (As, Cd, Cr, Hg, Ni, Pb)
3. Aquatic ecotoxicity <AETP>, 6 substances, (As, Cd, Cr, Hg, Ni, Pb)
4. Terrestrial ecotoxicity <TETP>, 6 substances, (As, Cd, Cr, Hg, Ni, Pb)
5. Acidification <DAP>, 4 substances, (NOx, NOx/mobile source, SO_2, SOx)
6. Fossil energy resource consumption <MJ>, 5 substances, (NGL reserves, coal[coke], coal[combustion], natural gas, oil reserves)

Impact categories listed above are important indexes when knowing environmental load for specific purpose and also for sensitivity analysis to compare variety kinds of patterns of printing methods.

3.3.2 **Standout aspects of LCI and LCIA**

3.3.2.1 Treatments for make-ready and trimmed part of paper

One sheet of paperboard (660mm*830mm) weights 230g, so actual number of sheets which are necessary for 100,000 copies is 10,000 sheets because 10 impositions on one sheet.

Additionally, make-ready which is necessary for adjusting registration and color balance is around 500 sheets for 4-color job for offset printing. So, total input of paper is 10,500 sheets which equals to 2,416kg, is produced in west end of Japan and is transported to a warehouse of paper wholesale and delivered to the factory by 4-ton truck. Total travel distance is 829 km.

Paperboard is sorted into 3 parts; those are product, waste from make-ready and waste from die-cut. Paperboard weight for paper package is figured out by multiplication of weight/sheet, actual number of sheets and product area percentage which is a solution of division led from proportion of total area and product area. Weight breakout is shown in Figure 3.3.

Item	Length (m)	Width (m)	Area (㎡)	Weight/㎡ (g)	Weight/sheet (g)
A sheet of Paperboard	0.66	0.83	0.5478	420	230.076

Item	Actual (Sheets)	Make-ready (Sheets)	Total (Sheets)	Total weight (kg)
Total of Paperboard	10,000	500	10,500	2,416

Item	Weight (kg)	Explanation
Product	1,863	(Weight/sheet × Actual × Product area %)
Waste from Make-ready	115	(Weight/sheet × Make-ready)
Waste from die-cut	438	(Weight/sheet × Actual × Non-product area %)

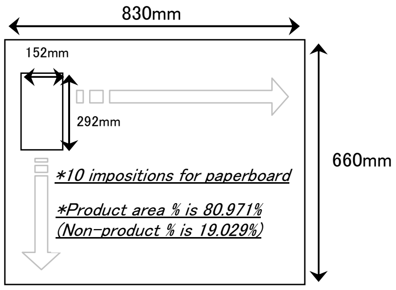


Figure 3.3 Weight breakout of Paperboard

There is an argument whether palette which just weights 7kg each should be included in environmental load or not for paper transportation. It is clear that influence from it is minor issue, so is out of consideration in this case study.

3.3.2.2 Cumulative method for calculation of ink thickness

There is a commonly-held view that colored printed matters are composed almost entirely of four basic inks; they are black, cyan, magenta and yellow.

It is not so difficult to know that amount of ink usage for specific job when measuring actual quantity, but not easy when forecasting. It is sometimes essential to know amount of ink usage before completing a job for CFP or Carbon offset use, so a formula of ink usage is originated out of the necessity of forecasting it.

Thanks to great advancement of computerization in printing production, each ink's coverage area for actual paper size could be calculated with no burden. It means that formula to forecast ink usage is not puzzle if thickness of ink is known in correct manner. It is shown in Table 3.5 explaining the difference between actual ink usage and forecasted ink usage for a job. Calculation of ink thickness is explained when it is printed by UV Waterless High-Definition consisting of 10-micron square dot.

Ink thicknesses for different printing methods are set 1.0 micron for high-definition printing and 1.5 micron for normal printing. A reason of ink thickness of 1.0 micron is based on the idea that high-definition printing method can reduce one third of ink usage compared to 1.5 micron for normal printing method.

Table 3.5　Forecast of ink usage for 4-color printing

<Difference between "Actual" and "Forecast" of ink usage>

Ink	Actual(g)	Dot area	Sheets	Forecasted (g)	Difference	Difference%
Bk	318	5.2%	7,700	301	17	105.6%
C	287	6.9%	7,700	399	−112	71.8%
M	170	4.4%	7,700	255	−85	66.7%
Y	382	6.5%	7,700	376	6	101.5%
4C:	1,157	−	−	1,332	−175	86.9%
OPvarnish	3,605	66.6%	7,700	3,856	−251	93.5%
4C+OP:	4,762	−	−	5,188	−426	91.8%

*UV Waterless High-Definition (10-micron dot) printing method is applied

*"Forecasted (g)" is calculated on the premise of ink thickness is 1-micron

<Calculation for ink thickness>

Ink	Actual(g)	Dot area	Sheets	ink thickness(μ)	Difference(μ)	Difference%
Bk	318	5.2%	7,700	1.056	0.056	105.6%
C	287	6.9%	7,700	0.718	−0.282	71.8%
M	170	4.4%	7,700	0.667	−0.333	66.7%
Y	382	6.5%	7,700	1.015	0.015	101.5%
Average ink thickness for 4-color:				0.864	−0.136	86.4%
OPvarnish	3,605	66.6%	7,700	0.935	−0.065	93.5%
Average ink thickness for 4-color+OPvarnish:				0.900	−0.100	90.0%

*UV Waterless High-Definition (10-micron dot) printing method is applied

*"Difference"=ink thickness−1micron(assumption)

Another issue for UV ink and varnish is that what kind of item's inventory data should be utilized for assessment. Data only for CO_2 emission is disclosed to the public by Japan Printing Ink Makers Association (JPIA), it is summarized in Table 3.6. It is time consuming to estimate CO_2 emission since many pigments are imported from different countries.

Contents of ink and varnish should cover broad range of pigments, resins and other additives. It is very difficult to trace each one of those items to calculate CO_2 emission factors and transportation distance including overseas, so it is difficult to hang on to a cumulative method only to be figured out.

Table 3.6 CO_2 emissions for Offset ink and Gravure Ink

Item	Offset ink	Gravure ink
Production	0.15-0.47	0.06-0.13
Average of Production	0.29	0.09
Material*	1.17-2.20	2.49-3.29
Average of Material	1.73	2.89
Total	**1.32-2.67**	**2.55-3.42**
Average of Total	**2.02**	**2.98**

Reference: "CO2 emission for Offset Ink and Gravure Ink" Japan Printing Ink Makers Association

(kg-CO2/kg)

*CO_2 emission from material origin is calculated by an ink manufacturer

Much further detailed data is organized by a private printing ink manufacturer; it is shown in Table 3.7.

Table 3.7 Trial calculation of CO_2 emission factors for UV/Conventional ink and varnish

Item		Weight %	CO_2 emission ($kg-CO_2/kg$)					Calculation method
			Black	Cyan	Magenta	Yellow	OP	
Energy for production			0.44	0.44	0.44	0.44	0.44	Accumulated
Material	Pigment	5～21%	0.55	2.96	2.08	2.08	0.01	3EID*1&partly accumulated
	Resin&Oligomer	66～82%	2.24	2.17	2.17	2.36	2.69	3EID&partly accumulated
	Photo initiator	8～10%	0.48	0.60	0.60	0.60	0.60	3EID
	Additives	3%	-	-	-	-	-	Not evaluated
Waste loss		3%	0.01	0.01	0.01	0.01	0.01	-
Total*2:			3.82	6.36	5.44	5.65	3.85	

Item		Weight %	CO_2 emission ($kg-CO_2/kg$)					Calculation method
			Black	Cyan	Magenta	Yellow	OP	
Energy for production			0.44	0.44	0.44	0.44	0.44	Accumulated
Material	Pigment	0～24%	1.26	2.96	2.08	2.08	0.00	3EID&partly accumulated
	Resin&Vegetable oil	52～68%	0.69	0.72	0.72	0.77	0.96	3EID&partly accumulated
	Solvent	21～30%	0.11	0.12	0.12	0.12	0.15	3EID
	Additives	3%	-	-	-	-	-	Not evaluated
Waste loss		3%	0.01	0.01	0.01	0.01	0.01	-
Total:			2.56	4.36	3.44	3.51	1.58	

($kg-CO_2/kg$)

Reference: Ink manufacturer

*1:3EID=Embodied Energy & Emission Intensity Data for Japan Using Input-Output Tables based on Interindustry analyses

*2:Total CO_2 emission=total amount÷97% (bacause "additives" are not numerically included)

Both data provided by JPIA and private ink manufacturer are just focused on CO_2 emission, so those might be determined to be less than perfect as inventory data. If uncompleted inventory data is utilized, then result from LCIA will not be well balanced. Therefore, substituted data for ink and varnish is searched in data list of JEMAI LCA Pro, finally polyurethane is selected since it is approximated to main resin of UV ink.

Amount of ink usage is calculated by multiplication of ink thickness, maximum paper size of the press, dot area percentage and number of sheets; it is explained in comprehensive manner in Table 3.8.

Table 3.8 Ink usage calculation

	Ink thickness			Max.Paper size of Press					Dot area%		Number of sheets		Ink usage
Black:	0.0015	mm	×	730 mm	×	1030 mm	×		10%	×	10,500 sheets	=	1.184 kg
Cyan:	0.0015	mm	×	730 mm	×	1030 mm	×		15%	×	10,500 sheets	=	1.776 kg
Magenta:	0.0015	mm	×	730 mm	×	1030 mm	×		15%	×	10,500 sheets	=	1.776 kg
Yellow:	0.0015	mm	×	730 mm	×	1030 mm	×		15%	×	10,500 sheets	=	1.776 kg
OP varnish:	0.0020	mm	×	730 mm	×	1030 mm	×		61%	×	10,500 sheets	=	9.576 kg
													16.089 kg

Total ink usage including OP varnish is 16kg and travel distance to the factory by 2-ton truck is 64 km.

There is discussion whether ink cans which only weights less than 3kg (18 cans, 140g/can,) should be included in environmental load or not. It is obvious that impact from it is trivial matter, so is out of concern here.

3.3.2.3 Cumulative method for calculation of water usage

Figure 3.4 shows that printing mechanism which is explained by a unit of printing machine viewed from cross-section drawing. Ink which is thrown in ink fountain is transferred between rollers, and then transcribed both on printing plate made of aluminum and blanket made of rubber, finally printed on paper.

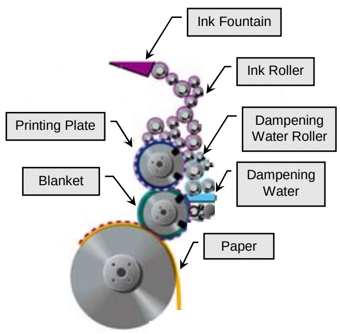


Figure 3.4 Ink flow from cross-sectional view of printing machine unit

What is discussed about water here is dampening water solution on a printing machine which repels ink to have non-printed area on paper. For that matter, it is taken place by effect of lipophilic nature of ink and repellency of ink against water in contrasting way.

Measuring amount of dampening water used for printing is long protracted assignment to struggle with, but still goes unanswered since no response from both ink manufacturer and printing machine manufacturer after questioning. It could be imagined that dampening water is commingled in ink, transferred to stack and evaporates in the air because of heat by printing machine. But, it is very difficult to forecast how much of dampening water will be used for a specific job when using variety kinds of inks which have different emulsification tendency and stacks which have different surface water absorption coefficient.

In order to find a solution, dampening water was measured and summarized in Table 3.9.

Table 3.9 The ratio of dampening water used to ink usage

Paper:	Paperboard			Size:	0.915 × 0.550	=	0.503 m²	Sheets:	19,490	Speed:	7,500s/h
Bk:	2,180 g	C:	1,607 g	M:	1,663 g	Y:	2,501 g	Primer:	0 g	OP varnish:	0 g
S1:	0 g	S2:	0 g	S3:	0 g	Total:	7,951 g	g/sheet	0.408 g	g/m²:	0.811 g
Dampening water+additives:	15.0 ℓ			Dampening water÷Ink usage:	1.89 times						
Paper:	Paperboard			Size:	0.940 × 0.640	=	0.602 m²	Sheets:	19,550	Speed:	8,000s/h
Bk:	1,166 g	C:	277 g	M:	842 g	Y:	2,059 g	Primer:	0 g	OP varnish:	0 g
S1:	0 g	S2:	0 g	S3:	0 g	Total:	4,344 g	g/sheet	0.222 g	g/m²:	0.369 g
Dampening water+additives:	15.0 ℓ			Dampening water÷Ink usage:	3.45 times						
Paper:	Paperboard			Size:	0.720 × 0.450	=	0.324 m²	Sheets:	16,400	Speed:	7,500s/h
Bk:	886 g	C:	1,968 g	M:	0 g	Y:	0 g	Primer:	0 g	OP varnish:	0 g
S1:	2,943 g	S2:	348 g	S3:	537 g	Total:	6,682 g	g/sheet	0.407 g	g/m²:	1.258 g
Dampening water+additives:	10.1 ℓ			Dampening water÷Ink usage:	1.51 times						
Paper:	Paperboard			Size:	0.950 × 0.650	=	0.618 m²	Sheets:	17,390	Speed:	7,500s/h
Bk:	652 g	C:	1,068 g	M:	2,151 g	Y:	2,225 g	Primer:	0 g	OP varnish:	0 g
S1:	0 g	S2:	0 g	S3:	0 g	Total:	6,096 g	g/sheet	0.351 g	g/m²:	0.568 g
Dampening water+additives:	8.0 ℓ			Dampening water÷Ink usage:	1.31 times						
Paper:	Paperboard			Size:	0.710 × 0.620	=	0.440 m²	Sheets:	13,800	Speed:	7,000s/h
Bk:	857 g	C:	1,073 g	M:	1,241 g	Y:	3,876 g	Primer:	0 g	OP varnish:	0 g
S1:	0 g	S2:	0 g	S3:	0 g	Total:	7,047 g	g/sheet	0.511 g	g/m²:	1.160 g
Dampening water+additives:	11.0 ℓ			Dampening water÷Ink usage:	1.56 times						
Paper:	Paperboard			Size:	0.545 × 0.390	=	0.213 m²	Sheets:	13,600	Speed:	8500s/h
Bk:	897 g	C:	630 g	M:	854 g	Y:	1,048 g	Primer:	0 g	OP varnish:	0 g
S1:	0 g	S2:	0 g	S3:	0 g	Total:	3,429 g	g/sheet	0.252 g	g/m²:	1.186 g
Dampening water+additives:	11.5 ℓ			Dampening water÷Ink usage:	3.35 times						
Paper:	Paperboard			Size:	0.650 × 0.950	=	0.618 m²	Sheets:	1,303	Speed:	7000s/h
Bk:	109 g	C:	88 g	M:	180 g	Y:	373 g	Primer:	0 g	OP varnish:	0 g
S1:	0 g	S2:	0 g	S3:	0 g	Total:	750 g	g/sheet	0.576 g	g/m²:	0.932 g
Dampening water+additives:	2.0 ℓ			Dampening water÷Ink usage:	2.67 times						
Paper:	Paperboard			Size:	0.940 × 0.640	=	0.602 m²	Sheets:	12,750	Speed:	7000s/h
Bk:	467 g	C:	341 g	M:	724 g	Y:	773 g	Primer:	0 g	OP varnish:	0 g
S1:	1,273 g	S2:	0 g	S3:	0 g	Total:	3,578 g	g/sheet	0.281 g	g/m²:	0.466 g
Dampening water+additives:	10.0 ℓ			Dampening water÷Ink usage:	2.79 times						
Paper:	Paperboard			Size:	0.470 × 0.640	=	0.301 m²	Sheets:	2,200	Speed:	7000s/h
Bk:	85 g	C:	67 g	M:	96 g	Y:	85 g	Primer:	0 g	OP varnish:	0 g
S1:	1,273 g	S2:	0 g	S3:	0 g	Total:	1,606 g	g/sheet	0.730 g	g/m²:	2.427 g
Dampening water+additives:	2.0 ℓ			Dampening water÷Ink usage:	1.25 times						
Paper:	Paperboard			Size:	0.915 × 0.550	=	0.503 m²	Sheets:	7,350	Speed:	6500s/h
Bk:	322 g	C:	552 g	M:	917 g	Y:	708 g	Primer:	0 g	OP varnish:	0 g
S1:	0 g	S2:	0 g	S3:	0 g	Total:	2,499 g	g/sheet	0.340 g	g/m²:	0.676 g
Dampening water+additives:	6.5 ℓ			Dampening water÷Ink usage:	2.60 times						
Paper:	Paperboard			Size:	0.800 × 0.700	=	0.560 m²	Sheets:	6,500	Speed:	6000s/h
Bk:	127 g	C:	975 g	M:	219 g	Y:	373 g	Primer:	0 g	OP varnish:	0 g
S1:	0 g	S2:	0 g	S3:	0 g	Total:	1,694 g	g/sheet	0.261 g	g/m²:	0.465 g
Dampening water+additives:	4.0 ℓ			Dampening water÷Ink usage:	2.36 times						
Paper:	Paperboard			Size:	0.650 × 0.475	=	0.309 m²	Sheets:	15,623	Speed:	7500s/h
Bk:	177 g	C:	620 g	M:	524 g	Y:	697 g	Primer:	0 g	OP varnish:	0 g
S1:	0 g	S2:	0 g	S3:	0 g	Total:	2,018 g	g/sheet	0.129 g	g/m²:	0.418 g
Dampening water+additives:	10.0 ℓ			Dampening water÷Ink usage:	4.96 times						
Paper:	Paperboard			Size:	0.550 × 0.400	=	0.220 m²	Sheets:	2,000	Speed:	7500s/h
Bk:	293 g	C:	344 g	M:	128 g	Y:	322 g	Primer:	0 g	OP varnish:	0 g
S1:	0 g	S2:	0 g	S3:	0 g	Total:	1,087 g	g/sheet	0.544 g	g/m²:	2.470 g
Dampening water+additives:	5.0 ℓ			Dampening water÷Ink usage:	4.60 times						
Paper:	Paperboard			Size:	0.550 × 0.400	=	0.220 m²	Sheets:	1,668	Speed:	6000s/h
Bk:	23 g	C:	46 g	M:	68 g	Y:	104 g	Primer:	0 g	OP varnish:	454 g
S1:	0 g	S2:	0 g	S3:	0 g	Total:	695 g	g/sheet	0.417 g	g/m²:	1.894 g
Dampening water+additives:	0.8 ℓ			Dampening water÷Ink usage:	1.15 times						
Paper:	Paperboard			Size:	0.690 × 0.840	=	0.580 m²	Sheets:	4,400	Speed:	6000s/h
Bk:	307 g	C:	489 g	M:	783 g	Y:	1,238 g	Primer:	0 g	OP varnish:	0 g
S1:	0 g	S2:	0 g	S3:	0 g	Total:	2,817 g	g/sheet	0.640 g	g/m²:	1.105 g
Dampening water+additives:	2.9 ℓ			Dampening water÷Ink usage:	1.03 times						
Paper:	Paperboard			Size:	0.788 × 0.475	=	0.374 m²	Sheets:	32,500	Speed:	7000s/h
Bk:	1,690 g	C:	3,612 g	M:	1,921 g	Y:	1,035 g	Primer:	0 g	OP varnish:	8,710 g
S1:	2,096 g	S2:	1,840 g	S3:	0 g	Total:	20,904 g	g/sheet	0.643 g	g/m²:	1.718 g
Dampening water+additives:	45.0 ℓ			Dampening water÷Ink usage:	2.15 times						
Paper:	Paperboard			Size:	0.788 × 0.475	=	0.374 m²	Sheets:	31,123	Speed:	7000s/h
Bk:	1,249 g	C:	3,612 g	M:	1,921 g	Y:	1,035 g	Primer:	0 g	OP varnish:	6,279 g
S1:	1,493 g	S2:	2,699 g	S3:	0 g	Total:	18,288 g	g/sheet	0.588 g	g/m²:	1.570 g
Dampening water+additives:	30.0 ℓ			Dampening water÷Ink usage:	1.64 times						
Paper:	Paperboard			Size:	0.800 × 0.700	=	0.560 m²	Sheets:	15,338	Speed:	7000s/h
Bk:	394 g	C:	393 g	M:	997 g	Y:	4,112 g	Primer:	0 g	OP varnish:	g
S1:	0 g	S2:	0 g	S3:	0 g	Total:	5,896 g	g/sheet	0.384 g	g/m²:	0.686 g
Dampening water+additives:	27.0 ℓ			Dampening water÷Ink usage:	4.58 times						
				Average Dampening water÷Ink usage:	**2.49 times**						

Total amount of ink usage is added up and dampening water is measured by quantity decreased in dampening water tank. Since it is necessary to calculate the amount of dampening water used as multiple number to something, dampening water is divided by total amount of ink usage to know the ratio of dampening water used to ink usage. According to real jobs survey, average ratio of dampening water used to ink usage for paperboard was calculated; it is around 2.5 times as ink usage.

Total water usage is calculated by multiplication of 16kg of ink/varnish and the ratio of 2.5, so 40 liter is pumped in a printing machine. For additives, it is common to use 5% of isopropyl alcohol (IPA) mixed in dampening water; therefore amount of it is calculated by multiplication of 40 liter of water and IPA ratio of 5%. Travel distance of IPA to the factory by 2-ton truck is 94 km.

3.3.2.4 Application of substituted data for printing plate

In accordance with Ecoleaf which is TypeⅢ environmental labeling program by Japan Environmental Management Association for Industry (JEMAI), printing plate consists mostly of aluminum, it has high proportion of printing plate itself. Table 3.10 definitely shows that aluminum occupies almost all of printing plate based on weight.

Table 3.10 Product data sheet of “Ecoleaf” by JEMAI

Product category:	Sheetfed pre-sensitized plate for CTP (Comuputer to plate)				
Product type:	CTP thermal type including chemicals in developing process				
Product unit:	1㎡	Product (kg):	0.813	Thickness (mm):	0.30

Breakdown of materials composing product		
Material	Weight(kg)	%
New bare aluminum	7.39E-01	90.7%
Recycled bare aluminum	7.45E-02	9.1%
Photosensitive resin	1.10E-03	0.1%
Total:	8.15E-01	

Reference: ″Fuji Film printing plate″, JEMAI ″Ecoleaf″ environmental labeling

Accordingly, substituted data for printing plate is screened in data list of JEMAI LCA Pro, finally aluminum sheet is selected since aluminum has almost all impacts on printing plate though photosensitive resin has quite small of it. Other than environmental load from aluminum, water and chemical additives should be considered at the point of gateway and exit of developing process. Table 3.11 indicates summary of plate processing.

Table3.11 Estimated average input of water and additive for printing plate at a packaging printer

Usage of plate (area)	1200	㎡/month
Usage of plate (plates)	1481	plates/month
Working hours	12	hours/day
Working days	22	days/month

Additive	39.7	ℓ/month
Water	363.7	ℓ/month
Total input of Water & Additives	403.4	ℓ/month

Usage of water & additives/㎡	0.336	ℓ/㎡
Usage of water & additives/plate	0.272	ℓ/plate

Reference: Fuji Film

As being understood from Table 3.11, water usage for one plate has minor impact, less than 1.4 litters is used for four colors plus overprint varnish (5 plates). On the other hand, input of water and additive which will change into specially-controlled disposal is not minor impact when it is seen as total amount since it will be incinerated after use. Although the load from incineration of dampening water and additives should be examined, it is not fully investigated here since detailed requisite data cannot be submitted from incineration facility.

Total printing plate usage is calculated by multiplication of 0.5kg/plate and the number of plate used, so four colors plus overprint varnish (5 plates) which weighs 2.5kg is used in total. It is supposed that printing plates travel by 4-ton truck from 284km away to the factory.

3.3.2.5 Application of interviewed data of die-cut and blanking plates

Right after printing, die-cutting and blanking (tearing off unnecessary part of printed sheet) is run to fold and glue packages in latter process. In order to take out product part, die-cutting and blanking plates which are installed on an automatic die-cutting machine should be made outside of the factory. To end that knowing the load from its process, hearing investigation was conducted but only amount of wood for plates and stainless steel for cutter/creaser are figured out. Result of interview is shown in Table 3.12.

Table 3.12 Input for die-cutting and blanking plate

＜Die-cut plate＞								
Wood form	1	set	×	6.000	kg	＝	6.000	kg
Cutter & Creaser	25	m	×	0.125	kg/m	＝	3.125	kg
＜Blanking plate＞								
Wood form	1	set	×	6.000	kg	＝	6.000	kg
						Wood for wood form:	12.000	kg
						Stainless steel for cutter & creaser:	3.125	kg

Electricity of facilities and transportation of materials should be included to calculate the load precisely, but above-mentioned data are provided at maximum. One additional load is transportation of die-cutting and blanking plate from a subcontractor to the factory by 1-ton truck is 77km.

3.3.2.6 Application of substituted data for glue

Completing printing and die-cutting/blanking process, package shaped paper is folded and glued. Instantaneous gluing is utilized for paper packages since enormous volume of them should be produced in short time. It is illustrated by Figure 3.5.

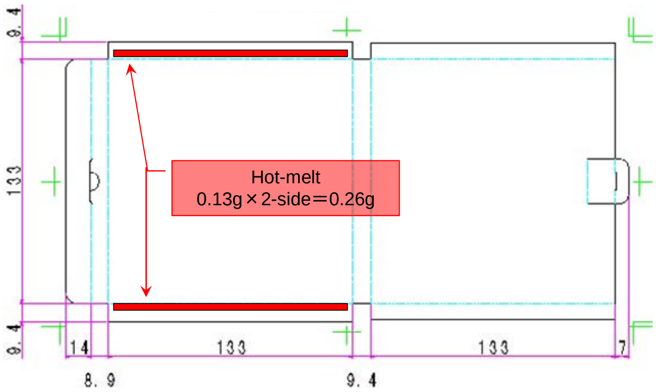


Figure 3.5　Explanation of hot-melt usage on developed figure of package

Glue which is commonly called hot-melt mainly consists of ethylene-vinyl acetate (EVA); its data can be found on the list of JEMAI-LCA Pro.

Total amount of hot-melt used is calculated by multiplication of 0.26g/package and a batch of 100,000 copies, so total of 26kg of hot-melt is consumed. Transportation of glue by 2-ton truck from a hot-melt manufacture to the factory is 73km.

3.3.2.7 Application of rated output data of facilities for pre-press

Paper package is designed by graphic software of PC; it is estimated to take five hours to finalize package designing work per one kind of package. Here in this case study, three different kinds of them are printed, so 15 hours are spent for editing.

Printing plate is outputted from computer to plate system (CtP). It is unfortunate that electricity usage is not monitored, so 100% of rated output is used for calculation of environmental load. Generally speaking, using full of rated output for calculation is improbable, but load factor of CtP is neither studied here nor found in bibliographical survey.

Electricity usage for data creation is summation of data creation related activity (PC, air-conditioning and lighting) and of CtP related activity (plate setter, air-conditioning and lighting).

Electricity usage of both air-conditioning and lighting are allocated based on monitoring data of 10-color printing machine room. Actual data is monitored and is based on annual average data, but the data of 10-color printing machine room is limited to data which is collected in only summer. It might be a bit higher than real averaged data since load factor during summer is usually high compared with other seasons. Amount of usage and allocation percentage are summarized in Table 3.13.

Table 3.13 Summary of electricity usage for data creation and CtP

<Data creation>							
PC working *1:	0.06	kW	×	15 hours	=	0.90	kW
	(↑kW per an hour is based on desktop type)						
Air-conditioning:	1.25	kW	×	15 hours	=	18.75	kW
	(↑kW per an hour is 13% of printing room)						
Lighting:	0.50	kW	×	15 hours	=	7.50	kW
	(↑kW per an hour is 27% of printing room)						
	Sub total of electricity use for Designing:					27.15	kW
<CtP>							
Plate setter:	12.50	kW	×	15 hours	=	187.50	kW
	(↑kW per an hour is full of rated output)						
Air-conditioning:	2.50	kW	×	15 hours	=	37.50	kW
	(↑kW per an hour is 25% of printing room)						
Lighting:	1.02	kW	×	15 hours	=	15.30	kW
	(↑kW per an hour is 55% of printing room)						
	Sub total of electricity use for CtP:					240.30	kW

Reference: "Average electricity usage for PCs",The Energy Conservation Center of Japan
*1: 473.2W(Electricity use for desktop)÷8h=0.05915kW≒0.06kW

Total of electricity use for both data creation and CtP is 267kWh including air-conditioning and lighting combined together.

3.3.2.8 Application of actual monitored data of facilities for press

A printing machine which is 7-color with coating unit is utilized for this case study. A machine has been under monitoring since it was installed in 2007, so has accumulated electricity data for years; one is press and the other is UV curing device.

In order to finalize a job, it takes three hours from printing to changeover for next job, average electricity usage is 85.0kW which is only 50% of total rated output. Actual running hours of printing machine is 95 minutes which equals to 1.6 hours, so average printing speed is 6,645 sheets per an hour led by division of total paper input and running hours. It is summarized in Figure 3.6.

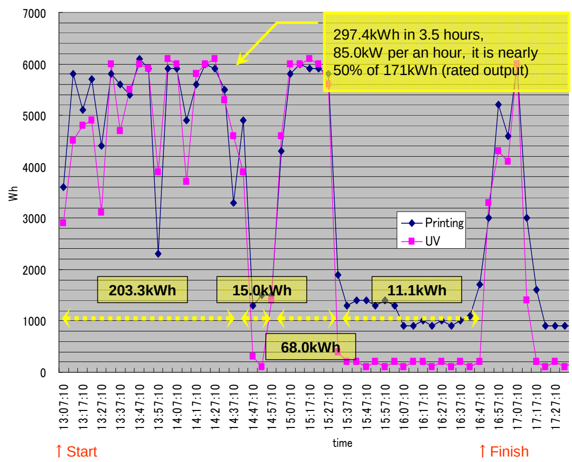


Figure 3.6 Electricity usage for package production by UV 7-color printing machine

It is the same as that of other calculation; electricity usage is also forecasted before completing a job. Average electricity usage per an hour which becomes the basis for calculation was drawn by electricity monitoring for press itself and UV device for one year. Only electricity usage for compressor is not actual data and is estimated from rated output. It is shown in Table 3.14.

Table 3.14 Average electricity usage for UV 7-color printing machine

Average Electricity (kW)/hour for Press	40.27	48%
Average Electricity (kW)/hour for UV	22.65	27%
Average Electricity (kW)/hour for Press+UV:	62.92	75%
Average Electricity (kW)/hour for Compressor*1	8.54	10%
Average Electricity (kW)/hour for Air−cond.&Lighting	12.54	15%
Average Electricity (kW)/hour for compressor+others:	84.00	25%

*1: Electricity usage for compressor is based on allocated rated output

Total of electricity usage for press including UV curing device, compressor allocated based on rated output and air-conditioning/lighting is 252kWh for three hours run.

3.3.2.9 Application of short-termed actual monitored data of facilities for post-press

Average electricity usage per an hour which becomes the basis for calculation was led by electricity monitoring for one time shot for both die-cut and gluer since electricity monitoring device was not prepared in full.

For die-cut, it was measured 2.536kW in 40 minutes, so average electricity usage per an hour was 3.804kW. For glue, it was measured 0.082kW in 30 minutes, so average electricity usage per an hour was 0.164kW excluding constant-temperature unit for glue. Only maximum usage was measured but standby electricity was not, so average electricity usage is only based on full operational electricity usage.

Total of electricity usage for die-cut, glue and air-conditioning/lighting allocated based on printing room is 323kWh for 44 hours run, mostly for 40 hours run at glue process. It is quite long time for glue because of slow production speed for difficult folding of thick paperboard.

3.3.2.10 Consideration of adjunct packing materials for delivery

After going through in-house process and packed in carton boxes, paper packages go to designated area for CD-ROM packing work.

Carton boxes which weigh 440g are produced by a carton box factory located 710m away from the factory. One carton box can contain 250 paper packages, so 400 of those are prepared for delivery. Weight only for carton boxes is calculated by multiplication of 440g/piece and 400 carton boxes, so 176 kg for all.

As shown in Figure 3.3, weight for paper packages is 1,863kg, so sum of 176kg for carton boxes and 1,863kg is 2,039kg which is total delivered weight by 4-ton truck traveling 124km. Controversy about counting weight for palettes might be coming on again, but total of 98kg of pallets (14 pallets) should not be issue and ignored as usual.

3.3.2.11 Skippable stage for Use

For this case study, environmental load for using paper packages are not considered. If it had electrical accessory or so, the load from use should be concerned, but it is not applied here since paper packages are usually damped straight to garbage boxes after opening.

3.3.2.12 Transportation for incineration

It is fuzzy that whether all paper packages are kept for storage purpose or not, but all should be thought to be wasted for calculation purpose in the field of LCA.

After paper packages are damped, cleansing department of local government collects garbage by 2-ton truck. Fundamental idea of calculation is summarized by the illustration in Figure 3.7.

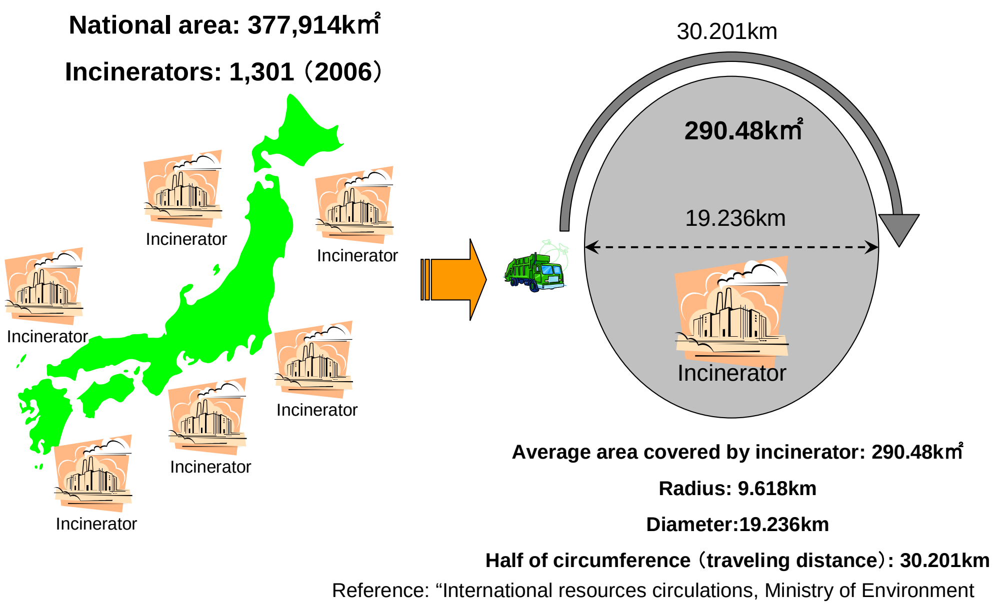


Figure 3.7 Fundamental idea of transportation of incineration.

Calculation of traveling distance by a garbage truck is assumed that the average area covered by incinerator is 290km^2 (national area 377,914km^2÷1,301 incinerators in Japan), it is a point of starting. If area covered by incinerator is assumed to be rounded shape, a diameter is calculated as 19km (square root of division of 290 km^2 and 3.14), and supposing it moves half of circumference, it will be set to around 30km (19km×3.14÷2).

Total amount of garbage, namely product part of paper which is burned at incineration facility weighs 1,863kg as shown in Figure 3.3.

3.3.2.13 Recycle materials from production

Unnecessary part of paperboard is wasted from two processes, one is printing and the other is die-cut. These wasted papers are recycled by contracted paper waste collector.

It is understandable when seeing Figure 3.3, 115kg of waste from make-ready in printing process and 438kg of waste in die-cut process are non-product part. Recycled paperboard sent 237km by 2-ton truck to paper mill factory is free of charge.

All printing plates are recycled just like paper waste. It travels 180km by 2-ton truck to smelting facility for second-order bare metal. It is onerous contract, but the price of aluminum is unstable and decided by market value in world trend.

3.3.2.14 Summary of input/output data

All of input and output data explained above for production of paper packages are summarized in Figure 3.8. It shows four consecutive stages; procurement, production, delivery and disposal/recycle. Stage for consumer use is out of boundary here, it is not included in the boundary.

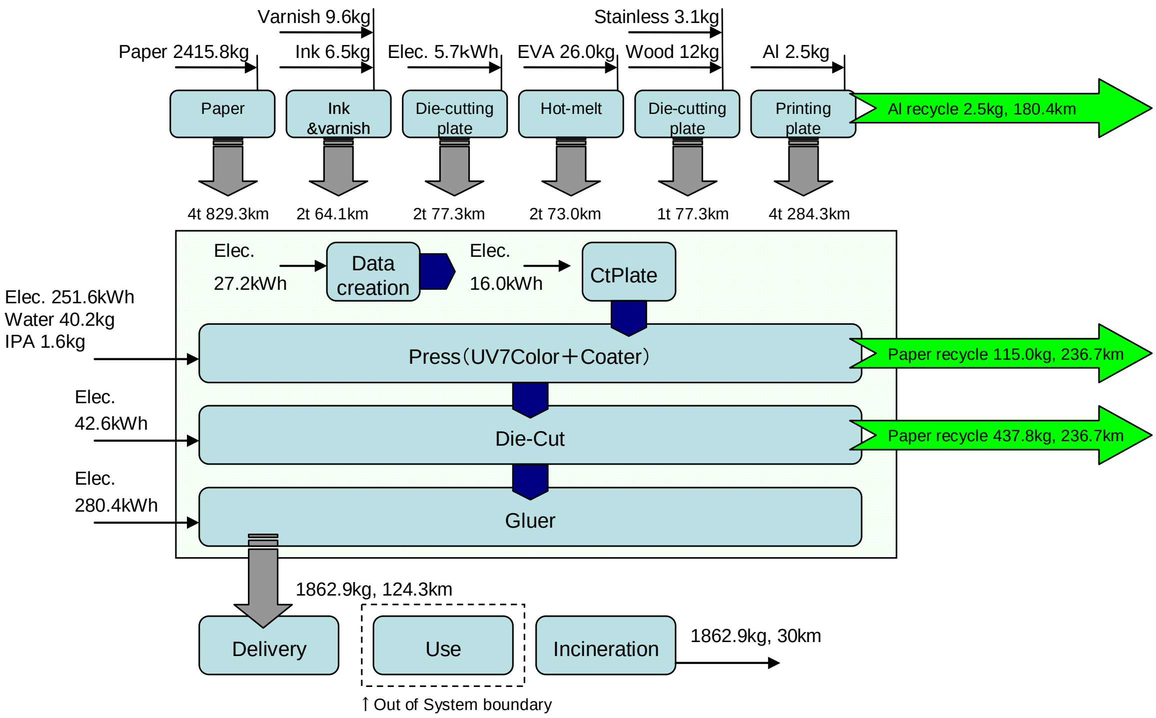


Figure 3.8 Input and output summary for production of paper packages

3.3.3 Result

LCI result consists of input (resource) and output, then output is divided into 3 items (air, water and industrial), shown in Table 3.15.

Table 3.15 LCI of paper packages production

Category	No.	Item	Units	Total	Paperboard	Ink&varnish	Water+IPA	Printing plate	Pre-press	Press	Post-press	Delivery	Paper recycle	Al recycle	Incineration
Resources	1	Al reserves	kg	2.50E+00			8.98E-06	2.05E+00						4.47E-01	
	2	Cr reserves	kg	6.65E-01							6.65E-01				
	3	Cu reserves	kg	1.86E-06			1.86E-06								
	4	Fe reserves	kg	7.06E-01							7.06E-01				
	5	Mn reserves	kg	8.42E-02							8.42E-02				
	6	Ni reserves	kg	4.94E-01							4.94E-01				
	7	Pb reserves	kg	6.85E-08			6.85E-08								
	8	U reserves	kg	5.11E-03	5.02E-03	2.62E-04	1.01E-06	4.12E-05	3.70E-04	2.15E-03	3.07E-03	5.68E-04	2.31E-03	1.10E-05	-8.70E-03
	9	Zn reserves	kg	3.80E-07			3.80E-07								
	10	coal (coke)	kg	8.93E+00			2.62E-06				9.44E-01	7.98E+00			
	11	coal (combustion)	kg	2.12E+02	2.02E+02	2.97E+00	2.46E-01	6.23E+00	4.20E+00	2.45E+01	3.67E+01	6.48E+00	2.62E+01	1.24E+00	-9.88E+01
	12	cryolite	kg	1.51E-01				1.24E-01						2.70E-02	
	13	dolomite	kg	3.95E-02							3.95E-02				
	14	fluorspar	kg	2.11E-03							2.11E-03				
	15	limestone	kg	1.83E+01		1.81E+01	9.65E-04				1.74E-01				
	16	natural gas	kg	8.47E+01	8.28E+01	1.38E+00	2.22E-02	8.69E-01	1.95E+00	1.14E+01	1.63E+01	3.00E+00	1.22E+01	2.60E-01	-4.54E+01
	17	oil reserves	kg	3.82E+02	2.70E+02	2.28E+01	1.63E+00	3.54E+00	7.78E-01	4.54E+00	3.44E+01	5.08E+01	4.93E+00	8.11E-01	-1.27E+01
	18	silica sand	kg	4.59E-03			5.54E-07				4.59E-03				
Air	1	CO2	kg	2.83E+03	1.67E+03	6.00E+01	3.34E+00	2.98E+01	1.92E+01	1.12E+02	2.06E+02	3.21E+02	1.20E+02	6.58E+00	2.79E+02
	2	As	kg	4.80E-06	4.76E-06	2.48E-07	9.55E-10	1.59E-08	3.51E-07	2.04E-06	2.91E-06	5.39E-07	2.19E-06	1.11E-09	-8.25E-06
	3	CH4	kg	5.39E-02	4.71E-02	2.43E-03	1.45E-04	1.38E-04	4.12E-04	2.40E-03	5.82E-03	2.54E-03	2.57E-03	2.40E-05	-9.66E-03
	4	Cd	kg	3.97E-07	3.93E-07	2.05E-08	7.89E-11	1.31E-09	2.90E-08	1.69E-07	2.41E-07	4.46E-08	1.81E-07	9.14E-11	-6.82E-07
	5	Cr	kg	8.74E-06	8.65E-06	4.52E-07	1.74E-09	2.89E-08	6.38E-07	3.72E-06	5.30E-06	9.81E-07	3.99E-06	2.01E-09	-1.50E-05
	6	Hg	kg	5.80E-06	5.74E-06	3.00E-07	1.15E-09	1.91E-08	4.23E-07	2.47E-06	3.52E-06	6.51E-07	2.64E-06	1.34E-09	-9.96E-06
	7	N2O	kg	6.03E-02	5.03E-02	1.83E-03	1.06E-04	2.93E-03	8.34E-04	4.86E-03	8.91E-03	3.88E-03	5.21E-03	6.28E-04	-1.91E-02
	8	NMHC	kg	1.06E-02	1.05E-02	5.47E-04	2.10E-06	3.49E-05	7.72E-04	4.50E-03	6.41E-03	1.19E-03	4.82E-03	2.43E-06	-1.82E-02
	9	NOx	kg	1.93E+00	9.56E-01	2.41E-02	1.45E-03	5.76E-02	8.02E-03	4.67E-02	9.20E-02	7.68E-01	5.01E-02	1.27E-02	-8.17E-02
	10	NOx (mobile source)	kg	9.15E-01	1.08E-01	7.85E-03	2.29E-04	2.30E-03	2.26E-03	1.32E-02	5.51E-02	6.98E-01	1.54E-02	1.02E-03	1.20E-02
	11	Ni	kg	9.83E-06	9.73E-06	5.08E-07	1.95E-09	3.24E-08	7.17E-07	4.18E-06	5.95E-06	1.10E-06	4.48E-06	2.26E-09	-1.69E-05
	12	PM10 (mobile source)	kg	6.34E-02	7.91E-03	5.79E-04	1.07E-05	1.58E-04	1.66E-04	9.67E-04	4.15E-03	5.12E-02	1.16E-03	8.42E-05	-2.93E-03
	13	Pb	kg	2.30E-05	2.28E-05	1.19E-06	4.57E-09	7.60E-08	1.68E-06	9.79E-06	1.39E-05	2.58E-06	1.05E-05	5.30E-09	-3.95E-05
	14	SO2	kg	1.74E+00	1.52E+00	4.30E-02	2.73E-03	1.02E-01	5.64E-04	3.29E-03	5.31E-02	8.02E-03	3.53E-03	2.09E-02	-1.29E-02
	15	SOx	kg	4.88E-01	7.91E-02	7.88E-03	1.60E-04	5.83E-04	3.04E-03	1.77E-02	2.98E-02	3.89E-01	1.91E-02	1.47E-04	-5.86E-02
	16	dust	kg	2.78E-01	2.56E-01	5.23E-03	4.01E-04	7.47E-03	1.51E-04	8.80E-04	7.13E-03	1.45E-03	9.44E-04	1.51E-03	-3.48E-03
	17	hydrocarbons	kg	1.16E-01	2.12E-02	1.24E-03	3.85E-05	7.26E-04	4.19E-04	2.44E-03	8.65E-03	8.42E-02	2.87E-03	2.74E-04	-5.57E-03
Water	1	As	kg	8.92E-11			8.92E-11								
	2	BOD	kg	1.48E-03			1.48E-03				1.01E-07				
	3	Cd	kg	1.34E-11			1.34E-11								
	4	Cr	kg	2.68E-10			2.68E-10								
	5	Hg	kg	8.92E-12			8.92E-12								
Industrial	1	earth & sand (landfill)	kg	5.37E+00				4.41E+00						9.60E-01	
	2	industrial waste landfill (unspecified)	kg	1.40E+02			1.11E-07	5.54E-01						1.21E-01	1.39E+02
	3	low-level radioactive waste	kg	3.57E-03	3.51E-03	1.83E-04	7.08E-07	2.88E-05	2.58E-04	1.51E-03	2.15E-03	3.97E-04	1.61E-03	7.69E-06	-6.08E-03
	4	paper wastes (landfill)	kg	5.44E+00								5.44E+00			
	5	plastic wastes (landfill)	kg	1.40E-09			1.40E-09								
	6	rubbles (landfill)	kg	2.78E-09			2.78E-09								
	7	slag (landfill)	kg	5.45E-01			3.59E-06				5.45E-01				
	8	sludge (landfill)	kg	6.53E+00								6.53E+00			

LCI data is calculated by JEMAI-LCA Pro

Processes are originally sorted into 17 processes, but some are combined together since each of those has small environmental loads. Pre-press (data creation and printing plate output), post-press (die-cut, die-cut plate and glue) and paper recycle (paper waste from printing, paper waste from die-cut and recycle of carton boxes for transportation) are the processes which are integrated together because of being easily comprehensive by summarizing small loads.

In input (resource), coal for combustion to generate electricity has certain amount of input. Additionally, oil reserves are utilized for transportation of material and products. Other items have minimal influences which are negligible quantity. For two items, process of paperboard procurement occupies great portion.

In output (air), outstanding numerical number is found in CO_2. When CO_2 is checked in detail, paper related items get a majority of the loads again. For further details, analyzed description will be added later. In addition, as a required thing of explanation, negative numerical numbers in the item of incineration should be mentioned. This is because only biomass portion in all can be allowed to be deducted its portion only for paper incineration based on carbon-neutral concept set by IPCC.

In output (water), usage of water is not influential issue when looking at amount of output in hydrosphere. In printing industry, waterless printing is getting popular in terms of water conservation, but it might enjoy its popularity by other reasons.

In output (industrial), industrial wastes from all processes are assessed. Although there are small numerical numbers which do not affect entire processes, but only landfill from incineration should be remarkable.

For LCIA result, six impact categories which have more than positive number are selected among 14 of those. Simple explanations for six impact categories are described below.

Global warming is resulted by greenhouse effect by the emission of greenhouse gases such as CO_2, CH_4, N_2O, PFC, HFC and SF_6 determined by Kyoto Protocol. Global temperature rise is expected to cause climate change, desertification, sea levels rise and infection of communicable disease. This impact category is widely well known because of CFP and Carbon Offset.

Human toxicity is based on calculation of emission from substances (mainly heavy metals) which can have impacts on human health. Assessments of toxicity are based on allowable concentrations in air and water, tolerable daily intake and acceptable daily intake for human toxicity.

Ecotoxicity for water and land is measured separately, one is aquatic ecotoxicity (AETP) and the other is terrestrial ecotoxicity (TETP). Assessments of toxicity are based on tolerable concentrations of water and land in ecological system.

Acidification is based on assessment of acidic gases emission such as NOx, SOx and SO_2. Those gases react with water in atmosphere to form acid rain eventually, it is called acid deposition. It might cause ecosystem impairment at different levels and has severe damage to structural objects.

Fossil energy resource consumption is scaled by mega joule (MJ). One MJ is unit of heat quantity instead of using kilocalorie, is equivalent to heat quantity which can melt down 3 kg of ice at zero degrees Celsius and it is also equal to 0.278 kW.

LCIA which is multiplication of LCI and characterization factor is shown in Table 3.16.

Table 3.16 LCIA of Paper packages production

Global warming : IPCC-100 years (2001) Global warming : IPCC-100 years (2001)

	Item	LCI result	Unit	Characterization factor	Converted result
air	CO2	2.83E+03	kg	1.00E+00	2.83E+03
air	CH4	5.39E-02	kg	2.30E+01	1.24E+00
air	N2O	6.03E-02	kg	2.96E+02	1.79E+01
				Indicator result:	2.85E+03

Human toxicity : HTP_cancer Human toxicity (carcinogenicity) : HTP_cancer

	Item	LCI result	Unit	Characterization factor	Converted result
air	As	4.80E-06	kg	1.95E+04	9.39E-02
air	Cd	3.97E-07	kg	3.76E+03	1.49E-03
air	Cr	8.74E-06	kg	1.54E+04	1.34E-01
air	Ni	9.83E-06	kg	8.40E+01	8.25E-04
air	Pb	2.30E-05	kg	5.26E+01	1.21E-03
water	As	8.92E-11	kg	3.14E+04	2.80E-06
water	Cd	1.34E-11	kg	7.50E+03	1.00E-07
water	Cr	2.68E-10	kg	3.50E+04	9.38E-06
				Indicator result:	2.32E-01

Aquatic ecotoxicity : AETP Aquatic ecotoxicity : AETP

	Item	LCI result	Unit	Characterization factor	Converted result
air	As	4.80E-06	kg	5.31E+03	2.55E-02
air	Cd	3.97E-07	kg	2.69E+05	1.07E-01
air	Cr	8.74E-06	kg	9.04E+03	7.90E-02
air	Hg	5.80E-06	kg	4.33E+04	2.51E-01
air	Ni	9.83E-06	kg	6.71E-04	6.59E-09
air	Pb	2.30E-05	kg	6.02E+03	1.39E-01
water	As	8.92E-11	kg	1.55E+04	1.39E-06
water	Cd	1.34E-11	kg	7.89E+05	1.05E-05
water	Cr	2.68E-10	kg	2.65E+04	7.08E-06
water	Hg	8.92E-12	kg	1.94E+06	1.73E-05
				Indicator result:	6.01E-01

Terrestrial ecotoxicity : TETP Terrestrial ecotoxicity : TETP

	Item	LCI result	Unit	Characterization factor	Converted result
air	As	4.80E-06	kg	1.06E+06	5.07E+00
air	Cd	3.97E-07	kg	9.72E+04	3.86E-02
air	Cr	8.74E-06	kg	1.12E+05	9.78E-01
air	Hg	5.80E-06	kg	1.29E+06	7.45E+00
air	Ni	9.83E-06	kg	9.92E-05	9.75E-10
air	Pb	2.30E-05	kg	4.18E+03	9.61E-02
water	Hg	8.92E-12	kg	1.68E-10	1.50E-21
				Indicator result:	1.36E+01

Acidification : DAP Acidification : DAP

	Item	LCI result	Unit	Characterization factor	Converted result
air	NOx	1.93E+00	kg	7.17E-01	1.39E+00
air	NOx (mobile source)	9.15E-01	kg	7.17E-01	6.56E-01
air	SO2	1.74E+00	kg	1.00E+00	1.74E+00
air	SOx	4.88E-01	kg	1.00E+00	4.88E-01
				Indicator result:	4.27E+00

Fossil energy resource consumption : MJ Fossil energy resource consumption : MJ

	Item	LCI result	Unit	Characterization factor	Converted result
resource	coal (coke)	8.93E+00	kg	2.75E+01	2.46E+02
resource	coal (combustion)	2.12E+02	kg	2.75E+01	5.85E+03
resource	natural gas	5.43E+01	kg	5.43E+01	4.60E+03
resource	oil reserves	3.82E+02	kg	4.13E+01	1.58E+04
				Indicator result:	2.65E+04

LCIA data is calculated by JEMAI LCA Pro

Among six impact categories, global warming has notable impact compared to the others in paper packages production. So on that point, global warming, namely CO_2 equivalent (CO_2e) for each process is summarized in Table 3.17 independently.

Table 3.17 Global warming (CO_2e) for each process

Category	Item	Units	Total	Paperboard	Ink&varnish	Water+IPA	Printing plate	Pre-press	Press	Post-press	Delivery	Paper recycle	Al recycle	Incineration
Air	CO_2	kg	2.83E+03	1.67E+03	6.00E+01	3.34E+00	2.98E+01	1.92E+01	1.12E+02	2.06E+02	3.21E+02	1.20E+02	6.58E+00	2.79E+02
	CH4	kg	5.39E-02	4.71E-02	2.43E-03	1.45E-04	1.38E-04	4.12E-04	2.40E-03	5.82E-03	2.54E-03	2.57E-03	2.40E-05	-9.66E-03
	CH_4(CO_2e=CO_2×23)	kg	1.24E+00	1.08E+00	5.59E-02	3.34E-03	3.18E-03	9.47E-03	5.52E-02	1.34E-01	5.85E-02	5.91E-02	5.52E-04	-2.22E-01
	N2O	kg	6.03E-02	5.03E-02	1.83E-03	1.06E-04	2.93E-03	8.34E-04	4.86E-03	8.91E-03	3.88E-03	5.21E-03	6.28E-04	-1.91E-02
	N_2O(CO_2e=CO_2×296)	kg	1.79E+01	1.49E+01	5.41E-01	3.13E-02	8.68E-01	2.47E-01	1.44E+00	2.64E+00	1.15E+00	1.54E+00	1.86E-01	-5.66E+00
	Total CO_2e:	kg	2.85E+03	1.69E+03	6.06E+01	3.38E+00	3.07E+01	1.95E+01	1.14E+02	2.09E+02	3.22E+02	1.22E+02	6.76E+00	2.73E+02
	Percentage of each process:			59.2%	2.1%	0.1%	1.1%	0.7%	4.0%	7.3%	11.3%	4.3%	0.2%	9.6%

LCI data is calculated by JEMAI-LCA Pro

In paper package production, three greenhouse gases out of six gases are emitted; CH_4 and N_2O which are converted as CO_2e and CO_2. This figure is general case which is based on utilization of water, IPA, normal screening method (175 lines per inch) and normal thickness of paper (420g per square meter). Total CO_2e emission is 2,850kg-CO_2e, it has same value of 28.5g-CO_2e per a paper package when producing 100,000 copies.

Global warming is eccentrically located; paperboard related load including recycle emits 1,650kg-CO_2e (65%), almost two thirds of all. The result of influence from paper is a lot more than expected. The second largest load is delivery which is simply for conveyance of finished goods and emits 322 kg-CO_2e (11%).

Three major processes from paperboard related, delivery and incineration emits 2,407 kg-CO_2e (85%), other processes emits residual amount. Ink/varnish, printing plate and actual production are regarded as key processes in printing service, but result proves contrary to our expectations completely.

Other characterization models are not scrutinized in details here since each environmental load does not have significant impacts.

3.3.4 Environmental and economical analysis by printing related factors

3.3.4.1 CO_2e comparison by alternations of printing patterns

Sensitivity analyses at the time of changing contents of processes, namely printing materials and methods which may affect environmental loads are carried out to seek out best technology combination at this moment.

Printing patterns are;

A Normal practice (water and IPA are used, normal printing dot=175lines/inch)

B Waterless printing method

C Frequency Modulation (FM) screening (20-micron printing dot)

D Paper weight saving

E Best practice (B+C+D)

Global warming comparison of five different printing patterns is performed. It is shown in Figure 3.9.

Printing pattern	Item	Units	Total	Paperboard	Ink/varnish	Water+IPA	Printing plate	Pre-press	Press	Post-press	Delivery	Paper recycle	Al recycle	Incineration
A: Normal	CO2	kg	2.83E+03	1.67E+03	6.00E+01	3.34E+00	2.98E+01	1.92E+01	1.12E+02	2.06E+01	3.21E+02	1.20E+02	6.58E+00	2.79E+02
	CH4	kg	5.39E−02	4.71E−02	2.43E−03	1.45E−04	1.38E−04	4.12E−04	2.40E−03	5.82E−03	2.54E−03	2.57E−03	2.40E−05	−9.66E−03
	N2O	kg	6.03E−02	5.03E−02	1.83E−03	1.06E−04	2.93E−03	8.34E−04	4.86E−03	8.91E−03	3.88E−03	5.21E−03	6.28E−04	−1.91E−02
	CO2equivalent:	kg	2.85E+03	1.69E+03	6.06E+01	3.38E+00	3.07E+01	1.95E+01	1.14E+02	2.09E+02	3.22E+02	1.22E+02	6.76E+00	2.73E+02
B: Waterless	CO2	kg	2.80E+03	1.67E+03	6.00E+01	0.00E+00	2.98E+01	1.92E+01	1.12E+02	2.06E+01	3.21E+02	1.20E+02	6.58E+00	2.79E+02
	CH4	kg	5.38E−02	4.71E−02	2.43E−03	0.00E+00	1.38E−04	4.12E−04	2.40E−03	5.82E−03	2.54E−03	2.57E−03	2.40E−05	−9.66E−03
	N2O	kg	5.91E−02	5.03E−02	1.83E−03	0.00E+00	2.93E−03	8.34E−04	4.86E−03	8.91E−03	3.88E−03	5.21E−03	6.28E−04	−1.91E−02
	CO2equivalent:	kg	2.82E+03	1.69E+03	6.06E+01	0.00E+00	3.07E+01	1.95E+01	1.14E+02	2.09E+02	3.22E+02	1.22E+02	6.76E+00	2.73E+02
C: FM screening	CO2	kg	2.79E+03	1.67E+03	5.19E+01	3.34E+00	2.98E+01	1.92E+01	1.12E+02	2.06E+01	3.21E+02	1.20E+02	6.58E+00	2.79E+02
	CH4	kg	5.36E−02	4.71E−02	2.10E−03	1.45E−04	1.38E−04	4.12E−04	2.40E−03	5.82E−03	2.54E−03	2.57E−03	2.40E−05	−9.66E−03
	N2O	kg	5.89E−02	5.03E−02	1.58E−03	1.06E−04	2.93E−03	8.34E−04	4.86E−03	8.91E−03	3.88E−03	5.21E−03	6.28E−04	−1.91E−02
	CO2equivalent:	kg	2.81E+03	1.69E+03	5.25E+01	3.38E+00	3.07E+01	1.95E+01	1.14E+02	2.09E+02	3.22E+02	1.22E+02	6.76E+00	2.73E+02
D: Paper weight saving	CO2	kg	2.51E+03	1.43E+03	6.00E+01	3.34E+00	2.98E+01	1.92E+01	1.12E+02	2.06E+01	3.19E+02	1.07E+02	6.58E+00	2.41E+02
	CH4	kg	4.83E−02	4.04E−02	2.43E−03	1.45E−04	1.38E−04	4.12E−04	2.40E−03	5.82E−03	2.54E−03	2.29E−03	2.40E−05	−8.28E−03
	N2O	kg	5.42E−02	4.31E−02	1.83E−03	1.06E−04	2.93E−03	8.34E−04	4.86E−03	8.91E−03	3.85E−03	4.65E−03	6.28E−04	−1.64E−02
	CO2equivalent:	kg	2.53E+03	1.45E+03	6.06E+01	3.38E+00	3.07E+01	1.95E+01	1.14E+02	2.09E+02	3.20E+02	1.09E+02	6.76E+00	2.36E+02
E: Best practice	CO2	kg	2.50E+03	1.43E+03	5.19E+01	0.00E+00	2.98E+01	1.92E+01	1.12E+02	2.06E+01	3.19E+02	1.07E+02	6.58E+00	2.41E+02
	CH4	kg	4.78E−02	4.04E−02	2.10E−03	0.00E+00	1.38E−04	4.12E−04	2.40E−03	5.82E−03	2.54E−03	2.29E−03	2.40E−05	−8.28E−03
	N2O	kg	5.38E−02	4.31E−02	1.58E−03	0.00E+00	2.93E−03	8.34E−04	4.86E−03	8.91E−03	3.85E−03	4.65E−03	6.28E−04	−1.64E−02
	CO2equivalent:	kg	2.51E+03	1.45E+03	5.25E+01	0.00E+00	3.07E+01	1.95E+01	1.14E+02	2.09E+02	3.20E+02	1.09E+02	6.76E+00	2.36E+02

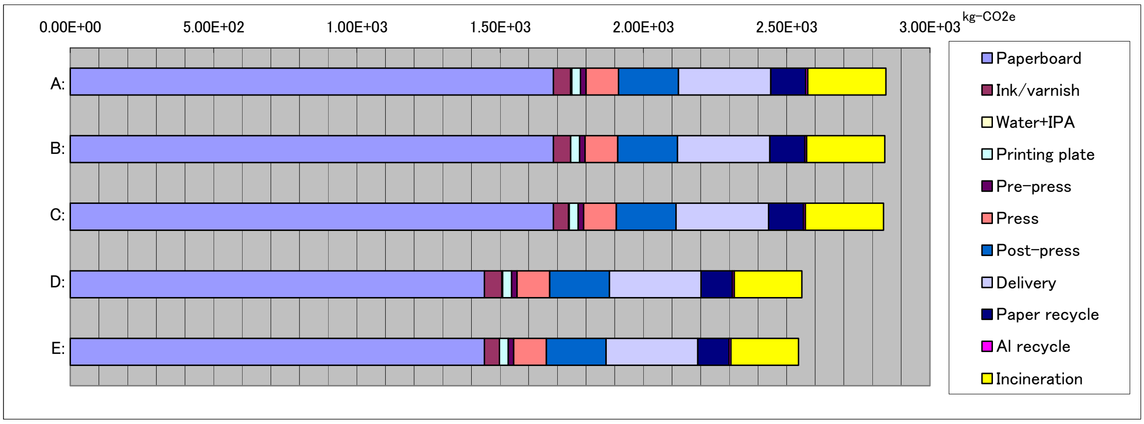


Figure 3.9 Global warming comparison of five printing patterns

In pattern B (waterless printing), total CO_2e emission is almost changeless since impacts from water and IPA is almost none, its emission from 40 litters of water and 2 litters of IPA is only 3kg-CO_2e which equals to 0.1% of all. This result shows that using of dampening water (water and IPA) cannot be a crucial factor in printing production.

In pattern C (FM screening), CO_2e emission is calculated under the precondition that the amount of the ink usage can be reduced 30% for four basic color inks because of minimization of printing dots. But, amount of over print varnish usage is not influenced by the difference of printing dots since it is whole surface coating. As it turned out, total ink usage including over print varnish is reduced from 16kg to 14kg, it has very small impact on whole environmental load. Total CO_2e emission from ink and varnish usage is reduced from 61kg-CO_2e to 53kg-CO_2e, 13% reduction only in ink procurement and almost no reduction compared to whole amount.

In pattern D (paper weight saving), CO_2e reduction effect is in visual contact here. Basis weight of paper was trimmed from 420g/㎡ to 360 g/㎡, it is 14% weight reduction. Total CO_2e emission is cut downed from 2,850kg-CO_2e to 2,530kg-CO_2e, it is 11% drastic cut by contribution of paper weight saving in the process not only of paperboard, but also of delivery, paper recycle and incineration which are related closely with paper weight. Although CO_2e emission reduction does not reach at the percentage of paper weight saving, it turned out that paper weight has tremendous power of influence in printing production.

In pattern E (Best practice), all changed conditions are combined together. Total CO_2e emission is cut downed to 2,510kg-CO_2e, it is almost same as pattern D because of almost no reduction impacts from pattern B and C.

From above-mentioned sensitivity analyses, reduction of CO_2e cannot be performed by printing high technology such as waterless printing method or FM screening since CO_2e emission from procurements of water/IPA and ink/varnish are only 2% of whole CO_2e emission.

On the other hand, reduction of paper weight has significant impact on CO_2e emission cutback. Since carrying out paper weight saving would reduce volume of total input extensively, it also would reduce amount of delivery, paper recycle and waste. It is reconfirmed numerically that changing on the policy about procurement of paper works the most compared with the other processes.

3.3.4.2 CO_2e comparison by alternations of printed matter

Discussion of the case here is focused only on packaging related printing service, but LCA for information related printing service is conducted here to know how environmental load is scattered and the difference between the two. Production for 10,000 copies of 36-page brochures with saddle stitch binding is chosen as a representative example of information related printing service. Specification is summarized in Table 3.18 and comparison of input for each item is shown in Table3.19.

Table 3.18 Specification for 10,000 copies of 36-page brochures with saddle stitch binding

Dimension:	210mm×297mm×6mm	Water & Additives:	Water & Isopropyl alchohol
Weight:	139.3g	Pre-press:	Printing plate (Computer to Plate)
Paper:	Coated paper, 157g/㎡	Press:	UV 10-color+coating unit, perfector (4-color/4-color)
Printing method:	Ultraviolet(UV) Offset		
Ink & Varnish:	UV hybrid ink	Post-press:	Guillotine, folding and saddle stitch binding

Table 3.19 Comparison of input of Paper package and 36-page brochure

Input item	Paper package	36-page brochure
Paper:	2,416 kg	1,969 kg
Ink:	16 kg	26 kg
Water:	40 litters	65 litters
IPA:	2 litters	3 litters
Printing plate:	3 kg	8 kg
Pre-press:	43 kWh	155 kWh
Press:	252 kWh	455 kWh
Post-press:	323 kWh	186 kWh
Delivery:	124 km	100 km
Incineration:	1,863 kg	1,393 kg
Paper recycle:	553 kg	576 kg
Aluminum recycle:	3 kg	8 kg

In order to compare 10,000 copies of 36-page brochures with 100,000 copies of paper packages, total CO_2e emissions are summarized in the same format in the same printing patterns as global warming of paper packages, it is shown in Figure 3.10.

Printing pattern	Item	Units	Total	Paper	Ink	Water+IPA	Printing plate	Pre-press	Press	Post-press	Delivery	Paper recycle	Al recycle	Incineration
A: Normal practice	CO2	kg	3.79E+03	2.79E+03	9.72E+01	5.39E+00	9.53E+01	6.89E+01	2.03E+02	8.27E+01	1.15E+02	6.65E+01	2.09E+01	2.36E+02
	CH4	kg	1.41E-01	1.32E-01	3.94E-03	2.35E-04	4.42E-04	1.47E-03	4.34E-03	1.77E-03	3.48E-03	1.42E-03	7.68E-05	-8.12E-03
	N2O	kg	6.69E-02	4.83E-02	2.96E-03	1.71E-04	9.39E-03	2.99E-03	8.80E-03	3.58E-03	1.94E-03	2.88E-03	2.01E-03	-1.60E-02
	CO2equivalent:	kg	3.81E+03	2.81E+03	9.82E+01	5.45E+00	9.81E+01	6.98E+01	2.06E+02	8.38E+01	1.16E+02	6.74E+01	2.15E+01	2.31E+02
B: Waterless	CO2	kg	3.78E+03	2.79E+03	9.72E+01		9.53E+01	6.89E+01	2.03E+02	8.27E+01	1.15E+02	6.65E+01	2.09E+01	2.36E+02
	CH4	kg	1.41E-01	1.32E-01	3.94E-03		4.42E-04	1.47E-03	4.34E-03	1.77E-03	3.48E-03	1.42E-03	7.68E-05	-8.12E-03
	N2O	kg	6.68E-02	4.83E-02	2.96E-03		9.39E-03	2.99E-03	8.80E-03	3.58E-03	1.94E-03	2.88E-03	2.01E-03	-1.60E-02
	CO2equivalent:	kg	3.80E+03	2.81E+03	9.82E+01	0.00E+00	9.81E+01	6.98E+01	2.06E+02	8.38E+01	1.16E+02	6.74E+01	2.15E+01	2.31E+02
C: FM screening	CO2	kg	3.75E+03	2.79E+03	6.48E+01	5.40E+00	9.53E+01	6.89E+01	2.03E+02	8.27E+01	1.15E+02	6.65E+01	2.09E+01	2.36E+02
	CH4	kg	1.40E-01	1.32E-01	2.62E-03	2.35E-04	4.42E-04	1.47E-03	4.34E-03	1.77E-03	3.48E-03	1.42E-03	7.68E-05	-8.12E-03
	N2O	kg	6.59E-02	4.83E-02	1.97E-03	1.71E-04	9.39E-03	2.99E-03	8.80E-03	3.58E-03	1.94E-03	2.88E-03	2.01E-03	-1.60E-02
	CO2equivalent:	kg	3.78E+03	2.81E+03	6.55E+01	5.45E+00	9.81E+01	6.98E+01	2.06E+02	8.38E+01	1.16E+02	6.74E+01	2.15E+01	2.31E+02
D: Paper weight saving	CO2	kg	3.21E+03	2.28E+03	9.72E+01	5.40E+00	9.53E+01	6.89E+01	2.03E+02	8.27E+01	1.14E+02	5.42E+01	2.09E+01	1.95E+02
	CH4	kg	1.18E-01	1.07E-01	3.94E-03	2.35E-04	4.42E-04	1.47E-03	4.34E-03	1.77E-03	3.48E-03	1.16E-03	7.68E-05	-6.62E-03
	N2O	kg	6.04E-02	3.93E-02	2.96E-03	1.71E-04	9.39E-03	2.99E-03	8.80E-03	3.58E-03	1.92E-03	2.34E-03	2.01E-03	-1.30E-02
	CO2equivalent:	kg	3.23E+03	2.29E+03	9.82E+01	5.45E+00	9.81E+01	6.98E+01	2.06E+02	8.38E+01	1.14E+02	5.49E+01	2.15E+01	1.91E+02
E: Best practice	CO2	kg	3.17E+03	2.28E+03	6.48E+01		9.53E+01	6.89E+01	2.03E+02	8.27E+01	1.14E+02	5.42E+01	2.09E+01	1.95E+02
	CH4	kg	1.16E-01	1.07E-01	2.62E-03		4.42E-04	1.47E-03	4.34E-03	1.77E-03	3.48E-03	1.16E-03	7.68E-05	-6.62E-03
	N2O	kg	5.93E-02	3.93E-02	1.97E-03		9.39E-03	2.99E-03	8.80E-03	3.58E-03	1.92E-03	2.34E-03	2.01E-03	-1.30E-02
	CO2equivalent:	kg	3.19E+03	2.29E+03	6.55E+01	0.00E+00	9.81E+01	6.98E+01	2.06E+02	8.38E+01	1.14E+02	5.49E+01	2.15E+01	1.91E+02

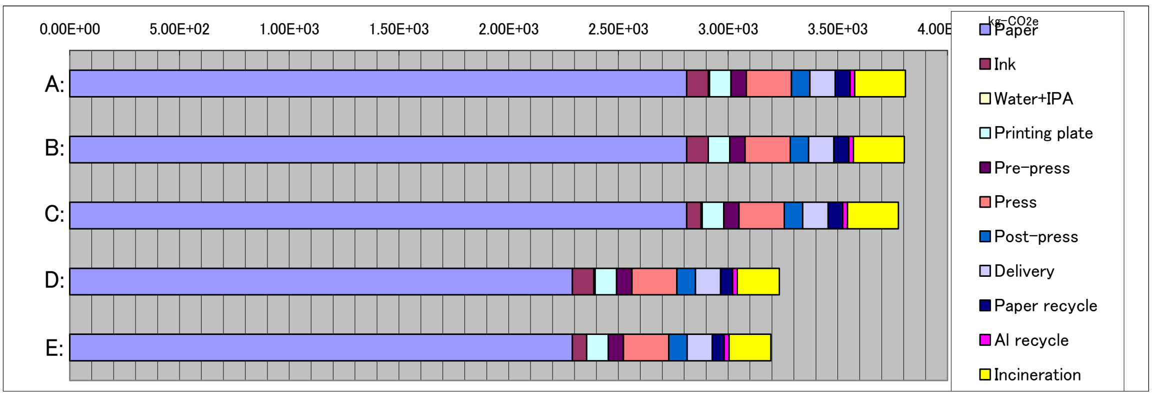


Figure 3.10 Global warming comparison of 5 printing patterns for 36-page brochures

From the rough view point comparing with paper packages, proportion of post-press and delivery are smaller, but the one of paper occupies more in all.

What is more, in order to dig a little deeper and to compare key elements, changing rate of CO_2e emission for every pattern and important processes which can influence whole environmental load is extracted and summarized in Table 3.20.

Table 3.20 Extracted important processes for paper package and 36-page brochure

<Paper package>

Printing pattern	CO2 equivalent	% to A	Paper related*1		Ink/varnish		Water+IPA	
A Normal practice	2.85E+03	–	2.41E+03	84.5%	6.06E+01	2.1%	3.38E+00	0.1%
B Waterless	2.82E+03	98.9%	2.41E+03	85.4%	6.06E+01	2.1%	0.00E+00	0.0%
C FM screening	2.81E+03	98.6%	2.41E+03	85.7%	5.25E+01	1.9%	3.38E+00	0.1%
D Paper weight saving	2.53E+03	88.8%	2.12E+03	83.6%	6.06E+01	2.4%	3.38E+00	0.1%
E Best practice	2.51E+03	88.1%	2.12E+03	84.3%	5.25E+01	2.1%	0.00E+00	0.0%

<Saddle stitch binding>

Printing pattern	CO2 equivalent	% to A	Paper related		Ink/varnish		Water+IPA	
A Normal practice	3.81E+03	–	3.22E+03	84.6%	9.82E+01	2.6%	5.45E+00	0.1%
B Waterless	3.80E+03	99.7%	3.22E+03	84.8%	6.55E+01	1.7%	0.00E+00	0.0%
C FM screening	3.78E+03	99.2%	3.22E+03	85.3%	9.82E+01	2.6%	5.45E+00	0.1%
D Paper weight saving	3.23E+03	84.8%	2.65E+03	82.0%	9.82E+01	3.0%	5.45E+00	0.2%
E Best practice	3.19E+03	83.7%	2.65E+03	83.1%	6.55E+01	2.1%	0.00E+00	0.0%

*1: "Paper related" includes process of paper, delivery, paper recycle and incineration

It is almost the same that total CO_2e emission is reduced proportionally from Normal practice to Best practice for both cases. Highly important matter is paper related process which includes procurement of paper, delivery, paper recycle and incineration occupies over 80% in the whole for both cases. Ink usage which is reminded firstly from printing production and water usage which comes under the spotlight in the field of environmental issue have only insignificant influence.

As a conclusion of sensitivity analyses, as long as environmental load from paper is the greatest in packaging related and information related printing services, it is clear that CO_2e emission never be reduced without reducing amount of paper usage.

3.3.4.3 Positive influence by expansion of system boundary

System boundary here is expanded from previous studies shown in previous chapter; case example is inclusion of transportation for materials and products. The load from transportation is calculated separately from materials or processes and summarized in Figure 3.11.

Item	Total (kg-CO2e)	Paperboard	Ink&varnish	Water+IPA	Printing plate	Pre-press	Press	Post-press	Delivery	Recycle	Incineration
Transportation	3.64E+02	2.79E+02	2.00E-01	0.00E+00	1.00E-01	-	-	7.00E-01	4.67E+01	2.67E+01	1.13E+01
Material or Process	2.49E+03	1.41E+03	6.04E+01	3.40E+00	3.06E+01	1.95E+01	1.14E+02	2.08E+02	2.75E+02	1.02E+02	2.61E+02
Total CO2e:	2.85E+03	1.69E+03	6.06E+01	3.40E+00	3.07E+01	1.95E+01	1.14E+02	2.09E+02	3.22E+02	1.29E+02	2.73E+02

Calculated by JEMAI-LCA Pro

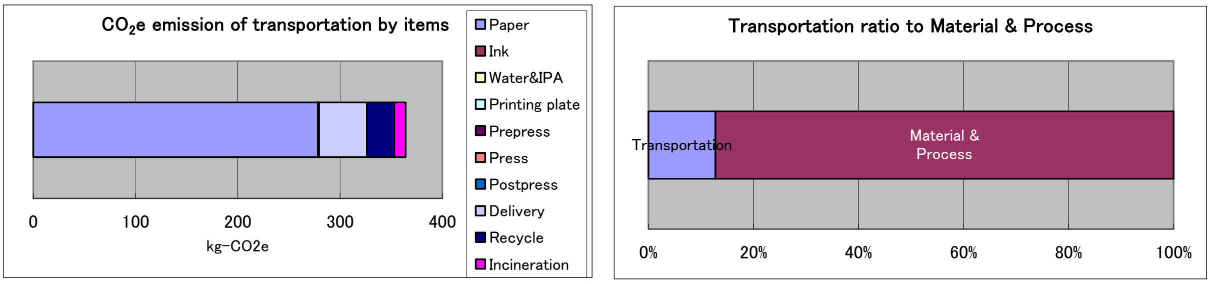


Figure 3.11 The ratio of transportation after expansion of system boundary

The bar graph on the left indicates that major load among all materials and processes is paper transportation which occupies around three fourth of total. And on the other hand, the bar graph on the right demonstrates that all of transportation is around 13% of total load, in another words, previous system boundary is expanded around 15% after including the load from transportation. Many past studies could not conduct detailed research to check all of transportation at every single process.

Transportation of materials and products is not ignorable, so should be included to verify total environmental load accurately.

3.3.4.4 Environmental factor and economical factor analysis

Although environmental impacts have been pointed out up to this time, environmental factor and economical factor, namely six impact categories and cost of paper packages are compared as LCA versus Life Cycle Costing (LCC) to know mutual relationship. It is shown in Table 3.21.

Table 3.21 Relative comparison of environmental and economical (LCIA & LCC) factors

Printing pattern	Environmental factor						Economical factor
	Global warming (kg-CO2e)	Human toxicity (carcinogenicity) (kg)	Aquatic ecotoxicity (kg)	Terrestrial ecotoxicity (kg)	Acidification (kg)	Fossil energy resource consumption (MJ)	Production cost (not ¥)
A:Normal practice	2.846E+03	2.319E-01	6.014E-01	1.364E+01	4.273E+00	2.646E+04	7.600E+04
	-	-	-	-	-	-	-
B:Waterless	2.816E+03	2.318E-01	6.013E-01	1.364E+01	4.269E+00	2.638E+04	7.684E+04
	98.9%	100.0%	100.0%	100.0%	99.9%	99.7%	101.1%
C:FM screening	2.811E+03	2.303E-01	5.972E-01	1.354E+01	4.263E+00	2.630E+04	7.525E+04
	98.8%	99.3%	99.3%	99.3%	99.8%	99.4%	99.0%
D:Paper weight saving	2.526E+03	2.210E-01	5.730E-01	9.011E+00	3.938E+00	2.406E+04	7.022E+04
	88.8%	95.3%	95.3%	66.1%	92.2%	90.9%	92.4%
E:Best practice	2.514E+03	2.193E-01	5.687E-01	8.943E+00	3.924E+00	2.384E+04	7.007E+04
	88.3%	94.6%	94.6%	65.6%	91.8%	90.1%	92.2%

*Production cost is not real numerical number. They are assumed value when cost price for water & additives is set as "1".

In environmental factor, global warming is already compared by printing patterns, so other impact categories are also compared in the same way. There is no practical difference about reduction trend of environmental load among impact categories; it means that high-tech printing methods do not contribute for easing of the load, however only paper reduction can reduce certain amount of the load. As what should be said, outstanding reduction is seen when changing weight of paper in terrestrial ecotoxicity (TETP) since arsenic and mercury which mainly consists of TETP are reduced more than a bit. It is presumed that reduction of incineration in quantity is a reason for improvement.

For LCC, cost of purchased price for materials (paper/ink/printing plate), utility (electricity), manpower and outsourcing are estimated by real value in money. Cost breakdown cannot be opened to the public by real numerical value, so it is set as relative value at the time of setting the price of water and IPA to one. It is thought that total cost should fall proportionally like six impact categories, but waterless printing method is the most expensive pattern because of utilizing relatively expensive ink and printing plate compared with normal process. Other than that, production cost is similarly reduced like impact categories since influence of paper is also large portion in cost breakdown.

In conclusion, environmental loads and total cost is also determined by strong influence of paper again.

3.3.4.5 Effectiveness of actual data analysis from field site

Collecting and analyzing of real data from actual production line by life-cycle approach are extremely effective for improvement of organizational operation from the viewpoint of environmental factor and economical factor, so essential points are summarized below.

(Environmental factor)

- Break jobs which are printed in-house down into patterns and pinpoint dominant factors to raise environmental load at each process
- After improving problematic processes, the degree of improvement can be comprehended by specific numerical numbers
- By accumulating each single job, total environmental load or reduction portion of the load is tangible as monthly or annual data

(Economical factor)

- Variable cost items which are material (paper, ink and plate) and utility (electricity and water) are investigated in detail in terms of quantity and unit price
- Fixed cost items which are mainly payrolls of first line workers, average of wage is calculated for all production lines
- Outsourcing costs for variable cost and fixed cost are investigated and added to production cost in-house

There are number of advantages to run simulation of environmental and economical factor analysis based on real data at first line by being independent from textbook method or other case studies at different printing companies. The results from simulation can be verified after completing a job, so the difference between simulation and actual result can be compared and degree of accuracy for simulation would be enhanced each time. Filling a gap between forecast and reality is quite important when working on continuous improvements.

After improvements for Environmental and Economical factors are successfully completed, print buyers can use an objective evaluation that looks result. Providing information from two different aspects would lead to reduction of the load and cost at the same time, it will set the relationship on the right footing and develop it to a higher level.

3.4 CONCLUSION

Firstly, since primary and secondary data from procurement stage to disposal stage in Printing Service is organized in detail, the scenario which is true figure of actual condition is established and visualization of environmental load is completed successfully. It is not necessary to rely on old-fashioned sensuous evaluation method any more, now can stay focus on quantitative assessment method.

Secondly, when considering shifting to Eco-design, it is understood that on which improvement activities should be worked to improve the load in quantitative way not like in qualitative way as before. Paper weight saving could be practicable by performing a specification improvement and structural improvement; it is definitely principal axis to reduce the load.

Thirdly, since the load is unevenly concentrated on global warming, a method of calculating it could be changed from full scale of LCA to $LCCO_2e$ which is focused only on global warming when detailed study is not necessary. It will be just part of LCA, but could be simplified calculation tool whenever working on Carbon offset and CFP. Additionally, calculation of CO_2e also can help cost reduction activity, so Life cycle concept could be useful for both environmental and economical analyses in simplified calculation scheme.

For Packaging Printing Service, there is an obstacle to change to digitalized one since many of contents inside packages cannot be sent via optical fiber. Exactly the same method as Information Printing Service cannot be applied physically, so different style of LCA approaches with a broad viewpoint should be innovated and examined to come up the best solution to reduce the load.

For Information Printing Service, usage of paper should correspond to a direction of reduction, substitution and cancellation in the near future. Although applications fit to all kinds are quite difficult, information which needs frequent updates will be replaced from current paper-based to digitalized-based at first. This movement is hard-hit for publishing and printing industries, but it is not avoidable.

In consideration of understanding of real environmental load, there is still argument whether focusing only on CO_2e is appropriate or not. In order to evaluate both Packaging Printing Service and Information Printing Service by different viewpoints, Integrated LCA approaches which are developed in Japan and overseas should be experimented for compositive analysis.

CHAPTER 4

INTEGRATED LCA APPROACH FOR PRINTING SERVICE

ABSTRACT

In Chapter 3, quantitative analysis method for Printing Service is established to promote evaluation for environmental load, not by qualitative assessment which is based on individual's perception. As a result of Printing Service LCA, major impact from paper usage attracts a lot of attention and shifting to digital media from paper media is proposed to reduce the load. But, there are still many printing services rooting in paper usage for both Packaging Printing Service and Information Printing Service, so complete and total changing to digital media is impracticable, digitalizing cannot be all-purpose cure for all applications. Therefore, Integrated LCA method which can evaluate the load in a balanced manner should come under the review, not only by $LCCO_2e$ which promotes paper usage reduction only. Carefully selected Integrated LCA methods are Environmental Load Point, Life cycle Impact assessment Method based on Endpoint modeling, Eco Indicator 95, Eco Point and Environment Priority Strategies for product design. These five different methods are utilized to evaluate for both package production and book production to discriminate the difference of the load between Normal practice and Best practice. Life cycle inventory data is investigated first, then basic information is input for each Integrated LCA method and unified weighted points are calculated. Integrated LCA methods have different characteristics spreading weighted points over different impact categories. Among these methods, Environmental Load Point is considered as the best one since it is well balanced to evaluate all impact categories.

4.1 INTRODUCTION

Practical attempts have been done in last chapter to demonstrate Printing Service LCA as quantitative analysis. Three purposes are fully achieved.

Firstly, visualization of environmental load by mathematical value is not associated with any difficulties since all parameters from procurement, production, disposal and recycle are determined to be calculated. Additionally, data collective methods at production site are also fixed and formulated as rigid calculation scheme.

Secondly, shifting to Eco-design which is based on numerical numbers of environmental load is currently possible, so it must be firstly performed to improve deflected part of each phase under the highest load. But, it is adopted not only for the highest load, but also for particular target which should be improved.

Thirdly, full scale of Printing Service LCA is considered to be time consuming and less well understood sometimes, so focusing only on CO_2e emission which has significant negative impact by the approach of $LCCO_2e$ is an encouraging alternative in some cases when execution of CFP or carbon offset is necessary.

When observing the whole environmental load, even if it is concluded that reducing total input of paper is necessary by Printing Service LCCO_2e analysis, it cannot be a solution for Physical Printing Service standing on usage of paper in the fields of both Packaging Printing Service and Information Printing Service.

It goes without saying that Packaging Printing Service works out by utilizing paper which is tangible thing and needs paper to fulfill a role protecting content of a package.

On the other hand, Information Printing Service is considered that majority of it could be substituted by digital media since it consists mainly of newspaper, magazine and books which could be switched from physical printed matters to digital printed matters technically. But, digitalization is not brought forward so much as expected by some reasons such as cost for reading by special devises, portability, user-friendliness and so on.

At the same instant, there is confrontation for Information Printing Service to focus only on CO_2e emission because of demand to know wide range of environmental load. For instance, by the scale of CO_2e emission, incineration of products for paper is almost none when "carbon neutral" is applied, but many do not think in that way when confronting waste treatment problems such as abatement debris, waste burial facility, waste contamination and so forth.

4.2 PURPOSE OF THE STUDY

It is understood that environmental load of Physical Printing Service is reduced by cutting down of paper usage, but it cannot come into existence definitely only when not using paper as explained above. Additionally, wide scope of environmental load should be organized by collecting wide range of environmental load indicators influencing in negative way.

Usage of materials cannot be bypassed for Physical Printing Service since it can drastically reduce neither printing related materials such as inks and plates by digitization, nor can avoid logistics for material transportation and product delivery. Summarizing Life Cycle Inventory analysis (LCI) and only characterization part of Life Cycle Impact Assessment (LCIA) can lead to beneficial comprehensive tips, but to fragmented and uninformative idea on Physical Printing Service.

In order to figure out a solution which is confronted straits, multi-sided Integrated LCA approach is expected to look beyond the surface of environmental load to shed the light on the true nature of the load.

By the analysis of LCI and only characterization of LCIA from Printing Service LCA, no solution can be discerned to ease environmental load in Physical Printing Service except for making paper thinner which looks sole solution for all cases.

The purpose of study in this chapter is determined below.

Firstly, several different sorts of Integrated LCA methods invented in Japan and Europe are conducted to provide opportunities to know the nature of deep inside of environmental load of package production and book production representing Physical Printing Service.

Secondly, different methods of Integrated LCA in Japan and Europe are compared to identify specific characteristics. Each one of those is characterized by strengths and limitations to close up the essence of environmental load.

The advantages for digitalization are not fully received in the case of every single case of Printing Service, so turnaround from the approach which was utilized for Physical Printing Service should be adopted.

4.3 ANALYSIS

After LCI which tabulates all of input and output from material acquisition/energy/production/disposal/recycle and is completed at a result of LCA, each item is discerned for different types of environmental issues. This process is named as "Classification".

All input/output are lined up for specific impact categories after classification, and then environmental load is calculated. When summing up the load for an impact category, weighting is considered for relative influence. For instance, global warming is calculated as CO_2 equivalent by adding up carbon dioxide, 25 times of methane and 298 times of dinitrogen monoxide by the rule written in IPCC assessment report. This process is named as "Characterization"

Final assessment is the work of consolidating the results of all impact categories; it can show integrated indicator collecting up whole environmental load. It is necessary and is highly-esteemed to consider importance of impact category depending on area and people in different countries. One's concept of values and preferences are also often influenced by different perspectives. This process is named as "Normalization".

LCIA is formed by Classification, Characterization and Normalization in organized rotation explained above.

It is critical to consider what kinds of improvements should be done for Eco-design improving product performance in the viewpoint of environmental load from the results of LCI and LCIA. Integrated LCA approach which is backed up by full execution of Classification/Characterization/Normalization can lead to conclusions which are not ambiguous and recognized at a glance. It can grasp the nature of whole environmental load for different sorts of Printing Services at once.

4.3.1 Changes about scope of study

All parameters selected here for calculation is almost exactly the same as the one in last chapter except for adopting cutting off rule discarding small impacts which occupy less than 5% compared to total load by the scale of CO_2e and changing disposal method from incineration to landfill.

4.3.2 Product system to be studied

As a case study, 100,000 copies of packaging production which is analyzed by previous chapter is cited again as an example of Integrated LCA calculation.

In Normal practice, usual printing method which is applied by many printers is taken place. But in Best practice, UV waterless high-definition printing method which can reduce around one third of ink usage is utilized on thinnest paper at minimum which can bear the weight of content. Specifications for Normal/Best practices are presented in Table 4.1.

Table 4.1 Specification of package production by Normal/Best practice

【Normal practice】			【Best practice】
Carton paper	0.66 m × 0.83 m × 0.36 kg/m² × 10,500 sheet =	2,070.684 kg	1,783.089 kg
Al(Plate)	0.5 kg × 5 plates =	2.500 kg	
UV ink & varnish	B/C/M/Y: 0.0015 mm × 1030 mm × 730 mm × 23.0% × 10,500 sheet ÷ 1,000 =	2,723.758 g	1,906.630 g
	OP varnish: 2.94 g/m² × 0.66 m × 0.83 m × 85.0% × 10,500 sheet =	14,385.000 g	
Water	17.109 kg <Total of ink usage> × 2.5 times <average water usage for printing on paper> =	42.772 kg	0 kg
IPA	33.405 kg <Total of water*specif gravity 0.781> × 5% <average IPA percentage> =	1.670 kg	0 kg
Electricity	Editing: 0.06 kW × 15.00 h + (1.3 kW + 0.50 kW <Air cond. & lighting>) × 15.00 h =	27.150 kWh	
	CtP: 12.50 kW × 1.00 h + (2.5 kW + 1.02 kW <Air cond. & lighting>) × 1.00 h =	16.020 kWh	
	Press: 72.00 kW × 3.00 h + (10.0 kW + 1.85 kW <Air cond. & lighting>) × 3.00 h =	251.550 kWh	
	Die cut: 3.80 kW × 4.00 h + (5.0 kW + 1.85 kW <Air cond. & lighting>) × 4.00 h =	42.600 kWh	
	Gluer: 0.16 kW × 40.00 h + (5.0 kW + 1.85 kW <Air cond. & lighting>) × 40.00 h =	280.400 kWh	
Recycled Pulp	0.66 m × 0.83 m × 0.36 kg/m² × 10,500 sheet × 22.8% <non-product %> =	472.860 kg	407.185 kg
Recycled Al	0.5 kg × 5 plates =	2.500 kg	
Disposal	Landfill: 1,597.824 kg × 12.2% =	194.935 kg	167.860 kg
2t truck	UV ink/varnish: 0.017 t × 64.1 km =	1.097 tkm	1.044 tkm
	Disposal: 1.598 t × 30.0 km =	47.940 tkm	41.277 tkm
4t truck	Al(Plate): 0.003 t × 284.3 km =	0.711 tkm	
	Delivery: 1.598 t × 124.3 km =	198.631 tkm	171.025 tkm
	Recycled Pulp: 0.473 t × 236.7 km =	111.926 tkm	96.381 tkm
	Recycled Al: 0.003 t × 180.4 km =	0.451 tkm	
10t truck	Carton paper: 2.071 t × 829.3 km =	1,717.218 tkm	1,478.716 tkm

*In Best practice, printing manner is changed(grey cells are changed);
-Paper thickness is reduced from 360g/m² to 310g/m²
-Printing method was changed from 175lpi to 400lpi (FM screening), ink thickness is reduced around one third
-Printing method was changed from common method (water is used) to Waterless printing

In parallel, a case study of book production is set as 5,000 copies; conventional ink printing method which is common method is adopted instead of UV ink printing. In Best practice, waterless high-definition printing method is utilized on thinnest paper at minimum; concept of changing specification is exactly the same as package production. Detailed calculation basis of input and output for Normal/Best practices are shown in Table 4.2

On the assumption of case study scenarios for both package and book productions, “UV ink” for package production and “Conventional ink” for book production are calculated by having substitutes for it to fulfill inventory data since real inventory data is not prepared yet by ink manufacturers. What is more, waste disposal method is changed from incineration to “landfill” because of concerning permanent disposal. When calculating impact from landfill, disposal ratio of 12.2% (5,531,021t/year at final disposal site is divided by 45,180,244t/year of total collected disposal in 2008) is applied as calculation basis for disposal as landfill.

Table 4.2 Specification of book production by Normal/Best practice

【Normal practice】			【Best practice】
Paper for cover	0.536 m × 0.788 m × 0.26 kg/m² × 1,400 sheet =	153.599 kg	135.876 kg
Paper for text	0.636 m × 0.939 m × 0.10 kg/m² × 39,250 sheet =	2,454.195 kg	1,908.037 kg
Al(Plate)	0.5 kg × 20 plates =	10.000 kg	
Conventional ink	B/C/M/Y: 0.0015 mm × 1030 mm × 730 mm × 35.0% × 1,400 sheet ÷ 1,000 =	552.647 g	368.431 g
Conventional ink	B(text only): 0.0015 mm × 1030 mm × 730 mm × 20.0% × 39,250 sheet ÷ 1,000 =	8,853.623 g	
Water	9.406 kg <Total of ink usage> × 2.5 times <average water usage for printing on paper> =	23.516 kg	0 kg
IPA	18.366 kg <Total of water*specif gravity 0.781> × 5% <average IPA percentage> =	0.918 kg	0 kg
Electricity	Editing: 0.06 kW × 100.00 h + (1.3 kW + 0.50 kW <Air cond. & lighting>) × 100.00 h =	181.000 kWh	
	CtP: 12.50 kW × 4.00 h + (2.5 kW + 1.02 kW <Air cond. & lighting>) × 4.00 h =	64.080 kWh	
	Press: 54.15 kW × 2.00 h + (10.0 kW + 1.85 kW <Air cond. & lighting>) × 2.00 h =	132.000 kWh	
	Press: 65.55 kW × 12.00 h + (10.0 kW + 1.85 kW <Air cond. & lighting>) × 12.00 h =	928.800 kWh	
	Guillotine: 4.85 kW × 3.00 h + (5.0 kW + 1.85 kW <Air cond. & lighting>) × 3.00 h =	35.100 kWh	
	Folding: 4.10 kW × 8.00 h + (5.0 kW + 1.85 kW <Air cond. & lighting>) × 8.00 h =	87.600 kWh	
	P.Binding: 62.50 kW × 3.00 h + (5.0 kW + 1.85 kW <Air cond. & lighting>) × 3.00 h =	208.050 kWh	
Recycled Pulp	0.536 m × 0.788 m × 0.26 kg/m² × 1,400 sheet × 38.4% <non-product %> =	59.047 kg	52.234 kg
Recycled Pulp	0.636 m × 0.939 m × 0.10 kg/m² × 39,250 sheet × 11.3% <non-product %> =	277.105 kg	215.438 kg
Recycled Al	0.5 kg × 20 plates =	10.000 kg	
Disposal	Landfill: 2,271.642 kg × 12.2% =	277.140 kg	216.701 kg
2t truck	Conventional ink: 0.009 t × 64.1 km =	0.603 tkm	0.422 tkm
	Disposal: 2.272 t × 30.0 km =	68.160 tkm	53.280 tkm
4t truck	Al(Plate): 0.010 t × 284.3 km =	2.843 tkm	
	Delivery: 2.272 t × 124.3 km =	282.410 tkm	220.757 tkm
	Recycled Pulp: 0.336 t × 236.7 km =	79.531 tkm	63.436 tkm
	Recycled Al: 0.010 t × 180.4 km =	1.804 tkm	
10t truck	Paper: 2.608 t × 829.3 km =	2,162.643 tkm	1,695.089 tkm

*In Best practice, printing manner is changed(grey cells are changed);
-Paper thickness is reduced from 260g/m² to 230g/m² for cover and from 104.7g/m² to 84.1g/m² for text
-Printing method was changed from 175lpi to 400lpi (FM screening), ink thickness is reduced around one third
-Printing method was changed from common method (water is used) to Waterless printing

LCI summaries for package production and book production are presented in Table 4.3 and Table 4.4 separately.

There are many phases for both productions, so group all phases into five phases such as Paper, Other materials, Production, Delivery and Recycle/Disposal.

Procurement including paper, ink, varnish, water, IPA as water additives and plate should be categorized into one phase, but paper should not be included because influence of paper is significant and must be separated from the others.

Core part of production is environmental load from press and post press, namely printing machine and facilities for packaging/book productions.

Delivery is transportation by truck going back and forth between the factory and the place where a client designates.

As shown in both Table 4.3 and 4.4, environmental load from paper is big impact in resources, air, water and industrial categories. When producing paper, coal and oil reserves are used for energy to run paper mill facilities, as it turned out many items from production are diffused in the air.

LCI data is basic data for Integrated LCA. It is classified for research purpose, is characterized for specific impact category and is normalized to show consolidated indicators. It definitely leads to a further understanding of well balanced environmental load to avoid paying attention to global warming only.

Table 4.3 LCI result for of package production by Normal/Best practice

<Normal practice>

Category	No.	Item	Units	Total	Paper	%	other materials	Production	Delivery	Rec.&Disp.
Resources	1	Al reserves	kg	2.50E+00			2.05E+00			4.47E-01
	2	Cu reserves	kg	8.65E-06			8.65E-06			
	3	Pb reserves	kg	3.19E-07			3.19E-07			
	4	U reserves	kg	1.19E-02	4.30E-03	36.0%	2.76E-04	5.29E-03	5.68E-04	1.51E-03
	5	Zn reserves	kg	1.77E-06			1.77E-06			
	6	coal (coke)	kg	7.98E+00			1.22E-05		7.98E+00	
	7	coal (combustion)	kg	2.67E+02	1.73E+02	64.8%	9.15E+00	6.00E+01	6.48E+00	1.83E+01
	8	cryolite	kg	1.51E-01			1.24E-01			2.70E-02
	9	limestone	kg	1.92E+01			1.92E+01			
	10	natural gas	kg	1.12E+02	7.10E+01	63.2%	2.13E+00	2.79E+01	3.00E+00	8.19E+00
	11	oil reserves	kg	3.13E+02	2.32E+02	74.1%	2.64E+01	1.11E+01	3.85E+01	4.75E+00
	12	silica sand	kg	2.58E-06			2.58E-06			
Air	1	CO2	kg	2.17E+03	1.43E+03	66.0%	9.23E+01	2.75E+02	2.82E+02	8.72E+01
	2	As	kg	1.13E-05	4.08E-06	36.1%	2.39E-07	5.02E-06	5.39E-07	1.43E-06
	3	CH4	kg	5.31E-02	4.04E-02	76.1%	2.56E-03	5.89E-03	2.54E-03	1.71E-03
	4	Cd	kg	9.34E-07	3.37E-07	36.1%	1.98E-08	4.15E-07	4.45E-08	1.18E-07
	5	Cr	kg	2.06E-05	7.42E-06	36.1%	4.35E-07	9.13E-06	9.81E-07	2.59E-06
	6	Hg	kg	1.36E-05	4.92E-06	36.1%	2.89E-07	6.06E-06	6.51E-07	1.72E-06
	7	N2O	kg	6.71E-02	4.31E-02	64.3%	4.73E-03	1.19E-02	3.25E-03	4.06E-03
	8	NMHC	kg	2.49E-02	8.98E-03	36.1%	5.26E-04	1.10E-02	1.19E-03	3.14E-03
	9	NOx	kg	1.83E+00	8.19E-01	44.8%	8.29E-02	1.15E-01	7.67E-01	4.55E-02
	10	NOx (mobile source)	kg	3.73E-01	9.27E-02	24.9%	9.93E-03	3.24E-02	2.20E-01	1.77E-02
	11	Ni	kg	2.31E-05	8.34E-06	36.1%	4.89E-07	1.03E-05	1.10E-06	2.92E-06
	12	PM10 (mobile source)	kg	1.80E-02	6.78E-03	37.5%	7.14E-04	2.38E-03	7.34E-03	8.44E-04
	13	Pb	kg	5.41E-05	1.95E-05	36.1%	1.15E-06	2.40E-05	2.58E-06	6.83E-06
	14	SO2	kg	1.49E+00	1.30E+00	87.4%	1.50E-01	8.08E-03	7.55E-03	2.32E-02
	15	SOx	kg	5.13E-01	6.78E-02	13.2%	8.30E-03	4.35E-02	3.81E-01	1.29E-02
	16	dust	kg	2.39E-01	2.20E-01	92.0%	1.33E-02	2.16E-03	1.39E-03	2.15E-03
	17	hydrocarbons	kg	3.95E-02	1.82E-02	46.1%	1.92E-03	6.00E-03	1.10E-02	2.41E-03
Water	1	As	kg	4.15E-10			4.15E-10			
	2	BOD	kg	1.57E-03			1.57E-03			
	3	COD	kg	1.33E-02						1.33E-02
	4	Cd	kg	6.22E-11			6.22E-11			
	5	Cr	kg	1.24E-09			1.24E-09			
	6	Hg	kg	4.15E-11			4.15E-11			
Industrial	1	earth & sand (landfill)	kg	5.37E+00			4.41E+00			9.60E-01
	2	industrial waste landfill (unspecified)	kg	1.96E+02			5.54E-01			1.95E+02
	3	low-level radioactive waste	kg	8.35E-03	3.01E-03	36.0%	1.93E-04	3.70E-03	3.97E-04	1.06E-03
	4	paper wastes (landfill)	kg	5.44E+00					5.44E+00	
	5	plastic wastes (landfill)	kg	6.51E-09			6.51E-09			
	6	rubbles (landfill)	kg	1.29E-08			1.29E-08			
	7	slag (landfill)	kg	1.67E-05			1.67E-05			
	8	sludge (landfill)	kg	3.18E+02					6.53E+00	3.12E+02

<Best practice>

Category	No.	Item	Units	Total	Paper	%	other materials	Production	Delivery	Rec.&Disp.
Resources	1	Al reserves	kg	2.50E+00			2.05E+00			4.47E-01
	2	U reserves	kg	1.11E-02	3.70E-03	33.3%	2.64E-04	5.29E-03	5.68E-04	1.30E-03
	3	coal (coke)	kg	7.98E+00					7.98E+00	
	4	coal (combustion)	kg	2.41E+02	1.49E+02	62.1%	8.77E+00	6.00E+01	6.48E+00	1.59E+01
	5	cryolite	kg	1.51E-01			1.24E-01			2.70E-02
	6	limestone	kg	1.83E+01			1.83E+01			
	7	natural gas	kg	1.01E+02	6.11E+01	60.4%	2.05E+00	2.79E+01	3.00E+00	7.09E+00
	8	oil reserves	kg	2.73E+02	2.00E+02	73.1%	2.37E+01	1.11E+01	3.43E+01	4.29E+00
Air	1	CO2	kg	1.94E+03	1.23E+03	63.6%	8.59E+01	2.75E+02	2.68E+02	7.63E+01
	2	As	kg	1.05E-05	3.51E-06	33.4%	2.27E-07	5.02E-06	5.39E-07	1.23E-06
	3	CH4	kg	4.70E-02	3.48E-02	74.0%	2.30E-03	5.89E-03	2.54E-03	1.48E-03
	4	Cd	kg	8.70E-07	2.90E-07	33.4%	1.88E-08	4.15E-07	4.45E-08	1.01E-07
	5	Cr	kg	1.91E-05	6.39E-06	33.4%	4.14E-07	9.13E-06	9.80E-07	2.23E-06
	6	Hg	kg	1.27E-05	4.24E-06	33.4%	2.75E-07	6.06E-06	6.51E-07	1.48E-06
	7	N2O	kg	6.02E-02	3.71E-02	61.6%	4.54E-03	1.19E-02	3.03E-03	3.59E-03
	8	NMHC	kg	2.32E-02	7.73E-03	33.4%	5.01E-04	1.10E-02	1.19E-03	2.70E-03
	9	NOx	kg	1.71E+00	7.05E-01	41.3%	8.02E-02	1.15E-01	7.66E-01	4.09E-02
	10	NOx (mobile source)	kg	3.03E-01	7.99E-02	26.4%	9.43E-03	3.24E-02	1.64E-01	1.64E-02
	11	Ni	kg	2.15E-05	7.18E-06	33.4%	4.65E-07	1.03E-05	1.10E-06	2.51E-06
	12	PM10 (mobile source)	kg	1.52E-02	5.84E-03	38.4%	6.79E-04	2.38E-03	5.56E-03	7.50E-04
	13	Pb	kg	5.04E-05	1.68E-05	33.4%	1.09E-06	2.40E-05	2.58E-06	5.88E-06

Table 4.4 LCI result for of book production by Normal/Best practice

<Normal Practice>

Category	No.	Item	Units	Total	Paper		other materials	Production	Delivery	Rec.&Disp.
Resources	1	Al reserves	kg	1.00E+01			8.21E+00			1.79E+00
	2	Cu reserves	kg	4.75E−06			4.75E−06			
	3	Pb reserves	kg	1.75E−07			1.75E−07			
	4	U reserves	kg	2.49E−02	9.71E−03	39.0%	1.81E−04	1.43E−02	2.00E−05	7.10E−04
	5	Zn reserves	kg	9.70E−07			9.70E−07			
	6	coal (coke)	kg	6.68E−06			6.68E−06			
	7	coal (combustion)	kg	8.28E+02	6.25E+02	75.5%	2.66E+01	1.62E+02	1.28E+00	1.25E+01
	8	cryolite	kg	6.04E−01			4.96E−01			1.08E−01
	9	limestone	kg	2.33E−03			2.33E−03	3.01E−06		
	10	natural gas	kg	1.44E+02	5.92E+01	41.2%	4.30E+00	7.54E+01	1.21E−01	4.57E+00
	11	oil reserves	kg	6.83E+02	5.73E+02	83.9%	2.53E+01	5.52E+01	1.32E+01	1.62E+01
	12	silica sand	kg	1.42E−06			1.42E−06			
Air	1	CO2	kg	4.77E+03	3.70E+03	77.6%	1.45E+02	7.71E+02	4.61E+01	1.06E+02
	2	As	kg	2.35E−05	9.21E−06	39.2%	7.87E−08	1.35E−05	1.89E−08	6.36E−07
	3	CH4	kg	1.96E−01	1.75E−01	89.2%	1.57E−03	1.79E−02	3.56E−04	1.32E−03
	4	Cd	kg	1.94E−06	7.62E−07	39.2%	6.51E−09	1.12E−06	1.57E−09	5.26E−08
	5	Cr	kg	4.27E−05	1.68E−05	39.2%	1.43E−07	2.46E−05	3.45E−08	1.16E−06
	6	Hg	kg	2.84E−05	1.11E−05	39.2%	9.50E−08	1.63E−05	2.29E−08	7.68E−07
	7	N2O	kg	1.16E−01	6.39E−02	55.3%	1.27E−02	3.35E−02	7.51E−04	4.62E−03
	8	NMHC	kg	5.17E−02	2.03E−02	39.2%	1.73E−04	2.98E−02	4.17E−05	1.40E−03
	9	NOx	kg	3.09E+00	2.45E+00	79.3%	2.41E−01	3.20E−01	5.94E−03	7.20E−02
	10	NOx (mobile source)	kg	7.03E−01	3.41E−01	48.5%	9.43E−03	1.12E−01	1.59E−01	8.24E−02
	11	Ni	kg	4.80E−05	1.88E−05	39.2%	1.61E−07	2.77E−05	3.88E−08	1.30E−06
	12	PM10 (mobile source)	kg	3.91E−02	2.50E−02	63.8%	6.78E−04	6.80E−03	5.10E−03	1.61E−03
	13	Pb	kg	1.13E−04	4.41E−05	39.2%	3.77E−07	6.48E−05	9.08E−08	3.05E−06
	14	SO2	kg	4.07E+00	3.50E+00	86.0%	4.28E−01	4.21E−02	7.57E−03	9.28E−02
	15	SOx	kg	3.37E−01	1.94E−01	57.6%	3.49E−03	1.20E−01	8.29E−03	1.06E−02
	16	dust	kg	8.84E−01	8.34E−01	94.3%	3.28E−02	8.69E−03	1.76E−03	7.00E−03
	17	hydrocarbons	kg	8.66E−02	5.17E−02	59.6%	3.15E−03	1.80E−02	7.27E−03	6.54E−03
Water	1	As	kg	2.28E−10			2.28E−10			
	2	BOD	kg	3.56E−03			3.56E−03	5.43E−08		0.00E+00
	3	COD	kg	1.88E−02						1.88E−02
	4	Cd	kg	3.42E−11			3.42E−11			
	5	Cr	kg	6.83E−10			6.83E−10			
	6	Hg	kg	2.28E−11			2.28E−11			
Industrial	1	earth & sand (landfill)	kg	2.15E+01			1.76E+01			3.84E+00
	2	industrial waste landfill (unspecified)	kg	2.81E+02			2.21E+00			2.79E+02
	3	low-level radioactive waste	kg	1.74E−02	6.79E−03	39.0%	1.26E−04	9.97E−03	1.40E−05	4.96E−04
	4	plastic wastes (landfill)	kg	3.58E−09			3.58E−09			
	5	rubbles (landfill)	kg	7.10E−09			7.10E−09			
	6	slag (landfill)	kg	9.17E−06			9.17E−06			
	7	sludge (landfill)	kg	4.43E+02						4.43E+02

<Best Practice>

Category	No.	Item	Units	Total	Paper		other materials	Production	Delivery	Rec.&Disp.
Resources	1	Al reserves	kg	1.00E+01			8.21E+00			1.79E+00
	2	U reserves	kg	2.26E−02	7.61E−03	33.6%	1.80E−04	1.43E−02	1.99E−05	5.74E−04
	3	coal (combustion)	kg	6.91E+02	4.90E+02	71.0%	2.64E+01	1.62E+02	1.27E+00	1.10E+01
	4	cryolite	kg	6.04E−01			4.96E−01			1.08E−01
	5	limestone	kg	1.22E−03			1.70E−03	3.01E−06		
	6	natural gas	kg	1.30E+02	4.64E+01	35.7%	4.28E+00	7.54E+01	1.21E−01	3.85E+00
	7	oil reserves	kg	5.51E+02	4.49E+02	81.5%	2.42E+01	5.52E+01	1.06E+01	1.48E+01
Air	1	CO2	kg	3.94E+03	2.90E+03	73.6%	1.43E+02	7.71E+02	3.77E+01	9.36E+01
	2	As	kg	2.14E−05	7.22E−06	33.8%	7.78E−08	1.35E−05	1.89E−08	5.07E−07
	3	CH4	kg	1.57E−01	1.37E−01	87.0%	1.47E−03	1.79E−02	3.56E−04	1.07E−03
	4	Cd	kg	1.77E−06	5.97E−07	33.8%	6.43E−09	1.12E−06	1.56E−09	4.19E−08
	5	Cr	kg	3.89E−05	1.31E−05	33.8%	1.42E−07	2.46E−05	3.44E−08	9.23E−07
	6	Hg	kg	2.58E−05	8.72E−06	33.8%	9.40E−08	1.63E−05	2.28E−08	6.13E−07
	7	N2O	kg	1.01E−01	5.01E−02	49.7%	1.26E−02	3.35E−02	6.16E−04	4.26E−03
	8	NMHC	kg	4.70E−02	1.59E−02	33.8%	1.71E−04	2.98E−02	4.16E−05	1.12E−03
	9	NOx	kg	2.55E+00	1.92E+00	75.3%	2.40E−01	3.20E−01	5.74E−03	6.78E−02
	10	NOx (mobile source)	kg	5.94E−01	2.67E−01	45.0%	9.34E−03	1.12E−01	1.24E−01	8.16E−02
	11	Ni	kg	4.37E−05	1.48E−05	33.8%	1.59E−07	2.77E−05	3.87E−08	1.04E−06
	12	PM10 (mobile source)	kg	3.26E−02	1.96E−02	60.1%	6.72E−04	6.80E−03	4.00E−03	1.55E−03
	13	Pb	kg	1.02E−04	3.46E−05	33.8%	3.73E−07	6.48E−05	9.06E−08	2.43E−06
	14	SO2	kg	3.30E+00	2.74E+00	83.0%	4.26E−01	4.21E−02	7.47E−03	9.10E−02
	15	SOx	kg	2.92E−01	1.52E−01	52.2%	3.37E−03	1.20E−01	6.58E−03	9.38E−03
	16	dust	kg	7.03E−01	6.54E−01	93.0%	3.25E−02	8.69E−03	1.75E−03	6.81E−03
	17	hydrocarbons	kg	7.36E−02	4.05E−02	55.0%	3.12E−03	1.80E−02	5.71E−03	6.38E−03
Water	1	BOD	kg	1.89E−03			2.65E−03	5.43E−08		
	2	COD	kg	1.47E−02						1.47E−02
Industrial	1	earth & sand (landfill)	kg	2.15E+01			1.76E+01			3.84E+00
	2	industrial waste landfill (unspecified)	kg	2.21E+02			2.21E+00			2.18E+02
	3	low-level radioactive waste	kg	1.58E−02	5.32E−03	33.6%	1.26E−04	9.97E−03	1.39E−05	4.01E−04

4.3.3 Environmental Load Point (ELP)

4.3.3.1 Overview of ELP

Environmental Load Point method (ELP) is based on an evaluation of nine impact categories and originally invented by Nagata Laboratory at Waseda University. Outstanding feature is that order of priority for environmental load is decided by questionnaires from variety kinds of interest groups regardless of home and abroad. This idea is based on preference order about impact categories which should be determined by estimator’s concern level about impact categories.

Weighting for each impact category is called “category importance”; it is a critical factor when consolidating environmental loads as an integrated indicator. Category importance ratio, namely weight coefficient for impact category can be casting coefficient which can combines the loads for impact category as an environmental load credit. In ELP, questionnaire such as Analytic Hierarchy Process (AHP) is utilized primarily to specify category importance for a specific group. Table 4.5 indicates an example of AHP explaining how it determines category importance ratio as an example.

Table 4.5 Questionnaire designed by Analytic Hierarchy Process

	ELP 9-category	B									Multiplication of 9Cs*1	Category importance*2	Category importance ratio*3	Definition of importance	
		1.Energy drain	2.Global warming	3.Ozone depletion	4.Acid precipitate	5.Resource consumption	6.Air pollution	7.Ocean & water pollution	8.Problem of waste disposal	9.Ecosystem effect					
A	1.Energy drain	1.00	3.00	5.00	5.00	1.00	3.00	5.00	1.00	3.00	3,375.00	2.47	0.216	9.00	A is much more important to the max
	2.Global warming	0.33	1.00	3.00	3.00	0.33	1.00	0.33	0.20	1.00	0.07	0.74	0.065	7.00	A is much more important
	3.Ozone depletion	0.20	0.33	1.00	1.00	0.20	0.33	0.20	0.20	1.00	0.00	0.38	0.034	5.00	A is more important
	4.Acid precipitate	0.20	0.33	1.00	1.00	0.20	0.20	0.20	0.20	0.33	0.00	0.32	0.028	3.00	A is a bit more important
	5.Resource consumption	1.00	3.00	5.00	5.00	1.00	0.33	0.33	0.33	1.00	2.77	1.12	0.098	1.00	A is almost same as B
	6.Air pollution	0.33	1.00	3.00	5.00	3.00	1.00	0.33	0.20	1.00	1.00	1.00	0.088	1/3 (0.333)	B is a bit more important
	7.Ocean & water pollution	0.20	3.00	5.00	5.00	3.00	3.00	1.00	0.33	1.00	45.09	1.53	0.134	1/5 (0.200)	B is more important
	8.Problem of waste disposal	1.00	5.00	5.00	5.00	3.00	5.00	3.00	1.00	3.00	16,908.80	2.95	0.259	1/7 (0.143)	B is much more important
	9.Ecosystem effect	0.33	1.00	1.00	3.00	1.00	1.00	1.00	0.33	1.00	0.33	0.89	0.078	1/9 (0.111)	B is much more important to the max
											20,333.06	11.391	1.000		

Reference: Nagata Laboratory at Waseda University

*1: Multiplication of 9 impact categories
*2: One ninth power of multiplied answer of 9 impact categories
*3: One ninth power of multiplied answer of 9 impact categories is devided by total value of category importance

ELP has over 185 of input/output items such as crude oil, coal, iron ore, CO_2, landfill and others in nine impact categories. Weight coefficients for each item in impact category should be organized by related references; it is summarized in Table 4.6.

Table 4.6 Reference to fix weight coefficients for items in impact categories

Impact category	Item(number of items)	Reference to fix weight coefficient for items in impact category	Category importance from AHP*4
1 Energy drain	Cruide oil, coal..(5)	Low calorific value/Reserve production ratio (Crude oil=1)*2	0.089
2 Global warming	CO2, CH4,CFC..(38)	GWP100*1 (CO2=1)*2	0.082
3 Ozone depletion	CFCs..(24)	ODP (CFC−11=1)*2	0.098
4 Acid precipitate	NH3, SOx..(7)	AP (SOx=1)*2	0.086
5 Resource consumption*3	Iron ore, Boexite..(32)	1/Reserve production ratio (Iron ore=1)*2	0.072
6 Air pollution	SOx, NOx..(10)	1/Environmental criteria (SOx=1)*2	0.134
7 Ocean & water pollution	BOD, COD..(37)	1/Environmental criteria (BOD=1)*2	0.135
8 Problem of waste disposal	Weight calculation (1)	1 (Weight calculation)	0.107
9 Ecosystem influence	Hg, Dioxine..(32)	Hydrosphere biological toxic qualification factor(Cr=1)*2	0.197

Reference: Nagata Laboratory at Waseda University

*1: GWP values from IPCC AR2
*2: Relativize based on item in bracket
*3: Consumption of crude oil is not included
*4: Category importance determined by AHP from Chemical related Academi members

For example, division process of low calorific value and reserve-production ratio (recoverable reserves/annual production) fixing weight coefficients for items in Energy Drain can relativize all items based on precondition that crude oil is one.

After category importance is summarized for impact categories, and then annual load for each item and impact category is figured out; it is shown in Table 4.7.

Weight coefficients for items in impact categories are set by the explanation already mentioned above. Then, consumption or emission from each item should be investigated from statistics in Japan since target product is produced domestically. Annual load is led from multiplication of weight coefficient and consumption or emission; it is quite simple mathematical formula.

Continuous research to investigate consumption and emission of each item must be necessary to update ELP evaluation system, but it has not been done since anchoring point should be the same when comparing current data to past data.

Though considering a reason not to change basic data of consumption and emission, ELP utilized here is based on updated data because evaluating Printing Service by ELP is the very first trial, no data in the past can be compared.

There are some more reasons to change basic data. Firstly, Global Warming is worth noting issue now, so it should be weighted more than it used to be since danger of it is rated as the most influential factor. Additionally, some items are reduced to be used because those have hazardous components for human health.

Table 4.7 Annual loads for each item in each impact category

Impact category	Item	Weight coefficient C	Consumtion or Emission TQ	Annual load A=C×TQ	Year	Reference
Energy drain	oil	1.00E+00	1.99E+11	1.99E+11	2006	*1 Energy Statistics Yearbook 2006, United Nations
	coal	1.10E-01	1.79E+11	1.97E+10	2006	*1 Energy Statistics Yearbook 2006, United Nations
	natural gas	7.70E-01	7.22E+10	5.56E+10	2007	*2 BP Statistics 2008, BP
	uranium ore	1.48E+01	1.09E+07	1.61E+08	2010	*3 Uranium2003:Resources/Production/Demand, OECD Nuclear Energy Agency
	wood	5.00E-02	6.87E+10	3.43E+09	2005	*4 Wood Consumption & Self-sufficient Ratio, Forestry Agency
			Sub total:	2.78E+11		
Global warming	CO2	1.00E+00	1.21E+12	1.21E+12	2008	*5 GHG Emission Data, Greenhouse Gas Inventory Office of Japan
	N2O	3.20E+02	2.25E+10	7.19E+12	2008	*5 GHG Emission Data, Greenhouse Gas Inventory Office of Japan
	CH4	2.45E+01	2.13E+10	5.21E+11	2008	*5 GHG Emission Data, Greenhouse Gas Inventory Office of Japan
	CFC-11	4.00E+03	4.50E+04	1.80E+08	1999	*6 CFC Emission in Japan, Ministry of Environment
	CFC-12	8.50E+03	1.25E+05	1.06E+09	1999	*6 CFC Emission in Japan, Ministry of Environment
	CFC-113	5.00E+03	1.50E+04	7.50E+07	1999	*6 CFC Emission in Japan, Ministry of Environment
	CFC-114	9.30E+03	0.00E+00	0.00E+00	1999	*6 CFC Emission in Japan, Ministry of Environment
	CFC-115	9.30E+03	1.50E+04	1.40E+08	1999	*6 CFC Emission in Japan, Ministry of Environment
			Sub total:	8.92E+12		
Ozone depletion	CFC-11	1.00E+00	4.50E+04	4.50E+04	1999	*6 CFC Emission in Japan, Ministry of Environment
	CFC-12	1.00E+00	1.25E+05	1.25E+05	1999	*6 CFC Emission in Japan, Ministry of Environment
	CFC-113	1.07E+00	1.50E+04	1.61E+04	1999	*6 CFC Emission in Japan, Ministry of Environment
	CFC-114	8.00E-01	0.00E+00	0.00E+00	1999	*6 CFC Emission in Japan, Ministry of Environment
	CFC-115	5.00E-01	1.50E+04	7.50E+03	1999	*6 CFC Emission in Japan, Ministry of Environment
			Sub total:	1.94E+05		
Acid precipitate	NOx(NO2)	7.00E-01	8.90E+08	6.23E+08	2005	*7 Air Pollutant Emission, Ministry of Environment
	SOx(SO2)	1.00E+00	5.67E+08	5.67E+08	2005	*7 Air Pollutant Emission, Ministry of Environment
	NH3	1.88E+00	3.45E+08	6.48E+08	2009	*8 Chemical Industry Statistics, Ministry of Economy Trade & Industry
	HCl	8.80E-01	2.40E+06	2.11E+06	1985	*A Roskill's Metal Databook 6th Edition, Roskill Information Services
			Sub total:	1.84E+09		
Resource consumption	iron ore	1.00E+00	1.39E+11	1.39E+11	2007	*9 Imported Iron ore, World Steel Association
	bauxite	6.40E-01	1.81E+09	1.16E+09	2005	*10 Aluminum ore, National Institute of Radiological Sciences
	Cu	5.23E+00	1.28E+09	6.69E+09	2004	*11 Consumption Analysis of World Base Metal, Mineral Resources Information Center
	Pb	6.70E+00	2.16E+08	1.45E+09	2004	*11 Consumption Analysis of World Base Metal, Mineral Resources Information Center
	Zn	5.67E+00	6.21E+08	3.52E+09	2004	*11 Consumption Analysis of World Base Metal, Mineral Resources Information Center
	Sb	9.27E+00	1.20E+07	1.11E+08	2008	*12 Recycle of Rare metal, Ministry of Economy Trade & Industry
	As	5.65E+00	7.35E+05	4.15E+06	2005	*11 Consumption Analysis of World Base Metal, Mineral Resources Information Center
	Bi	4.25E+00	1.39E+06	5.91E+06	2006	*11 Consumption Analysis of World Base Metal, Mineral Resources Information Center
	Cd	4.68E+00	1.93E+06	9.05E+06	2007	*13 Newsletter#54, People's Association on Countermeasures of Dioxin & Eds
	Cr	5.00E-01	8.92E+08	4.46E+08	2003	*12 Recycle of Rare metal, Ministry of Economy Trade & Industry
	Co	8.90E-01	1.50E+07	1.34E+07	2008	*12 Recycle of Rare metal, Ministry of Economy Trade & Industry
	Ga	1.00E-02	1.40E+05	1.40E+03	2008	*12 Recycle of Rare metal, Ministry of Economy Trade & Industry
	Au	6.71E+00	3.52E+04	2.36E+05	2008	*14 Import Clearance, Ministry of Finance
	In	1.30E+01	5.00E+05	6.52E+06	2008	*12 Recycle of Rare metal, Ministry of Economy Trade & Industry
	Hg	2.70E+00	9.50E+03	2.57E+04	2005	*15 Materialflow of Mercury, Ministry of Environment
	Ni	3.50E+00	1.80E+08	6.30E+08	2008	*12 Recycle of Rare metal, Ministry of Economy Trade & Industry
	Pt	5.50E-01	5.00E+04	2.75E+04	2008	*12 Recycle of Rare metal, Ministry of Economy Trade & Industry
	rare earthes	1.10E-01	2.00E+07	2.20E+06	2008	*12 Recycle of Rare metal, Ministry of Economy Trade & Industry
	Re	2.51E+00	3.00E+03	7.53E+03	2004	*11 Consumption Analysis of World Base Metal, Mineral Resources Information Center
	Se	2.54E+00	2.68E+05	6.81E+05	2004	*11 Consumption Analysis of World Base Metal, Mineral Resources Information Center
	Ag	8.01E+00	4.45E+06	3.56E+07	2008	*14 Import Clearance, Ministry of Finance
	Tl	5.57E+00	0.00E+00	-	-	
	Sn	3.85E+00	7.01E+06	2.70E+07	2004	*11 Consumption Analysis of World Base Metal, Mineral Resources Information Center
	W	2.21E+00	5.00E+06	1.11E+07	2008	*12 Recycle of Rare metal, Ministry of Economy Trade & Industry
	Mo	3.31E+00	3.00E+07	9.93E+07	2008	*12 Recycle of Rare metal, Ministry of Economy Trade & Industry
	Mn	1.40E+00	9.00E+08	1.26E+09	2008	*12 Recycle of Rare metal, Ministry of Economy Trade & Industry
	V	5.60E-01	6.50E+06	3.64E+06	2008	*12 Recycle of Rare metal, Ministry of Economy Trade & Industry
	Ta	5.56E+00	6.00E+05	3.34E+06	2008	*12 Recycle of Rare metal, Ministry of Economy Trade & Industry
	Mg	1.60E-01	4.30E+07	6.88E+06	2004	*16 Agenda of Manganese industry, Ministry of Economy Trade & Industry
	Ge	9.52E-04	3.72E+04	3.54E+01	2000	*17 Newsletter#49, People's Association on Countermeasures of Dioxin & Eds
	Li	6.20E-01	1.97E+07	1.22E+07	2007	*18 Demand & Supply of Rare earthes, Japan Oil/Gas/Metals National Corporation
	Zr	1.77E+00	9.17E+06	1.62E+07	2002	*19 Demand & Supply of 7 metals, Ministry of Economy Trade & Industry
			Sub total:	1.54E+11		
Air pollution	NOx(NO2)	1.40E+00	8.90E+08	1.25E+09	2005	*7 Air Pollutant Emission, Ministry of Environment
	SOx(SO2)	1.00E+00	5.67E+08	5.67E+08	2005	*7 Air Pollutant Emission, Ministry of Environment
	CO	1.00E-02	0.00E+00	-	-	
	NMHC	8.10E-01	7.70E+07	6.24E+07	1991	*20 Emission of NMHC, Tokyo Metropolitan Government
	Particulates	1.09E+00	5.80E+07	6.32E+07	2005	*7 Air Pollutant Emission, Ministry of Environment
	HCl	7.25E-01	2.40E+06	1.74E+06	1985	*A Roskill's Metal Databook 6th Edition, Roskill Information Services
	Dioxin	1.91E+08	3.63E-01	6.93E+07	2004	*21 Emission Inventory of Dioxin, Ministry of Environment
			Sub total:	2.01E+09		
Ocean & water pollution	BOD	1.00E+00	7.80E+08	7.80E+08	1988	*B Columbium & Tantalum Minerals Yearbook, US Geological Survey
	COD	1.00E+00	1.56E+09	1.56E+09	1988	*B Columbium & Tantalum Minerals Yearbook, US Geological Survey
	Dioxin	2.00E+10	5.60E-04	1.12E+07	1993	*C Mineral Commodity Summaries, US Geological Survey
			Sub total:	2.35E+09		
Waste disposal	Solid Waste	1.00E+00	4.81E+10	4.81E+10	2008	*22 Emission & Processing of Disposal in 2008, Ministry of Environment
			Sub total:	4.81E+10		
Ecosystem influence	Dioxin	1.40E+03	3.63E-01	5.08E+02	2004	*21 Emission Inventory of Dioxin, Ministry of Environment
			Sub total:	5.08E+02		

After LCI data of items are organized (Classification), all items are assigned to nine impact categories (Characterization) which are taken up, then summarized (Normalization) as ELP which is an integrated indicator for each process. A stream of Classification, Characterization and Normalization is shown in Figure 4.1.

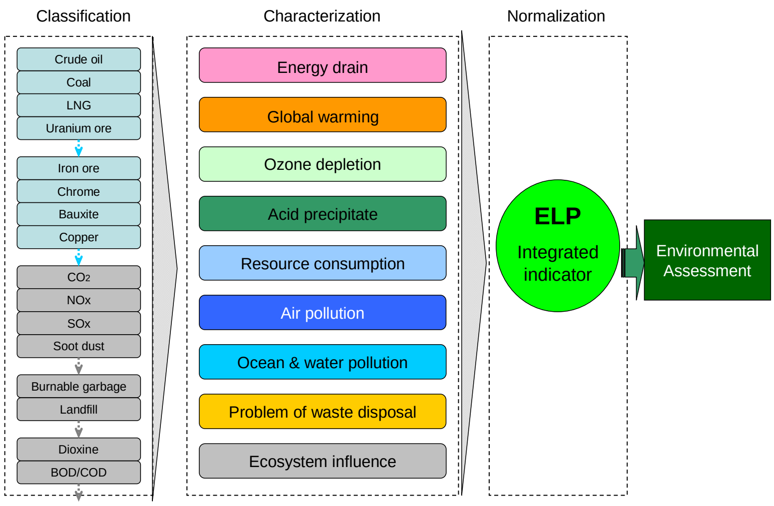


Figure 4.1 Stream of Environmental Load Point

In order to calculate ELP, Environmental Load Factor (ELF) which is emission factor of ELP must be formulated in advance. Its method is shown in Table 4.8.

Table 4.8 ELF calculations for items in nine impact categories

Impact category	Item	Weighting coefficient C	Consumption or TQ	Annual load AL=C*TQ	ELF for item C*AHP[*1]/AL*10^16
Energy drain	oil	1.00E+00	1.99E+11	1.99E+11	3.20E+03
	coal	1.10E-01	1.79E+11	1.97E+10	3.52E+02
	natural gas	7.70E-01	7.22E+10	5.56E+10	2.46E+03
	uranium ore	1.48E+01	1.09E+07	1.61E+08	4.74E+04
	wood	5.00E-02	6.87E+10	3.43E+09	1.60E+02
			Sub total:	2.78E+11	
Global warming	CO2	1.00E+00	1.21E+12	1.21E+12	9.19E+01
	N2O	3.20E+02	2.25E+10	7.19E+12	2.94E+04
	CH4	2.45E+01	2.13E+10	5.21E+11	2.25E+03
	CFC-11	4.00E+03	4.50E+04	1.80E+08	3.68E+05
	CFC-12	8.50E+03	1.25E+05	1.06E+09	7.81E+05
	CFC-113	5.00E+03	1.50E+04	7.50E+07	4.59E+05
	CFC-114	9.30E+03	0.00E+00	0.00E+00	8.54E+05
	CFC-115	9.30E+03	1.50E+04	1.40E+08	8.54E+05
			Sub total:	8.92E+12	
Ozone depletion	CFC-11	1.00E+00	4.50E+04	4.50E+04	5.06E+09
	CFC-12	1.00E+00	1.25E+05	1.25E+05	5.06E+09
	CFC-113	1.07E+00	1.50E+04	1.61E+04	5.42E+09
	CFC-114	8.00E-01	0.00E+00	0.00E+00	4.05E+09
	CFC-115	5.00E-01	1.50E+04	7.50E+03	2.53E+09
			Sub total:	1.94E+05	
Acid precipitate	NOx(NO2)	7.00E-01	8.90E+08	6.23E+08	3.27E+05
	SOx(SO2)	1.00E+00	5.67E+08	5.67E+08	4.67E+05
	NH3	1.88E+00	3.45E+08	6.48E+08	8.79E+05
	HCl	8.80E-01	2.40E+06	2.11E+06	4.11E+05
			Sub total:	1.84E+09	
Resource consumption	iron ore	1.00E+00	1.39E+11	1.39E+11	4.66E+03
	bauxite	6.40E-01	1.81E+09	1.16E+09	2.98E+03
	Cu	5.23E+00	1.28E+09	6.69E+09	2.44E+04
	Pb	6.70E+00	2.16E+08	1.45E+09	3.12E+04
	Zn	5.67E+00	6.21E+08	3.52E+09	2.64E+04
	Sb	9.27E+00	1.20E+07	1.11E+08	4.32E+04
	As	5.65E+00	7.35E+05	4.15E+06	2.63E+04
	Bi	4.25E+00	1.39E+06	5.91E+06	1.98E+04
	Cd	4.68E+00	1.93E+06	9.05E+06	2.18E+04
	Cr	5.00E-01	8.92E+08	4.46E+08	2.33E+03
	Co	8.90E-01	1.50E+07	1.34E+07	4.15E+03

Impact category	Item	Weighting coefficient C	Consumption or TQ	Annual load AL=C*TQ	ELF for item C*AHP/AL*10^16
Resource consumption	Ga	1.00E-02	1.40E+05	1.40E+03	4.66E+01
	Au	6.71E+00	3.52E+04	2.36E+05	3.13E+04
	In	1.30E+01	5.00E+05	6.52E+06	6.07E+04
	Hg	2.70E+00	9.50E+03	2.57E+04	1.26E+04
	Ni	3.50E+00	1.80E+08	6.30E+08	1.63E+04
	Pt	5.50E-01	5.00E+04	2.75E+04	2.56E+03
	rare earthes	1.10E-01	2.00E+07	2.20E+06	5.13E+02
	Re	2.51E+00	3.00E+03	7.53E+03	1.17E+04
	Se	2.54E+00	2.68E+05	6.81E+05	1.18E+04
	Ag	8.01E+00	4.45E+06	3.56E+07	3.73E+04
	Tl	5.57E+00	0.00E+00	-	-
	Sn	3.85E+00	7.01E+06	2.70E+07	1.79E+04
	W	2.21E+00	5.00E+06	1.11E+07	1.03E+04
	Mo	3.31E+00	3.00E+07	9.93E+07	1.54E+04
	Mn	1.40E+00	9.00E+08	1.26E+09	6.53E+03
	V	5.60E-01	6.50E+06	3.64E+06	2.61E+03
	Ta	5.56E+00	6.00E+05	3.34E+06	2.59E+04
	Mg	1.60E-01	4.30E+07	6.88E+06	7.46E+02
	Ge	9.52E-04	3.72E+04	3.54E+01	4.44E+00
	Li	6.20E-01	1.97E+07	1.22E+07	2.89E+03
	Zr	1.77E+00	9.17E+06	1.62E+07	8.25E+03
			Sub total:	1.54E+11	
Air pollution	NOx(NO2)	1.40E+00	8.90E+08	1.25E+09	9.34E+05
	SOx(SO2)	1.00E+00	5.67E+08	5.67E+08	6.67E+05
	CO	1.00E-02	0.00E+00	-	-
	NMHC	8.10E-01	7.70E+07	6.24E+07	5.40E+05
	Particulates	1.09E+00	5.80E+07	6.32E+07	7.27E+05
	HCl	7.25E-01	2.40E+06	1.74E+06	4.83E+05
	Dioxin	1.91E+08	3.63E-01	6.93E+07	1.27E+14
			Sub total:	2.01E+09	
Ocean & water pollution	BOD	1.00E+00	7.80E+08	7.80E+08	5.74E+05
	COD	1.00E+00	1.56E+09	1.56E+09	5.74E+05
	Dioxin	2.00E+10	5.60E-04	1.12E+07	1.15E+16
			Sub total:	2.35E+09	
Waste disposal	Solid Waste	1.00E+00	4.81E+10	4.81E+10	2.22E+04
			Sub total:	4.81E+10	
Ecosystem influence	Dioxin	1.40E+03	3.63E-01	5.08E+02	5.43E+15
			Sub total:	5.08E+02	

Reference: Nagata Laboratory at Waseda University

*1: AHP is based on questionnaires from Chemical related Academi members

As explained above, case study in previous chapter is quoted as an example here. As preliminary preparation, total inputs or emissions per units (kg/kWh/tkm) from items are keyed in ELP's inventory datasheet for each process, it is presented in Table 4.9.

Table 4.9 ELF calculation for processes of package production (Normal)

Impact category	Item	ELF for item C*AHP/A*10^16	1.Cardboard		2.Al		3.Ink(Polyurethane)		4.Water		5.Electricity	
			Inventory data	ELF for process	Inventory data	ELF for process	Inventory data	ELF for process	Inventory data	ELF for process	Inventory data	ELF for process
Energy drain	oil	3.20E+03	1.12E-01	3.58E+02	1.45E+00	4.64E+03	1.42E+00	4.54E+03	4.93E-06	1.58E-02	1.80E-02	5.76E+01
	coal	3.52E+02	8.47E-02	2.98E+01	2.56E+00	9.01E+02	1.85E-01	6.51E+01	6.63E-08	2.33E-05	9.74E-02	3.43E+01
	natural gas	2.46E+03	3.43E-02	8.45E+01	3.56E-01	8.77E+02	8.59E-02	2.12E+02	1.08E-05	2.66E-02	4.52E-02	1.11E+02
	uranium ore	4.74E+04	2.07E-06	9.81E-02	1.73E-05	8.20E-01	1.63E-05	7.72E-01	2.05E-09	9.71E-05	8.55E-06	4.05E-01
	wood	1.60E+02										
Global warming	CO2	9.19E+01	6.91E-01	6.35E+01	1.22E+01	1.12E+03	3.73E+00	3.43E+02	1.08E-04	9.92E-03	4.46E-01	4.10E+01
	N2O	2.94E+04	2.08E-05	6.12E-01	1.20E-03	3.53E+01	1.14E-04	3.35E+00	4.66E-09	1.37E-04	1.94E-05	5.70E-01
	CH4	2.25E+03	1.95E-05	4.39E-02	5.84E-05	1.31E-01	1.51E-04	3.40E-01	2.36E-09	5.31E-06	9.45E-06	2.13E-02
Ozone depletion	CFC-11	5.06E+09										
	CFC-12	5.06E+09										
	CFC-113	5.42E+09										
	CFC-114	4.05E+09										
	CFC-115	2.53E+09										
Acid precipitate	NOx(NO2)	3.27E+05	4.42E-04	1.45E+02	2.45E-02	8.02E+03	1.98E-03	6.48E+02	5.91E-08	1.93E-02	2.39E-04	7.82E+01
	SOx(SO2)	4.67E+05	6.62E-04	3.09E+02	4.18E-02	1.95E+04	3.17E-03	1.48E+03	2.28E-08	1.07E-02	8.57E-05	4.01E+01
	NH3	8.79E+05										
	HCI	4.11E+05										
Resource consumption	iron ore	4.66E+03										
	bauxite	2.98E+03			3.52E+00	1.05E+04			9.35E-07	2.79E-03		
	Cu	2.44E+04							4.70E-08	1.15E-03		
	Cr	2.33E+03										
Air pollution	NOx(NO2)	9.34E+05	4.42E-04	4.13E+02	2.45E-02	2.29E+04	1.98E-03	1.85E+03	5.91E-08	5.52E-02	2.39E-04	2.23E+02
	SOx(SO2)	6.67E+05	6.62E-04	4.41E+02	4.18E-02	2.79E+04	3.17E-03	2.11E+03	2.28E-08	1.52E-02	8.57E-05	5.71E+01
	NMHC	5.40E+05										
	Particulates	7.27E+05	1.09E-04	7.92E+01	3.13E-03	2.27E+03	3.60E-04	2.62E+02	2.04E-09	1.48E-03	7.52E-06	5.47E+00
	HCI	4.83E+05										
	Dioxin	1.27E+14										
Ocean & water pollution	BOD	5.74E+05										
	COD	5.74E+05										
Waste disposal	Solid Waste	2.22E+04							4.65E-08	1.03E-03		
Ecosystem influence	Dioxin	5.43E+15										
		Total ELF:		1.92E+03		9.86E+04		1.15E+04		1.59E-01		6.49E+02

Impact category	Item	ELF for item C*AHP/A*10^16	6.Recycled Pulp		7.Recycled Al		8.2t-truck		9.4t-truck		10.10t-truck		11.Landfill	
			Inventory data	ELF for process	Inventory data	ELF for process	Inventory data	ELF for process	Inventory data	ELF for process	Inventory data	ELF	Inventory data	ELF for process
Energy drain	oil	3.20E+03	6.67E-03	2.13E+01	3.78E-01	1.21E+03	6.49E-02	2.08E+02	4.45E-02	1.42E+02	3.76E-02	1.20E+02	8.25E-04	2.64E+00
	coal	3.52E+02	3.60E-02	1.27E+01	5.81E-01	2.04E+02							1.95E-04	6.86E-02
	natural gas	2.46E+03	1.67E-02	4.11E+01	1.19E-01	2.93E+02							1.40E-04	3.45E-01
	uranium ore	4.74E+04	3.17E-06	1.50E-01	9.71E-06	4.60E-01							1.71E-08	8.10E-04
	wood	1.60E+02												
Global warming	CO2	9.19E+01	1.65E-01	1.52E+01	3.07E+00	2.82E+02	2.08E-01	1.91E+01	1.42E-01	1.30E+01	1.20E-01	1.10E+01	3.49E-03	3.21E-01
	N2O	2.94E+04	7.15E-06	2.10E-01	2.92E-04	8.59E+00	3.34E-06	9.82E-02	2.29E-06	6.73E-02	1.93E-06	5.67E-02	1.01E-07	2.97E-03
	CH4	2.25E+03	3.53E-06	7.95E-03	1.15E-05	2.59E-02							8.97E-08	2.02E-04
Ozone depletion	CFC-11	5.06E+09												
	CFC-12	5.06E+09												
	CFC-113	5.42E+09												
	CFC-114	4.05E+09												
	CFC-115	2.53E+09												
Acid precipitate	NOx(NO2)	3.27E+05	8.82E-05	2.89E+01	6.29E-03	2.06E+03	1.12E-03	3.66E+02	1.08E-03	3.53E+02	9.14E-04	2.99E+02	1.35E-06	4.42E-01
	SOx(SO2)	4.67E+05	3.09E-05	1.44E+01	9.80E-03	4.58E+03	4.50E-05	2.10E+01	3.08E-05	1.44E+01	2.60E-05	1.22E+01	3.30E-07	1.54E-01
	NH3	8.79E+05												
	HCI	4.11E+05												
Resource consumption	iron ore	4.66E+03												
	bauxite	2.98E+03			8.97E-01	2.68E+03								
	Cu	2.44E+04												
	Cr	2.33E+03												
Air pollution	NOx(NO2)	9.34E+05	8.82E-05	8.23E+01	6.29E-03	5.87E+03	1.12E-03	1.05E+03	1.08E-03	1.01E+03	9.14E-04	8.53E+02	1.35E-06	1.26E+00
	SOx(SO2)	6.67E+05	3.09E-05	2.06E+01	9.80E-03	6.53E+03	4.50E-05	3.00E+01	3.08E-05	2.05E+01	2.60E-05	1.73E+01	3.30E-07	2.20E-01
	NMHC	5.40E+05												
	Particulates	7.27E+05	2.72E-06	1.98E+00	7.38E-04	5.36E+02	1.17E-04	8.50E+01	7.94E-05	5.77E+01	6.70E-05	4.87E+01	1.14E-07	8.29E-02
	HCI	4.83E+05												
	Dioxin	1.27E+14												
Ocean & water pollution	BOD	5.74E+05												
	COD	5.74E+05											6.80E-05	3.90E+01
Waste disposal	Solid Waste	2.22E+04											1.60E+00	3.56E+04
Ecosystem influence	Dioxin	5.43E+15												
		Total ELF:		2.39E+02		2.43E+04		1.77E+03		1.61E+03		1.36E+03		3.56E+04

Reference: Nagata Laboratory at Waseda Univeristy

*ELF for process=ELF for item*Inventory data for process

Inventory data are excerpts from “Simple LCA” which is simplified version of LCA-Pro developed by JEMAI. Inventory data is weighted more in Energy drain and Global warming.

ELP's practical calculation steps are summarized below;

(1) In order to calculate annual load for each item in each impact category, weight coefficient which is fixed by the reference for item in category (Table 4.6) is multiplied by annual consumption or emission for item and summed up (Table 4.7) as annual load of base item equivalent for impact category.

(2) Weight coefficient for item in impact category is multiplied by category importance determined by AHP and divided by annual load for normalization (Table 4.8), then summed up for each impact category. Total of each item's consolidated coefficient is summarized as ELF which is emission factor of ELP for each process; it is basic element to calculate ELP. (Table 4.9)

(3) ELP is led by multiplication of ELFs for processes and total inputs or emissions for processes.

Mathematical formulas for three steps are shown below in concert with explanation.

$$A_j = \sum_k (C_{j,k} \times TQ_k) \qquad (1)$$

$$ELF_k = \sum_j (C_{j,k} \times W_j / A_j) \qquad (2)$$

$$ELP_i = \sum_k (ELF_k \times Q_{i,k}) \qquad (3)$$

ELP_i : Integrated indicator
A_j : Annual load in j impact category
$C_{j,k}$: Weight coefficient for k item in j impact category
TQ_k : Annual consumption or emission for k item
ELF_k: Integrated coefficient for k item
Wj: Weight coefficient from questionnaire in j impact category
$Q_{i,k}$: Total consumption or emission for k item in i process
Suffix I : Process or product
Suffix j : Impact category
Suffix k : Item in impact category

ELP evaluates environmental impacts with sufficient balance and is Integrated LCA approach illustrating environmental load from broad standpoints.

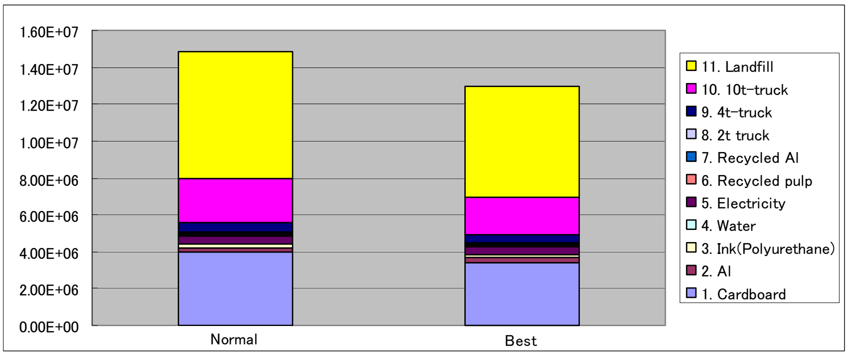
4.3.3.2 Practice of ELP

Comparison of Normal practice and Best practice of package production is performed; it is summarized in Figure 4.2. In the same light, Normal practice and Best practice of book production is compared, it is shown in Figure 4.3.

Process	ELF	Normal practice			Best practice			⊿	%
		Input	ELP		Input	ELP			
1. Cardboard	1.92E+03	2,070.684 kg	3.98E+06	26.8%	1,783.089 kg	3.43E+06	26.5%	-5.53E+05	-13.9%
2. Al	9.86E+04	2.500 kg	2.47E+05	1.7%	2.500 kg	2.47E+05	1.9%	0.00E+00	0.0%
3. Ink(Polyurethane)	1.15E+04	17.109 kg	1.97E+05	1.3%	16.292 kg	1.88E+05	1.5%	-9.41E+03	-4.8%
4. Water	1.59E-01	42.772 kg	6.82E+00	0.0%	0.000 kg	0.00E+00	0.0%	-6.82E+00	-100.0%
5. Electricity	6.49E+02	617.720 kWh	4.01E+05	2.7%	617.720 kWh	4.01E+05	3.1%	0.00E+00	0.0%
6. Recycled pulp	2.39E+02	472.860 kg	1.13E+05	0.8%	407.185 kg	9.73E+04	0.8%	-1.57E+04	-13.9%
7. Recycled Al	2.43E+04	2.500 kg	6.06E+04	0.4%	2.500 kg	6.06E+04	0.5%	0.00E+00	0.0%
8. 2t truck	1.77E+03	49.037 tkm	8.70E+04	0.6%	42.321 tkm	7.51E+04	0.6%	-1.19E+04	-13.7%
9. 4t-truck	1.61E+03	311.719 tkm	5.02E+05	3.4%	268.568 tkm	4.32E+05	3.3%	-6.95E+04	-13.8%
10. 10t-truck	1.36E+03	1,717.218 tkm	2.34E+06	15.7%	1,478.716 tkm	2.01E+06	15.6%	-3.25E+05	-13.9%
11. Landfill	3.56E+04	194.935 kg*1	6.95E+06	46.7%	167.860 kg*1	5.98E+06	46.3%	-9.65E+05	-13.9%
		Total ELP:	1.49E+07			1.29E+07		-1.95E+06	-13.1%

Reference: Nagata Laboratory at Waseda University

*Grey cells are changed by switching over from Normal practice to Best practice



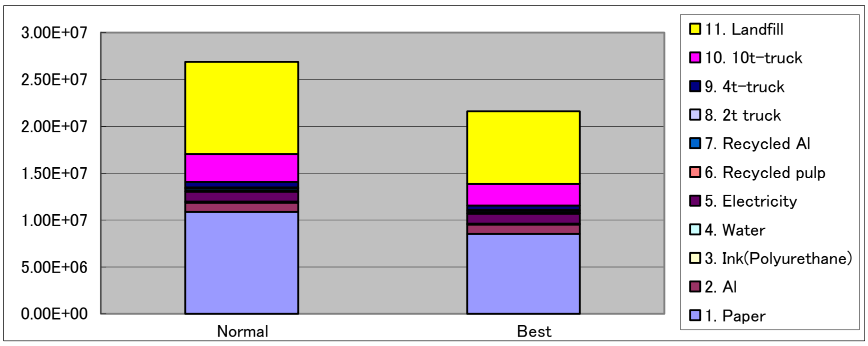
*1: Weight of products*Landfill ratio(12.2%)

Figure 4.2 Comparison of package production (Normal/Best) by ELP

Process	ELF	Normal practice			Best practice			⊿	%
		Input	ELP		Input	ELP			
1. Paper	4.18E+03	2,607.794 kg	1.09E+07	40.5%	2,043.913 kg	8.54E+06	39.5%	-2.35E+06	-21.6%
2. Al	9.86E+04	10.000 kg	9.86E+05	3.7%	10.000 kg	9.86E+05	4.6%	0.00E+00	0.0%
3. Ink(Polyurethane)	1.15E+04	9.406 kg	1.08E+05	0.4%	9.222 kg	1.06E+05	0.5%	-2.12E+03	-2.0%
4. Water	1.59E-01	23.516 kg	3.75E+00	0.0%	0.000 kg	0.00E+00	0.0%	-3.75E+00	-100.0%
5. Electricity	6.49E+02	1,636.630 kWh	1.06E+06	3.9%	1,636.630 kWh	1.06E+06	4.9%	0.00E+00	0.0%
6. Recycled pulp	2.39E+02	336.152 kg	8.03E+04	0.3%	267.672 kg	6.39E+04	0.3%	-1.64E+04	-20.4%
7. Recycled Al	2.43E+04	10.000 kg	2.43E+05	0.9%	10.000 kg	2.43E+05	1.1%	0.00E+00	0.0%
8. 2t truck	1.77E+03	68.763 tkm	1.22E+05	0.5%	53.702 tkm	9.53E+04	0.4%	-2.67E+04	-21.9%
9. 4t-truck	1.61E+03	366.588 tkm	5.90E+05	2.2%	288.840 tkm	4.65E+05	2.2%	-1.25E+05	-21.2%
10. 10t-truck	1.36E+03	2,162.643 tkm	2.95E+06	10.9%	1,695.089 tkm	2.31E+06	10.7%	-6.37E+05	-21.6%
11. Landfill	3.56E+04	277.140 kg*1	9.87E+06	36.7%	216.701 kg*1	7.72E+06	35.8%	-2.15E+06	-21.8%
		Total ELP:	2.69E+07			2.16E+07		-5.32E+06	-19.8%

Reference: Nagata Laboratory at Waseda University

*Grey cells are changed by switching over from Normal practice to Best practice



*1: Weight of products*Landfill ratio(12.2%)

Figure 4.3 Comparison of book production (Normal/Best) by ELP

ELP of package production from all processes is reduced from 1.49×10^7 to 1.29×10^7, it is cutback of 13.1% overall. Not surprisingly at all, it is certainly reduced in proportion to input of all processes.

A process with the highest ratio is Landfill though it is counted in only 12.2% of total waste; it occupies 46.7% of total ELP. The second highest ratio is Paper (Cardboard), its occupancy is just 26.8% which is totally different from over 70% from Global warming (CO_2e) calculation result in Table 4.3. The third highest ratio is 10t-truck for transportation for paper transportation; its occupancy is 15.7%. Total percentage of trucks for material transportation and delivery is almost 19.7%, it is regarded as outstanding load though it was not in Global warming calculation.

Meanwhile, ELP of book production from all processes is reduced from 2.69×10^7 to 2.16×10^7; it is cutdown of 19.8% total. Behavior of reduction from Normal to Best practice is all the same as package production.

Usage of paper is much more compared with package production, so its occupancy reaches over 40% of total ELP. Three major loads from Paper/Landfill/10t-truck is 88.1% total which is almost the same as 89.2% for package production though each process of major load is slightly different. Three major loads from Paper, Landfill, and Trucks occupy almost 90% of total ELP regardless of any sorts of Printing Services.

Total percentage of printing ink, printing machine and post-press related machines representing Printing Service is below 5% of ELP; those processes do not show their presence at all for both package and book production.

ELP can demonstrate what should be done to reduce environmental load other than reducing usage of paper clearly.

4.3.4 Life cycle Impact assessment Method based on Endpoint modeling (LIME)

4.3.4.1 Overview of LIME

LIME was originally invented based on environmental condition in Japan enhancing relationship with LCA National Project from 1998 to 2003. This method can calculate damage quantity at each endpoint such as human health through 11 impact categories and integrate environmental load by damage estimated approach. Invention of LIME is based on natural science perception such as epidemiology, meteorology, conservation biology and health statistics. Additionally, it is based on social science perception such as environmental economics, sociology and psychology taking a course of direction about general research in environmental field.

LIME grows out of current approach which takes stand on direct integration of environmental load. It can meet estimators' requirements because of organizing over 1,000 environment related materials and open to the public about its LCIA coefficients lists. Its stream is illustrated in Figure 4.4.

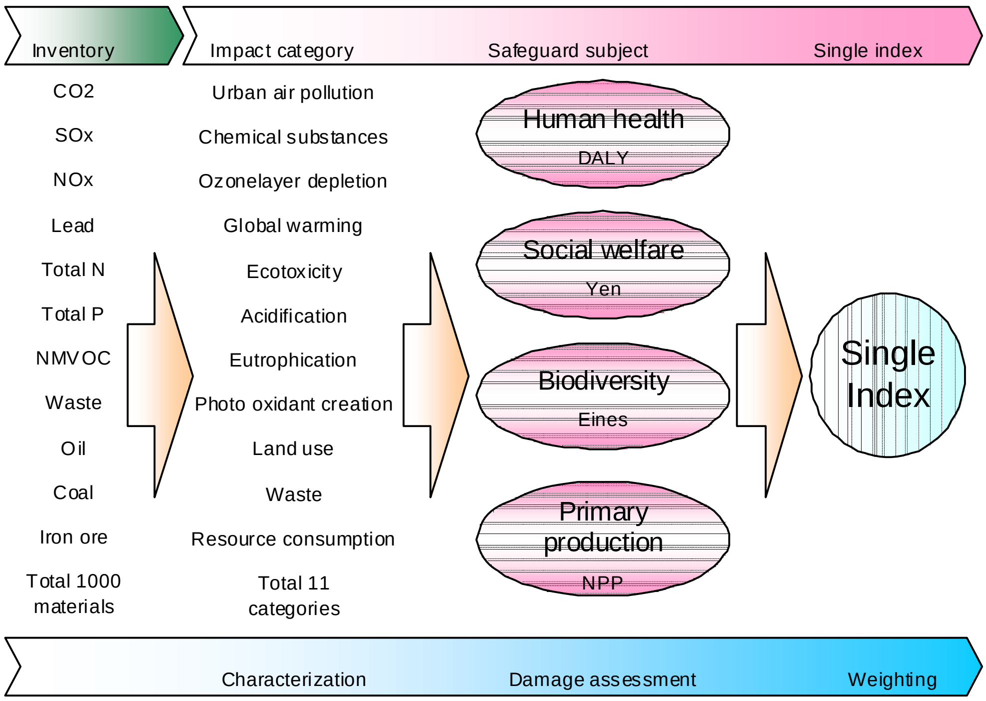


Figure 4.4 Stream of LIME

4.3.4.2 Practice of LIME

Some of impact categories are counted up in previous chapter already, so explain detailed process of calculation in Table 4.10 to lead indicator results. It shows actual case of Resource consumption for both package and book production. Environmental impacts from various kinds of resource extraction are calculated as one indicator by utilizing characterization factors for each item. Indicator result represents apparently-unified number summarizing the load from nine resources.

Table 4,10 Resource consumption of package/book production (Normal/Best) in LIME ver.3

Category	Item	Package production (Normal Practice)				Book production (Normal production)			
		LCI result	Unit	Characterization factor	Converted result*1	LCI result	Unit	Characterization factor	Converted result*1
resource	Al reserves	2.50E+00	kg	8.40E-05	2.10E-04	1.00E+01	kg	8.40E-05	8.40E-04
resource	coal (coke)	7.98E+00	kg	2.13E-06	1.70E-05	6.68E-06	kg	2.13E-06	1.42E-11
resource	coal (combustion)	2.67E+02	kg	2.13E-06	5.70E-04	8.28E+02	kg	2.13E-06	1.77E-03
resource	Cu reserves	8.65E-06	kg	6.18E-03	5.34E-08	4.75E-06	kg	6.18E-03	2.93E-08
resource	natural gas	1.12E+02	kg	1.61E-05	1.81E-03	1.44E+02	kg	1.61E-05	2.31E-03
resource	oil reserves	3.13E+02	kg	1.36E-05	4.25E-03	6.83E+02	kg	1.36E-05	9.28E-03
resource	Pb reserves	3.19E-07	kg	3.28E-02	1.05E-08	1.75E-07	kg	3.28E-02	5.74E-09
resource	U reserves	1.19E-02	kg	5.34E-01	6.38E-03	2.49E-02	kg	5.34E-01	1.33E-02
resource	Zn reserves	1.77E-06	kg	1.11E-02	1.95E-08	9.70E-07	kg	1.11E-02	1.07E-08
		Indicator result:			1.32E-02	Indicator result:			2.75E-02

Calculated by JEMAI LCA Pro

*1: Converted result=LCI result*Characterization factor

For characterization of Normal practice for both package and book productions, LCI result for each item is categorized into 11 impact categories indicating in Table 4.11. It clearly indicates that what sorts of characterization models are applied for impact categories to calculate Indicator result.

Table 4.11 Characterization for package/book production (Normal) by LIME ver.3

Impact category	Characterization model	Package production (Normal practice) Indicator result	Book production (Normal practice) Indicator result
Global warming	IPCC*1-100 years (2001)	2.19E+03	4.81E+03
Ozone depletion	WMO*2 1998	-	-
Human toxicity (carcinogenicity)	HTP*3_cancer	5.45E-01	1.13E+00
Human toxicity (chronic disease)	HTP*3 chronic disease	8.13E-04	1.69E-03
Aquatic ecotoxicity	AETP*4	1.41E+00	2.94E+00
Terrestrial ecotoxicity	TETP*5	3.21E+01	6.67E+01
Acidification	DAP*6	3.58E+00	7.12E+00
Eutrophication	EPMC*7	2.44E-02	4.19E-02
Photochemical oxidant	OCEF*8	2.72E-02	5.85E-02
Solid waste	m^3	5.49E-01	7.37E-01
Land use (occupation)	m^2/yr	-	-
Land use (transformation)	m^2	-	-
Resource consumption	1/R (Sb base)	1.32E-02	2.75E-02
Fossil energy resource consumption	MJ	2.66E+04	5.88E+04

Calculated by JEMAI LCA Pro

*1: Intergovernmental Panel on Climate Change
*2: World Meteorological Organization
*3: Human Toxicity Potential
*4: Aquatic Ecotoxicity Potential
*5: Terrestrial Ecotoxicity Potential
*6: Deposition-oriented Acidification Potential
*7: Eutrophication Potential considered marine Material Circulation
*8: Ozone Conversion Equivalency Factor

For Damage assessment, four safeguard subjects which are closely related to natural science and social science are calculated from LCI results in each category. Sum of Indicator result for each safeguard subject is summarized in Table 4.12. On the basis of summary from four safeguard subjects, both productions do not have significant impacts from the viewpoints of natural science and social science.

Table 4.12 Damage assessment for package/book production (Normal) by LIME ver.3

Item	Package Production (Normal Practice)				Book Production (Normal Practice)			
	Human health	Social assets	Biodiversity	Primary Productivity	Human health	Social assets	Biodiversity	Primary Productivity
	DALY*1	Yen	EINES*2	kg	DALY*1	Yen	EINES*2	kg
Global warming	2.68E−04	1.20E+03			5.89E−04	2.64E+03		
Ozone depletion								
Human toxicity	1.10E−06				2.29E−06			
Ecotoxicity			7.84E−13				1.63E−12	
Acidification		2.18E+02		1.16E+00		4.32E+02		2.30E+00
Eutrophication		9.49E−03				1.43E−02		
Photochemical oxidant	4.50E−07	1.75E+00		2.32E−01	9.67E−07	3.76E+00		4.98E−01
Solid waste			6.26E−11	1.73E+01			8.40E−11	2.32E+01
Land use								
Resource consumption		5.51E+02	7.67E−12	1.57E+01		1.13E+03	2.31E−11	4.73E+01
Urban air pollution	3.25E−04				7.88E−04			
Total:	5.95E−04	1.97E+03	7.10E−11	3.44E+01	1.38E−03	4.21E+03	1.09E−10	7.32E+01

Calculated by JEMAI LCA Pro

*1: Disability Adjusted Life Year
*2: Expected Increase in Number of Extinct Species

For weightings of both package and book production which are final works to summarize environmental loads as single indexes, items from four categories such as resource, air, water and industrial are summarized in Table 4.13 and Table 4.14.

Over 85% of total points for both practices come from emissions to the air since weighting coefficients are very high compared to other categories except for emission to the water. Highly estimated weight coefficients are used in referring to emissions from the water; but result is quite low because of low amount of emissions contrasting relatively high weighting coefficients. It is striking that industrial waste is estimated abundantly low though certain amount of packages and books are wasted and wind up in landfill. In spite of landfill is selected as disposal way, this low evaluation result contributes to a feeling of strangeness. The load might be too much weighted on air emission, especially on greenhouse gas, should be considered to be weighted on waste treatment.

During transition process from Normal to Best practice, the load scaled by LIME ver.3 is decreased at 7.3% in package production and 18.0% in book production individually.

Table 4.15 shows when the loads are categorized by 11 different characterizations for package and book productions for Normal/Best practices. At the bottom line, total points of 11 characterizations are summed as a result of LIME ver.3.

Table 4.13 Comparison of package production (Normal/Best) by LIME ver.3

Category	Item	Package production									
		Normal Practice				Best Practice				⊿	
		LCI result	Unit	Points	%	LCI result	Unit	Points	%	Points	%
resource	Al reserves	2.50E+00	kg	2.66E+00	0.0%	2.50E+00	kg	2.66E+00	0.0%	0.00E+00	0.0%
resource	coal (coke)	7.98E+00	kg	6.31E+00	0.1%	7.98E+00	kg	6.31E+00	0.1%	0.00E+00	0.0%
resource	coal (combustion)	2.67E+02	kg	2.11E+02	3.3%	2.41E+02	kg	1.90E+02	3.2%	−2.10E+01	−10.0%
resource	cryolite	1.51E−01	kg	5.74E−03	0.0%	1.51E−01	kg	5.74E−03	0.0%	0.00E+00	0.0%
resource	Cu reserves	8.65E−06	kg	2.37E−04	0.0%	0.00E+00	kg	0.00E+00	−	−2.37E−04	−
resource	limestone	1.92E+01	kg	7.31E−01	0.0%	1.83E+01	kg	6.96E−01	0.0%	−3.50E−02	−4.8%
resource	natural gas	1.12E+02	kg	3.87E+01	0.6%	1.01E+02	kg	3.49E+01	0.6%	−3.80E+00	−9.8%
resource	oil reserves	3.13E+02	kg	2.29E+02	3.6%	2.73E+02	kg	2.00E+02	3.4%	−2.90E+01	−12.7%
resource	Pb reserves	3.19E−07	kg	4.65E−06	0.0%	0.00E+00	kg	0.00E+00	−	−4.65E−06	−
resource	silica sand	2.58E−06	kg	9.80E−08	0.0%	0.00E+00	kg	0.00E+00	−	−9.80E−08	−
resource	U reserves	1.19E−02	kg	6.12E+00	0.1%	1.11E−02	kg	5.70E+00	0.1%	−4.20E−01	−6.9%
resource	Zn reserves	1.77E−06	kg	4.01E−05	0.0%	0.00E+00	kg	0.00E+00	−	−4.01E−05	−
			Sub total:	4.95E+02	7.8%		Sub total:	4.40E+02	7.5%	−5.43E+01	−11.0%
air	As	1.13E−05	kg	4.13E−01	0.0%	1.05E−05	kg	3.85E−01	0.0%	−2.80E−02	−6.8%
air	Cd	9.34E−07	kg	1.85E−01	0.0%	8.70E−07	kg	1.73E−01	0.0%	−1.20E−02	−6.5%
air	CH_4	5.31E−02	kg	1.69E+00	0.0%	4.70E−02	kg	1.50E+00	0.0%	−1.90E−01	−11.2%
air	CO_2	2.17E+03	kg	2.81E+03	44.5%	1.94E+03	kg	2.51E+03	42.9%	−3.00E+02	−10.7%
air	Cr	2.06E−05	kg	2.82E−01	0.0%	1.91E−05	kg	2.62E−01	0.0%	−2.00E−02	−7.1%
air	dust	2.39E−01	kg	5.02E+02	7.9%	2.07E−01	kg	4.36E+02	7.4%	−6.60E+01	−13.1%
air	Hg	1.36E−05	kg	1.03E+00	0.0%	1.27E−05	kg	9.55E−01	0.0%	−7.50E−02	−7.3%
air	hydrocarbons	3.95E−02	kg	4.63E+00	0.1%	3.41E−02	kg	4.00E+00	0.1%	−6.30E−01	−13.6%
air	N_2O	6.71E−02	kg	2.75E+01	0.4%	6.02E−02	kg	2.47E+01	0.4%	−2.80E+00	−10.2%
air	Ni	2.31E−05	kg	7.84E−02	0.0%	2.15E−05	kg	7.31E−02	0.0%	−5.30E−03	−6.8%
air	NMHC	2.49E−02	kg	2.92E+00	0.0%	2.32E−02	kg	2.72E+00	0.0%	−2.00E−01	−6.8%
air	NOx	1.83E+00	kg	2.67E+02	4.2%	1.71E+00	kg	2.49E+02	4.3%	−1.80E+01	−6.7%
air	NOx (mobile source)	0.00E+00	kg	0.00E+00	−	3.03E−01	kg	5.86E+01	1.0%	5.86E+01	−
air	Pb	0.00E+00	kg	0.00E+00	−	5.04E−05	kg	8.72E+00	0.1%	8.72E+00	−
air	PM10 (mobile source)	0.00E+00	kg	0.00E+00	−	1.52E−02	kg	1.45E+02	2.5%	1.45E+02	−
air	SO_2	1.49E+00	kg	1.35E+03	21.4%	1.30E+00	kg	1.18E+03	20.1%	−1.70E+02	−12.6%
air	SOx	5.13E−01	kg	4.65E+02	7.4%	4.99E−01	kg	4.52E+02	7.7%	−1.30E+01	−2.8%
			Sub total:	5.43E+03	86.0%		Sub total:	5.07E+03	86.6%	−3.59E+02	−6.6%
water	As	4.15E−10	kg	4.06E−05	0.0%	0.00E+00	kg	0.00E+00	−	−4.06E−05	−
water	BOD	1.57E−03	kg	5.02E−04	0.0%	0.00E+00	kg	0.00E+00	−	−5.02E−04	−
water	Cd	6.22E−11	kg	3.44E−05	0.0%	0.00E+00	kg	0.00E+00	−	−3.44E−05	−
water	COD	1.33E−02	kg	4.23E−03	0.0%	1.14E−02	kg	3.64E−03	0.0%	−5.90E−04	−13.9%
water	Cr	1.24E−09	kg	4.98E−05	0.0%	0.00E+00	kg	0.00E+00	−	−4.98E−05	−
water	Hg	4.15E−11	kg	1.32E−04	0.0%	0.00E+00	kg	0.00E+00	−	−1.32E−04	−
			Sub total:	4.99E−03	0.0%		Sub total:	3.64E−03	0.0%	−1.35E−03	−27.0%
industrial	earth & sand (landfill)	5.37E+00	kg	2.13E+00	0.0%	5.37E+00	kg	2.13E+00	0.0%	0.00E+00	0.0%
industrial	industrial waste landfill (unspecified)	1.96E+02	kg	1.40E+02	2.2%	1.69E+02	kg	1.20E+02	2.0%	−2.00E+01	−14.3%
industrial	low-level radioactive waste	8.35E−03	kg	5.97E−03	0.0%	7.78E−03	kg	5.56E−03	0.0%	−4.10E−04	−6.9%
industrial	paper wastes (landfill)	5.44E+00	kg	2.29E+01	0.4%	5.44E+00	kg	2.29E+01	0.4%	0.00E+00	0.0%
industrial	plastic wastes (landfill)	6.51E−09	kg	1.55E−08	0.0%	0.00E+00	kg	0.00E+00	−	−1.55E−08	−
industrial	rubbles (landfill)	1.29E−08	kg	5.14E−09	0.0%	0.00E+00	kg	0.00E+00	−	−5.14E−09	−
industrial	slag (landfill)	1.67E−05	kg	6.19E−06	0.0%	0.00E+00	kg	0.00E+00	−	−6.19E−06	−
industrial	sludge (landfill)	3.18E+02	kg	2.28E+02	3.6%	2.75E+02	kg	1.97E+02	3.4%	−3.10E+01	−13.6%
			Sub total:	3.93E+02	6.2%		Sub total:	3.42E+02	5.8%	−5.10E+01	−13.0%
			Total:	6.32E+03				5.86E+03		−4.64E+02	−7.3%

Table 4.14 Comparison of book production (Normal/Best) by LIME ver.3

Category	Item	Book production									
		Normal Practice				Best Practice				⊿	
		LCI result	Unit	Points	%	LCI result	Unit	Points	%	Points	%
resource	Al reserves	1.00E+01	kg	1.06E+01	0.1%	1.00E+01	kg	1.06E+01	0.1%	0.00E+00	0.0%
resource	coal (coke)	6.68E-06	kg	5.28E-06	0.0%	0.00E+00	kg	0.00E+00	0.0%	-5.28E-06	-
resource	coal (combustion)	8.28E+02	kg	6.55E+02	4.4%	6.91E+02	kg	5.46E+02	4.5%	-1.09E+02	-16.6%
resource	cryolite	6.04E-01	kg	2.30E-02	0.0%	6.04E-01	kg	2.30E-02	0.0%	0.00E+00	0.0%
resource	Cu reserves	4.75E-06	kg	1.30E-04	0.0%	0.00E+00	kg	0.00E+00	-	-1.30E-04	-
resource	limestone	2.33E-03	kg	8.85E-05	0.0%	1.70E-03	kg	6.48E-05	0.0%	-2.37E-05	-26.8%
resource	natural gas	1.44E+02	kg	4.94E+01	0.3%	1.30E+02	kg	4.48E+01	0.4%	-4.60E+00	-9.3%
resource	oil reserves	6.83E+02	kg	4.99E+02	3.4%	5.54E+02	kg	4.05E+02	3.3%	-9.40E+01	-18.8%
resource	Pb reserves	1.75E-07	kg	2.55E-06	0.0%	0.00E+00	kg	0.00E+00	-	-2.55E-06	-
resource	silica sand	1.42E-06	kg	5.38E-08	0.0%	0.00E+00	kg	0.00E+00	-	-5.38E-08	-
resource	U reserves	2.49E-02	kg	1.28E+01	0.1%	2.27E-02	kg	1.16E+01	0.1%	-1.20E+00	-9.4%
resource	Zn reserves	9.70E-07	kg	2.20E-05	0.0%	0.00E+00	kg	0.00E+00	-	-2.20E-05	-
			Sub total:	1.23E+03	8.3%		Sub total:	1.02E+03	8.4%	-2.09E+02	-17.0%
air	As	2.35E-05	kg	8.60E-01	0.0%	2.14E-05	kg	7.82E-01	0.0%	-7.80E-02	-9.1%
air	Cd	1.94E-06	kg	3.85E-01	0.0%	1.77E-06	kg	3.50E-01	0.0%	-3.50E-02	-9.1%
air	CH4	1.96E-01	kg	6.25E+00	0.0%	1.58E-01	kg	5.03E+00	0.0%	-1.22E+00	-19.5%
air	CO2	4.77E+03	kg	6.17E+03	41.6%	3.95E+03	kg	5.11E+03	42.0%	-1.06E+03	-17.2%
air	Cr	4.27E-05	kg	5.85E-01	0.0%	3.89E-05	kg	5.32E-01	0.0%	-5.30E-02	-9.1%
air	dust	8.84E-01	kg	1.86E+03	12.5%	7.04E-01	kg	1.48E+03	12.2%	-3.80E+02	-20.4%
air	Hg	2.84E-05	kg	2.13E+00	0.0%	2.58E-05	kg	1.94E+00	0.0%	-1.90E-01	-8.9%
air	hydrocarbons	8.66E-02	kg	1.02E+01	0.1%	7.37E-02	kg	8.64E+00	0.1%	-1.56E+00	-15.3%
air	N2O	1.16E-01	kg	4.74E+01	0.3%	1.01E-01	kg	4.15E+01	0.3%	-5.90E+00	-12.4%
air	Ni	4.80E-05	kg	1.63E-01	0.0%	4.37E-05	kg	1.48E-01	0.0%	-1.50E-02	-9.2%
air	NMHC	5.17E-02	kg	6.06E+00	0.0%	4.70E-02	kg	5.51E+00	0.0%	-5.50E-01	-9.1%
air	NOx	3.09E+00	kg	4.50E+02	3.0%	2.55E+00	kg	3.72E+02	3.1%	-7.80E+01	-17.3%
air	NOx (mobile source)	7.03E-01	kg	1.36E+02	0.9%	5.95E-01	kg	1.15E+02	0.9%	-2.10E+01	-15.4%
air	Pb	1.13E-04	kg	1.95E+01	0.1%	1.02E-04	kg	1.77E+01	0.1%	-1.80E+00	-9.2%
air	PM10 (mobile source)	3.91E-02	kg	3.73E+02	2.5%	3.26E-02	kg	3.10E+02	2.6%	-6.30E+01	-16.9%
air	SO2	4.07E+00	kg	3.68E+03	24.8%	3.31E+00	kg	2.99E+03	24.6%	-6.90E+02	-18.8%
air	SOx	3.37E-01	kg	3.05E+02	2.1%	2.92E-01	kg	2.64E+02	2.2%	-4.10E+01	-13.4%
			Sub total:	1.31E+04	88.2%		Sub total:	1.07E+04	88.2%	-2.34E+03	-17.9%
water	As	2.28E-10	kg	2.23E-05	0.0%	0.00E+00	kg	0.00E+00	-	-2.23E-05	-
water	BOD	3.56E-03	kg	1.14E-03	0.0%	2.65E-03	kg	8.44E-04	0.0%	-2.96E-04	-26.0%
water	Cd	3.42E-11	kg	1.89E-05	0.0%	0.00E+00	kg	0.00E+00	-	-1.89E-05	-
water	COD	1.88E-02	kg	6.01E-03	0.0%	1.47E-02	kg	4.70E-03	0.0%	-1.31E-03	-21.8%
water	Cr	6.83E-10	kg	2.73E-05	0.0%	0.00E+00	kg	0.00E+00	-	-2.73E-05	-
water	Hg	2.28E-11	kg	7.24E-05	0.0%	0.00E+00	kg	0.00E+00	-	-7.24E-05	-
			Sub total:	7.29E-03	0.0%		Sub total:	5.54E-03	0.0%	-1.75E-03	-24.0%
industrial	earth & sand (landfill)	2.15E+01	kg	8.53E+00	0.1%	2.15E+01	kg	8.53E+00	0.1%	0.00E+00	0.0%
industrial	industrial waste landfill (unspecified	2.81E+02	kg	2.01E+02	1.4%	2.21E+02	kg	1.58E+02	1.3%	-4.30E+01	-21.4%
industrial	low-level radioactive waste	1.74E-02	kg	1.24E-02	0.0%	1.58E-02	kg	1.13E-02	0.0%	-1.10E-03	-8.9%
industrial	plastic wastes (landfill)	3.58E-09	kg	8.52E-09	0.0%	0.00E+00	kg	0.00E+00	-	-8.52E-09	-
industrial	rubbles (landfill)	7.10E-09	kg	2.82E-09	0.0%	0.00E+00	kg	0.00E+00	-	-2.82E-09	-
industrial	slag (landfill)	9.17E-06	kg	3.40E-06	0.0%	0.00E+00	kg	0.00E+00	-	-3.40E-06	-
industrial	sludge (landfill)	4.43E+02	kg	3.17E+02	2.1%	3.47E+02	kg	2.48E+02	2.0%	-6.90E+01	-21.8%
			Sub total:	5.27E+02	3.6%		Sub total:	4.15E+02	3.4%	-1.12E+02	-21.3%
			Total:	1.48E+04				1.22E+04		-2.67E+03	-18.0%

Table 4.15 Comparison of Package/Book production (Normal/Best)

by characterization in LIME ver.3

Impact category	Package production				Book production			
	Normal practice Point	Best practice Point	⊿	%	Normal practice Point	Best practice Point	⊿	%
Global warming	2.83E+03	2.53E+03	-3.00E+02	-10.6%	6.23E+03	5.15E+03	-1.08E+03	-17.3%
Ozone depletion	-	-	-	-	-	-	-	-
Human toxicity	9.16E+00	8.54E+00	-6.20E-01	-6.8%	1.91E+01	1.73E+01	-1.80E+00	-9.4%
Ecotoxicity	2.18E+00	2.03E+00	-1.50E-01	-6.9%	4.54E+00	4.13E+00	-4.10E-01	-9.0%
Acidification	1.23E+02	1.11E+02	-1.20E+01	-9.8%	2.45E+02	2.01E+02	-4.40E+01	-18.0%
Eutrophication	4.73E-03	3.64E-03	-1.09E-03	-23.0%	7.15E-03	5.55E-03	-1.60E-03	-22.4%
Photochemical oxidant	7.54E+00	6.71E+00	-8.30E-01	-11.0%	1.62E+01	1.42E+01	-2.00E+00	-12.3%
Solid waste	3.92E+02	3.42E+02	-5.00E+01	-12.8%	5.27E+02	4.14E+02	-1.13E+02	-21.4%
Land use	-	-	-	-	-	-	-	-
Resource consumption	4.94E+02	4.40E+02	-5.40E+01	-10.9%	1.23E+03	1.02E+03	-2.10E+02	-17.1%
Urban air pollution	2.70E+03	2.41E+03	-2.90E+02	-10.7%	6.56E+03	5.33E+03	-1.23E+03	-18.8%
Total:	6.57E+03	5.85E+03	-7.20E+02	-11.0%	1.48E+04	1.22E+04	-2.60E+03	-17.6%

Calculated by JEMAI LCA Pro

4.3.5 Eco Indicator 95 (EI95)

4.3.5.1 Overview of EI95

EI95 was invented by private companies, research institutes and Dutch government aiming to develop user-friendly tool for product designers for shifting to Eco-design to improve their environment conscious products and services.

It uses assessment approach which is in accordance with Distance-to-Target (DtT) method deciding priority sequence of tackled impact categories. The distance from the target to the present point is determined by scientific or political agendas. It is totally different from Panel method such as ELP weighting impact categories by questionnaires to fix preference order for impact categories.

It strongly focuses on emissions to the ecosystem and excludes toxic substances which are only a problem in the workplace, depletion of raw material and the quantity of disposal which effects waste process.

Target values are related to three types of environmental damage. They are worsening of ecosystems (a target level has been chosen at which “only” 5% ecosystem aggravation will still happen over several decades), worsening of human health (it glances especially about winter and summer smog and the acceptable level is set that smog periods should hardly ever occur again) and human death (the level chosen as acceptable is one death rate per million residents per year). It is broad in scope but resource consumption including energy and waste are not in scope.

Weighting factors for impact categories utilized in EI95 are set based on criterion of characterization models. The current choices of impact categories are selected after consultation with various experts and a comparison with other evaluation systems.

4.3.5.2 Practice of EI95

LCI result of each item is organized for each impact category which can damage ecosystems or human health and multiplied by characterization factor cited from characterization model such as GWP, AP, NP, POCP and 1/EQS to calculate converted result as one indicator.

For seven characterization models, actually nine characterization models including Ozone layer depletion and Pesticides which are not available for this case study, consist of items which are contributing factors to determine environmental load for each model. Each item’s converted result of characterization model is calculated by multiplication of LCI result and characterization factor by the model, and then all items are summed up as one converted result as integrated indicator.

Environmental loads from same practice of both package and book productions are categorized into seven characterization models and are converted into integrated results. It is presented in Table 4.16.

Table 4.16 Characterization for Package/Book production (Normal) by EI95

Package production (Normal practice)

<Greenhouse effect/Characterization model: GWP*1>

Category	Item	LCI result	Unit	Charac. factor	Conv. Result*2
air	CO_2	2.17E+03	kg	1.00E+00	2.17E+03
air	CH_4	5.31E-02	kg	1.10E+01	5.84E-01
air	N_2O	6.71E-02	kg	2.70E+02	1.81E+01
				Indicator result*3 (CO_2 eq. kg):	2.19E+03

<Acidification/Characterization model: AP*4>

Category	Item	LCI result	Unit	Charac. factor	Conv. Result
air	NOx	1.83E+00	kg	7.00E-01	1.28E+00
air	NOx (mobile source)	3.73E-01	kg	7.00E-01	2.61E-01
air	SO_2	1.49E+00	kg	1.00E+00	1.49E+00
air	SOx	5.13E-01	kg	1.00E+00	5.13E-01
				Indicator result(SO_2 eq. kg):	3.55E+00

<Eutrophication/Characterization model: NP*5>

Category	Item	LCI result	Unit	Charac. factor	Conv. Result
air	NOx	1.83E+00	kg	1.30E-01	2.38E-01
air	NOx (mobile source)	3.73E-01	kg	1.30E-01	4.85E-02
water	COD	1.33E-02	kg	2.20E-02	2.93E-04
				Indicator result(Photosphate eq. kg):	2.87E-01

<Summer smog/Characterization model: POCP*6>

	Item	LCI result	Unit	Charac. factor	Conv. Result
air	hydrocarbons	3.95E-02	kg	3.98E-01	1.57E-02
air	CH_4	5.31E-02	kg	7.00E-03	3.72E-04
				Indicator result(Ethene eq. kg):	1.61E-02

<Winter smog/Characterization model: 1/EQS*7>

Category	Item	LCI result	Unit	Charac. factor	Conv. Result
air	dust	2.39E-01	kg	1.00E+00	2.39E-01
air	PM10 (mobile source)	1.89E-02	kg	1.00E+00	1.89E-02
air	SO_2	1.49E+00	kg	1.00E+00	1.49E+00
air	SOx	5.13E-01	kg	1.00E+00	5.13E-01
				Indicator result(SO_2 eq. kg):	2.26E+00

<Heavy metal/Characterization model: 1/EQS>

Category	Item	LCI result	Unit	Charac. factor	Conv. Result
air	Cd	9.34E-07	kg	5.00E+01	4.67E-05
air	Hg	1.36E-05	kg	1.00E+00	1.36E-05
air	Pb	5.41E-05	kg	1.00E+00	5.41E-05
water	As	4.15E-10	kg	1.00E+00	4.15E-10
water	Cd	6.22E-11	kg	3.00E+00	1.87E-10
water	Hg	4.15E-11	kg	1.00E+01	4.15E-10
water	Mn	6.22E-09	kg	2.00E-02	1.24E-10
				Indicator result(Pb eq. kg):	1.14E-04

<Carcinogenics/Characterization model: 1/EQS>

Category	Item	LCI result	Unit	Charac. factor	Conv. Result
air	As	1.13E-05	kg	4.40E-02	4.97E-07
air	Ni	2.31E-05	kg	4.40E-01	1.02E-05
				Indicator result(PAH*8 eq. kg):	1.07E-05

Book production (Normal practice)

<Greenhouse effect/Characterization model: GWP*1>

Category	Item	LCI result	Unit	Charac. factor	Conv. Result*2
air	CO_2	4.77E+03	kg	1.00E+00	4.77E+03
air	CH_4	1.96E-01	kg	1.10E+01	2.16E+00
air	N_2O	1.16E-01	kg	2.70E+02	3.13E+01
				Indicator result*3 (CO_2 eq. kg):	4.80E+03

<Acidification/Characterization model: AP*4>

Category	Item	LCI result	Unit	Charac. factor	Conv. Result
air	NOx	3.09E+00	kg	7.00E-01	2.16E+00
air	NOx (mobile source)	7.03E-01	kg	7.00E-01	4.92E-01
air	SO_2	4.07E+00	kg	1.00E+00	4.07E+00
air	SOx	3.37E-01	kg	1.00E+00	3.37E-01
				Indicator result(SO_2 eq. kg):	7.06E+00

<Eutrophication/Characterization model: NP*5>

Category	Item	LCI result	Unit	Charac. factor	Conv. Result
air	NOx	3.09E+00	kg	1.30E-01	4.02E-01
air	NOx (mobile source)	7.03E-01	kg	1.30E-01	9.14E-02
water	COD	1.88E-02	kg	2.20E-02	4.14E-04
				Indicator result(Photosphate eq. kg):	4.94E-01

<Summer smog/Characterization model: POCP*6>

Category	Item	LCI result	Unit	Charac. factor	Conv. Result
air	hydrocarbons	8.66E-02	kg	3.98E-01	3.45E-02
air	CH_4	1.96E-01	kg	7.00E-03	1.37E-03
				Indicator result(Ethene eq. kg):	3.58E-02

<Winter smog/Characterization model: 1/EQS*7>

Category	Item	LCI result	Unit	Charac. factor	Conv. Result
air	dust	8.84E-01	kg	1.00E+00	8.84E-01
air	PM10 (mobile source)	3.91E-02	kg	1.00E+00	3.91E-02
air	SO_2	4.07E+00	kg	1.00E+00	4.07E+00
air	SOx	3.37E-01	kg	1.00E+00	3.37E-01
				Indicator result(SO_2 eq. kg):	5.33E+00

<Heavy metal/Characterization model: 1/EQS>

Category	Item	LCI result	Unit	Charac. factor	Conv. Result
air	Cd	1.94E-06	kg	5.00E+01	9.70E-05
air	Hg	2.84E-05	kg	1.00E+00	2.84E-05
air	Pb	1.13E-04	kg	1.00E+00	1.13E-04
water	As	2.28E-10	kg	1.00E+00	2.28E-10
water	Cd	3.42E-11	kg	3.00E+00	1.03E-10
water	Hg	2.28E-11	kg	1.00E+01	2.28E-10
water	Mn	3.42E-09	kg	2.00E-02	6.84E-11
				Indicator result(Pb eq. kg):	2.38E-04

<Carcinogenics/Characterization model: 1/EQS>

Category	Item	LCI result	Unit	Charac. factor	Conv. Result
air	As	2.35E-05	kg	4.40E-02	1.03E-06
air	Ni	4.80E-05	kg	4.40E-01	2.11E-05
				Indicator result(PAH*8 eq. kg):	2.22E-05

Calculated by JEMAI LCA Pro

*1: Global Warming Potential
*2: Converted result=LCI result*Characterization factor
*3: Indicator result=Sum of Converted results of a category
*4: Acid Potential
*5: Nitrogen Potential
*6: Photochemical Ozone Creation Potential
*7: Environmental Quality Standard
*8: Potentially Affected Health

In order to calculate weighted result, indicator result which is counted by multiplication of LCI result shown in Table 4.18 and characterization factor is divided by Normalization value for each impact category firstly. Then, it is multiplied by weighting factor for each impact category secondly. Final step is adding all weighted results from nine different impact categories for Normal practice and Best practice individually to be compared. It is summarized in Table 4.17.

When changeover from Normal practice to Best practice for both productions, weighted result of package production in EI95 is reduced at 10.3% in, the one of book production is reduced at 17.4% respectively.

Table 4.17 Comparison of Normal/Best by EI95

[Package Production]

<Normal practice>

Impact category	Charac. model	Unit	Indicator result*1	Norm. value	Norm. result*2	Weighting factor	Weighted result*3	%
Greenhouse effect	GWP	CO2 eq. kg	2.19E+03	6.50E+12	3.36E−10	2.50E+00	8.41E+00	45.7%
Ozone layer depletion	ODP	CFC eq. kg	−	4.60E+08	−	1.00E+02	−	−
Acidification	AP	SO2 eq. kg	3.55E+00	5.60E+10	6.33E−11	1.00E+01	6.33E+00	34.4%
Eutrophication	NP	Phosphate eq. kg	2.87E−01	1.90E+10	1.51E−11	5.00E+00	7.54E−01	4.1%
Summer smog	POCP	ethene eq. kg	1.67E−02	8.90E+09	1.81E−12	2.50E+00	4.52E−02	0.2%
Winter smog	1 / EQS	SO2 eq. kg	2.26E+00	4.70E+10	4.81E−11	5.00E+00	2.41E+00	13.1%
Pesticides	−	kg	−	4.80E+08	−	2.50E+01	−	−
Heavy metals	1 / EQS	Pb eq. kg	1.14E−04	2.70E+07	4.24E−12	5.00E+00	2.12E−01	1.2%
Carcinogenics	1 / EQS	PAH eq. kg	1.07E−05	5.40E+06	1.98E−12	1.00E+01	1.98E−01	1.1%
Weighted result:							1.84E+01	

<Best practice>

Impact category	Charac. model	Unit	Indicator result	Norm. value	Norm. result	Weighting factor	Weighted result	%	⊿	%
Greenhouse effect	GWP	CO2 eq. kg	1.95E+03	6.50E+12	3.01E−10	2.50E+00	7.52E+00	45.6%	−8.90E−01	−10.6%
Ozone layer depletion	ODP	CFC eq. kg	−	4.60E+08	−	1.00E+02	−	−	−	−
Acidification	AP	SO2 eq. kg	3.21E+00	5.60E+10	5.73E−11	1.00E+01	5.73E+00	34.7%	−6.00E−01	−9.5%
Eutrophication	NP	Phosphate eq. kg	2.62E−01	1.90E+10	1.38E−11	5.00E+00	6.88E−01	4.2%	−6.60E−02	−8.8%
Summer smog	POCP	ethene eq. kg	1.39E−02	8.90E+09	1.56E−12	2.50E+00	3.90E−02	0.2%	−6.20E−03	−13.7%
Winter smog	1 / EQS	SO2 eq. kg	2.03E+00	4.70E+10	4.31E−11	5.00E+00	2.16E+00	13.1%	−2.50E−01	−10.4%
Pesticides	−	kg	−	4.80E+08	−	2.50E+01	−	−	−	−
Heavy metals	1 / EQS	Pb eq. kg	1.07E−04	2.70E+07	3.95E−12	5.00E+00	1.97E−01	1.2%	−1.50E−02	−7.1%
Carcinogenics	1 / EQS	PAH eq. kg	9.93E−06	5.40E+06	1.84E−12	1.00E+01	1.84E−01	1.1%	−1.40E−02	−7.1%
Weighted result:							1.65E+01	100.0%	−1.90E+00	−10.3%

[Book Production]

<Normal practice>

Impact category	Charac. model	Unit	Indicator result*1	Norm. value	Norm. result*2	Weighting factor	Weighted result*3	%
Greenhouse effect	GWP	CO2 eq. kg	4.80E+03	6.50E+12	7.39E−10	2.50E+00	1.85E+01	47.4%
Ozone layer depletion	ODP	CFC eq. kg	−	4.60E+08	−	1.00E+02	−	−
Acidification	AP	SO2 eq. kg	7.06E+00	5.60E+10	1.26E−10	1.00E+01	1.26E+01	32.3%
Eutrophication	NP	Phosphate eq. kg	4.93E+02	1.90E+10	2.59E−11	5.00E+00	1.30E+00	3.3%
Summer smog	POCP	ethene eq. kg	3.58E−02	8.90E+09	4.03E−12	2.50E+00	1.01E−01	0.3%
Winter smog	1 / EQS	SO2 eq. kg	5.33E+00	4.70E+10	1.13E−10	5.00E+00	5.67E+00	14.5%
Pesticides	−	kg	−	4.80E+08	−	2.50E+01	−	−
Heavy metals	1 / EQS	Pb eq. kg	2.38E−04	2.70E+07	8.81E−12	5.00E+00	4.41E−01	1.1%
Carcinogenics	1 / EQS	PAH eq. kg	2.22E−05	5.40E+06	4.11E−12	1.00E+01	4.11E−01	1.1%
Weighted result:							3.90E+01	

<Best practice>

Impact category	Charac. model	Unit	Indicator result	Norm. value	Norm. result	Weighting factor	Weighted result	%	⊿	⊿%
Greenhouse effect	GWP	CO2 eq. kg	3.97E+03	6.50E+12	6.12E−10	2.50E+00	1.53E+01	47.5%	−3.20E+00	−17.3%
Ozone layer depletion	ODP	CFC eq. kg	−	4.60E+08	−	1.00E+02	−	−	−	−
Acidification	AP	SO2 eq. kg	5.80E+00	5.60E+10	1.04E−10	1.00E+01	1.04E+01	32.3%	−2.20E+00	−17.5%
Eutrophication	NP	Phosphate eq. kg	4.09E−01	1.90E+10	2.15E−11	5.00E+00	1.08E+00	3.4%	−2.20E−01	−16.9%
Summer smog	POCP	ethene eq. kg	3.04E−02	8.90E+09	3.42E−12	2.50E+00	8.55E−02	0.3%	−1.55E−02	−15.3%
Winter smog	1 / EQS	SO2 eq. kg	4.33E+00	4.70E+10	9.22E−11	5.00E+00	4.61E+00	14.3%	−1.06E+00	−18.7%
Pesticides	−	kg	−	4.80E+08	−	2.50E+01	−	−	−	−
Heavy metals	1 / EQS	Pb eq. kg	2.16E−04	2.70E+07	8.02E−12	5.00E+00	4.01E−01	1.2%	−4.00E−02	−9.1%
Carcinogenics	1 / EQS	PAH eq. kg	2.02E−06	5.40E+06	3.73E−12	1.00E+01	3.13E−01	1.0%	−9.80E−02	−23.8%
Weighted result:							3.22E+01	100.0%	−6.80E+00	−17.4%

Calculated by JEMAI LCA Pro

*1: Indicator result=Sum of each(LCI result*Characterization factor)
*2: Normalized result=Indicator result/Normalization value
*3: Weighted result=Sum of each(Normalized value*Weighting factor*10^10)

4.3.6 Eco-Point (EP)

4.3.6.1 Overview of EP

EP was developed in Switzerland and is also called Eco-scarcity method as well. It has close relationship with governmental policy since coefficient named Eco-factor is determined by the numerical number responding to enactment or code issued by both national government and local governments. The process of work deciding the importance of environmental problems could be only one-sided view because of deep involvement from political matter.

Even though objectives are presented considering politically related target levels, this method has been widely utilized not only in Switzerland but also in many countries such as Germany, Norway, UK and Netherlands.

A step of classification is omitted, namely EP is directly calculated by the multiplication of LCI result and Eco-factor. It is directly evaluated as environmental impacts, so only a very limited number of impacts can be rated. It is thought to be a disadvantage when compared to the other method.

4.3.6.2 Practice of EP

Table 4.18 shows calculation method of EP for package production. As mentioned above, LCI result is sorted by emission range and energy usage, summarized for four categories.

Table 4.18 Categorizations for package production (Normal) by EP

<Emissions into the atmosphere>

Category	Item	LCI result	Unit	Eco-factor	Ecopoints*1
air	NOx	1.83E+00	kg	6.70E+04	1.23E+05
air	NOx (mobile source)	3.73E-01	kg	6.70E+04	2.50E+04
air	SOx	4.13E-01	kg	5.30E+04	2.72E+04
air	SO_2	1.49E+00	kg	5.30E+04	7.90E+04
air	dust	2.39E-01	kg	1.10E+05	2.62E+04
air	PM10 (mobile source)	1.80E-02	kg	1.10E+05	1.99E+03
air	CO_2	2.17E+03	kg	2.00E+02	4.34E+05
air	CH_4	5.31E-02	kg	4.20E+03	2.23E+02
air	N_2O	6.71E-02	kg	6.20E+04	4.16E+03
air	Pb	5.41E-05	kg	2.90E+06	1.57E+02
air	Cd	9.34E-07	kg	1.20E+08	1.12E+02
air	Zn	1.64E-04	kg	5.20E+05	8.55E+01
air	Hg	1.36E-05	kg	1.20E+08	1.64E+03
				Total:	7.22E+05

<Emissions to surface waters>

Category	Item	LCI result	Unit	Eco-factor	Ecopoints
water	COD	1.33E-02	kg	5.90E+03	7.82E+01
water	Hg	4.15E-11	kg	2.40E+08	9.96E-03
water	Cd	6.22E-11	kg	1.10E+07	6.84E-04
water	Cr	1.24E-09	kg	6.60E+05	8.21E-04
				Total:	7.82E+01

<Waste to landfill>

Category	Item	LCI result	Unit	Eco-factor	Ecopoints
industrial	low-level radioactive waste	8.35E-03	kg	3.30E+06	2.76E+04
				Total:	2.76E+04

<Primary energy>

Category	Energy source	LCI result	Unit	Heating value	Unit	Eco-factor	Ecopoints*2
resource	coal (coke)	7.98E+00	kg	2.20E+02	MJ	1.00E+00	1.76E+03
resource	coal (combustion)	2.67E+02	kg	7.36E+03	MJ	1.00E+00	1.97E+06
resource	natural gas	1.12E+02	kg	6.09E+03	MJ	1.00E+00	6.82E+05
resource	oil reserves	3.13E+02	kg	1.29E+04	MJ	1.00E+00	4.04E+06
						Total:	6.69E+06

Calculated by JEMAI LCA Pro

*1: Ecopoints=Sum of each(LCI result*Ecofactor)

*2: Ecopoints for Primary energy=Sum of each(LCI result*Heating value*Ecofactor)

Comparisons of package/book production are conducted indicating in Table 4.19. Ecopoints are reduced 20.5% for packages and 31.5% for books by the scale of EP.

Table 4.19　Comparison of Normal/Best in EP

Category	Package production						Book production					
	Ecopoints				⊿	%	Ecopoints				⊿	%
	Normal		Best				Normal		Best			
Emissions into the atmosphere	7.22E+05	9.7%	6.48E+05	11.0%	−7.40E+04	−10.2%	1.55E+06	3.8%	1.28E+06	4.6%	−2.70E+05	−17.4%
Emission to surface waters	7.82E+01	0.0%	6.73E+01	0.0%	−1.09E+01	−13.9%	1.11E+02	0.0%	8.69E+01	0.0%	−2.41E+01	−21.7%
Waste to landfill	−	−	−	−	−	−	−	−	−	−	−	−
Emission to soil and groundwater	−	−	−	−	−	−	−	−	−	−	−	−
Radioactive waste	2.76E+04	0.4%	2.57E+04	0.4%	−1.90E+03	−6.9%	5.74E+04	0.1%	5.23E+04	0.2%	−5.10E+03	−8.9%
Primary energy	6.69E+06	89.9%	5.24E+06	88.6%	−1.45E+06	−21.7%	3.93E+07	96.1%	2.67E+07	95.2%	−1.26E+07	−32.1%
Weighted result:	7.44E+06		5.91E+06		−1.53E+06	−20.5%	4.09E+07		2.80E+07		−1.29E+07	−31.5%

Calculated by JEMAI LCA Pro

4.3.7　Environment Priority Strategies for Product Design (EPS)

4.3.7.1 Overview of EPS

EPS was developed by Swedish Environmental Research Institute (IVL) and utilized for appraisal of Volvo automobiles at first. It is not based on governmental policy, but on evaluated financial continuity of environmental issues trying to interpret environmental load into a kind of social expenditure. It is a method which can convert the load into monetary value including neither classification nor normalization.

4.3.7.2 Practice of EPS

LCI result of each item is calculated for weighted result by being multiplied by weighting factor (Environmental Load Unit) based on payment willingness for three safeguards such as Resource, Human health and Bio-diversity. It is shown in Table 4.20.

Table 4.20 Weighted results for three safeguards for Package production (Normal practice) by EPS

<Resource>

Category	Item	LCI result	Unit	Weighting factor*1	Weighted result
resource	oil reserves	3.13E+02	kg	5.00E-01	1.56E+02
resource	Al reserves	2.50E+00	kg	4.20E-01	1.05E+00
resource	Cu reserves	8.65E-06	kg	5.70E+01	4.93E-04
resource	Pb reserves	3.19E-07	kg	2.40E+02	7.65E-05
resource	U reserves	1.19E-02	kg	1.26E+03	1.50E+01
resource	Zn reserves	1.77E-06	kg	4.90E+01	8.65E-05
				Weighted result*2(sum of items):	1.72E+02

<Human health>

Emission	LCI result	YOLL	Severe morbidity	Morbidity	Severe nuisance	Nuisance
As	1.13E-05	1.00E-05				
Cd	9.34E-07	1.20E-06		2.00E-03		
CH4	5.31E-02	6.13E-07	7.72E-06	7.72E-06		3.50E-06
CO	2.40E-01	7.50E-08	9.45E-07	9.48E-07		4.58E-07
CO2	2.17E+03	2.50E-08	3.15E-07	3.15E-07		
Cr	2.06E-05	8.00E-07				
dust	2.39E-01	3.64E-10			6.50E-08	6.51E-05
Hg	1.36E-05			1.16E-04		
NOx	1.83E+00					6.76E-04
NOx (mobile source)	3.73E-01					6.76E-04
Pb	5.41E-05				2.91E-01	
PM10 (mobile source)	1.80E-02	3.64E-10			6.50E-08	6.51E-05
SO2	1.49E+00	1.50E-09	1.14E-08	2.89E-06		2.88E-05
SOx	5.13E-01	1.50E-09	1.14E-08	2.89E-06		2.88E-05
Sub total:		5.42E-05	6.84E-04	6.89E-04	1.58E-05	1.56E-03
Weighting factor:		1.00E+06	1.00E+05	1.00E+04	1.00E+03	1.00E+02
Weighted value(Sub total*weighted value):		5.42E+01	6.84E+01	6.89E+00	1.58E-02	1.56E-01
Weighted result(sum of weighted value):		1.30E+02				

<Bio-diversity>

Category	Item	LCI result	Unit	Weighting factor	Weighted result
air	CH4	5.31E-02	kg	6.17E-13	3.27E-14
air	CO	2.40E-01	kg	7.56E-14	1.82E-14
air	CO2	2.17E+03	kg	2.52E-14	5.46E-11
air	Hg	1.36E-05	kg	1.16E-09	1.58E-14
air	NOx	1.83E+00	kg	4.40E-13	8.05E-13
air	NOx (mobile source)	3.73E-01	kg	4.40E-13	1.64E-13
air	SO2	1.49E+00	kg	1.29E-14	1.92E-14
air	SOx	5.13E-01	kg	1.29E-14	6.67E-15
				Sub total:	5.57E-11
				Weighting factor:	1.50E+11
				Weighted result(sub total*weighting factor):	8.35E+00

Calculated by JEMAI LCA Pro

*1: Weighted factor=Environmental Loading Unit (ELU)
*2: Weighted results=(Sum of each(LCI result*Characterization factor))*Weighting factor

When shifting from Normal practice to Best practice in both productions, weighted result in EPS for package production is reduced at 11.3%, on the other hand, for book production is reduced at 17.6%. It is shown in Table 4.21.

Table 4.21 Comparison of Normal/Best practice in EPS

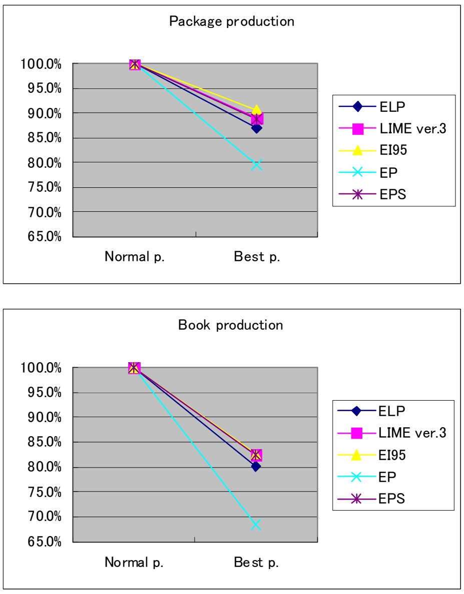
Item	Package production								Book production							
	Normal		Best		⊿		%		Normal		Best		⊿		%	
Ecosystem productive capacity	1.73E+02	55.6%	1.52E+02	55.1%	-2.10E+01		-12.1%		3.79E+02	55.6%	3.11E+02	55.3%	-6.80E+01		-17.9%	
Human health	1.30E+02	41.8%	1.16E+02	42.0%	-1.40E+01		-10.8%		2.85E+02	41.8%	2.36E+02	42.0%	-4.90E+01		-17.2%	
Bio-diversity	8.35E+00	2.7%	7.47E+00	2.7%	-8.80E-01		-10.5%		1.83E+01	2.7%	1.52E+00	0.3%	-1.68E+01		-91.7%	
Total:	3.11E+02		2.76E+02		-3.50E+01		-11.3%		6.82E+02		5.62E+02		-1.20E+02		-17.6%	

Calculated by JEMAI LCA Pro

4.4 CONCLUSION

Package and book productions are carefully analyzed by five different approaches of Integrated LCA. Reduction rates which come about by shifting from Normal practice to Best practice ranges from 9.7 % to 20.5% for package production and 17.4% to 31.5% for book production as weighted result points. It is illustrated in Figure 4.5.

	Package production		Book production	
	Normal p.	Best p.	Normal p.	Best p.
ELP	100.0%	86.9%	100.0%	80.2%
LIME ver.3	100.0%	89.0%	100.0%	82.4%
EI95	100.0%	90.7%	100.0%	82.6%
EP	100.0%	79.5%	100.0%	68.5%
EPS	100.0%	88.7%	100.0%	82.4%



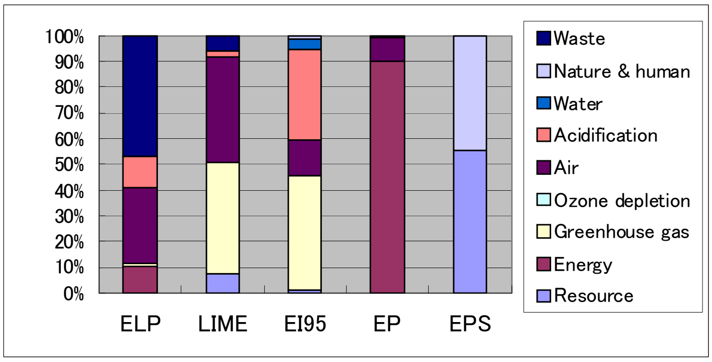
Calculated by JEMAI LCA Pro

Figure 4.5 Reduction rates by five different Integrated LCA methods

Taken all together, Integrated LCA methods except for EP show same tendency when shifting to Best practice in the point of reduction rate. It ranges from 9.7% to 13.1% for packages and 17.4% to 19.8% for books, so just around coverage of 3% could be thought as margin error. But, each method has different substance when watching with extremely watchful eyes since influential impact categories are absolutely different respectably.

There are 21 impact categories for five different methods. It is not easy to compare to know the difference of influential factors by methods at one time. Some of them are evaluated in an approximative ways under the different impact categories, so re-categorized into nine large impact categories as fresh categories. Only Normal practice of package production is evaluated since both production methods show more or less same tendency. It is presented in Figure 4.6 to compare the nature of each method.

Impact category		ELP	LIME3	EI95	EP	EPS
Resource	Resource	0.2%	7.5%	–	–	55.6%
	Heavy metal	–	–	1.2%	–	–
Energy	Energy drain	10.1%	–	–	–	–
	Primary Energy	–	–	–	89.9%	–
Greenhouse gas	Global warming	1.3%	43.1%	45.7%	–	–
Ozone depletion	Ozone depletion	0.0%	0.0%	0.0%	–	–
Air	Air pollution	29.4%	41.1%	–	9.7%	–
	Photochemical oxidant	–	0.1%	–	–	–
	Summer/Winter smog	–	–	13.4%	–	–
Acidification	Acidification	12.3%	1.9%	34.4%	–	–
Water	Ocean & water pollution	0.1%	0.0%	–	–	–
	Eutorophication	–	0.0%	4.1%	–	–
	Emission to surface water	–	–	–	0.0%	–
Nature & human	Ecosystem influence	0.0%	–	–	–	–
	Bio-diversity	–	–	–	–	2.7%
	Ecotoxicity	–	0.0%	–	–	–
	Carcinogenics	–	–	1.1%	–	–
	Human toxicity	–	0.1%	–	–	–
	Human health	–	–	–	–	41.8%
Waste	Waste disposal	46.6%	6.0%	–	–	–
	Waste to landfill	–	–	–	0.4%	–



Calculated by JEMAI LCAPro

Figure 4.6　Comparison of Integrated LCA approaches by large impact categories

Crucial points for the results led by essential nature of each Integrated LCA method are summarized as bullets points below.

- “Resource” is not influential factor except for EPS. Determinant figure is seen in EP, over 90% of environmental load occurs for energy production, so categorizing into “Resource” could be preferable.
- “Energy” is not influential entity in all methods. Not major impact which is 10.11% can be found in ELP, but none can be seen in other four methods except for EP whose impact could be recategorized into “Resource”.
- “Greenhouse gas” is sticking out in LIME and EI95 dominating 43.07% and 45.71% of the load respectively. Only minor impact which is 1.34% can be found in ELP. This impact category was not attention-getting issue when methods were invented in 90s, it could be a reason why no weighted results in two methods.
- “Ozone depletion” has no impact completely since chlorofluorocarbon is substituted or banned by rigid regulation. It is a subject which does not become center of attention nowadays.
- “Air” is covered by four methods and each has significant level of concernment. LIME

weights 41.21%, its proportions are quite high compared with the others. ELP shows second largest impact, it is 29.38%. EI95 and EP show ratios from 9.70% to 13.35%.

- "Acidification" is standing out in EI95 showing 34.40% of the load. ELP also shows certain level, but it is 12.26% which is around one third of EI95 based on influential proportion.
- "Water" is nowadays controversial issue and tried to be evaluated both locally and globally, but only EI 95 indicates 4.10% of the load. It is underestimated by any kind of indicator, so should be contended in the future.
- "Nature and human" consists of four impact categories relating closely with the natural world in where human beings live. Only EPS has determinate influence showing 2.68% from Bio-diversity and Human health showing 41.8% which is greatly influenced by the items exercising effects on Air pollution.
- "Waste" causes the increase of the proportion outstandingly in ELP. Even though the way of disposal is landfill, four methods underestimated it in the evaluation of waste treatment at end of life.

There are drawbacks and advantages for five different Integrated LCA methods with clarity. Although LIME has 14 impact categories and four damage assessment models, converted points from LCI results are summarized mainly in two impact categories which are Global warming and Urban air pollution only. EI95 evaluates impact categories in a balanced manner, but curtails assessment of waste. Both EP and EPS have crank-sided points of views showing highly evaluated proportion of specific impact categories. A selected method might be too much to be scaled by a category impact, but not enough by different category impacts.

It is necessary to indicate the most influential factors in printing production in blunt terms; those are NOx and SOx for all Integrated LCA methods. It is illustrated in Figure 4.7.

Item	ELP	LIME	EI95	EP	EPS
Impact category	Acidification, Air pollution	Air pollution	Acifdification, Eutrophication, Winter smog	Ecosystem productive capacity, Human health, Bio-diversity	Emission to the air
NOx	26.9%	4.2%	12.3%	19.7%	31.9%
SOx	12.8%	28.8%	21.8%	14.1%	0.4%
% to Total:	39.7%	33.0%	34.1%	33.8%	32.3%

Reference(ELP): Nagata Laboratory at Waseda University
Reference(LIME,EI95,EP,EPS): JEMAI LCA Pro

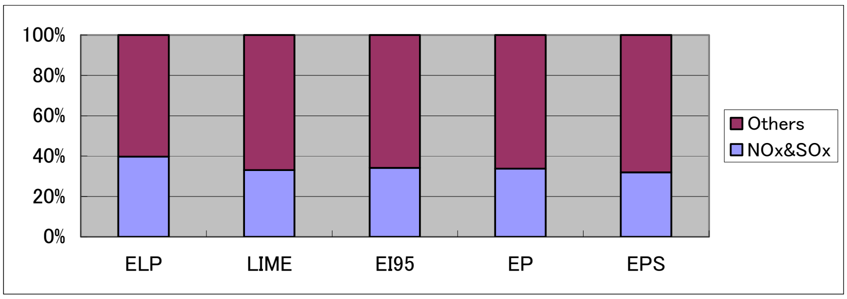


Figure 4.7 NOx and SOx proportion for Integrated LCA methods

The proportion of the load from NOx and SOx occupies around one third to total load, it is same tendency for all Integrated LCA methods. Among all, NOx and SOx are weighted to a maximum extent in ELP; those are evenly evaluated in impact categories such as Acidification and Air pollution.

Figure 4.8 describes the proportion of NOx and SOx in each material and process in ELP.

Item	1.Cardboard	2.Al	3.Ink	4.Water	5.Electricity	6.Recycled Pulp	7.Recycled Al	8.2t-truck	9.4t-truck	10.10t-truck	11.Landfill
NOx	7.8%	0.5%	0.3%	0.0%	1.3%	0.4%	0.1%	0.5%	2.9%	13.3%	0.0%
SOx	10.5%	0.8%	0.4%	0.0%	0.4%	0.1%	0.2%	0.0%	0.1%	0.3%	0.0%
Total%:	18.2%	1.3%	0.7%	0.0%	1.7%	0.5%	0.3%	0.5%	2.9%	13.6%	0.0%

Reference: Nagata Laboratory at Waseda University

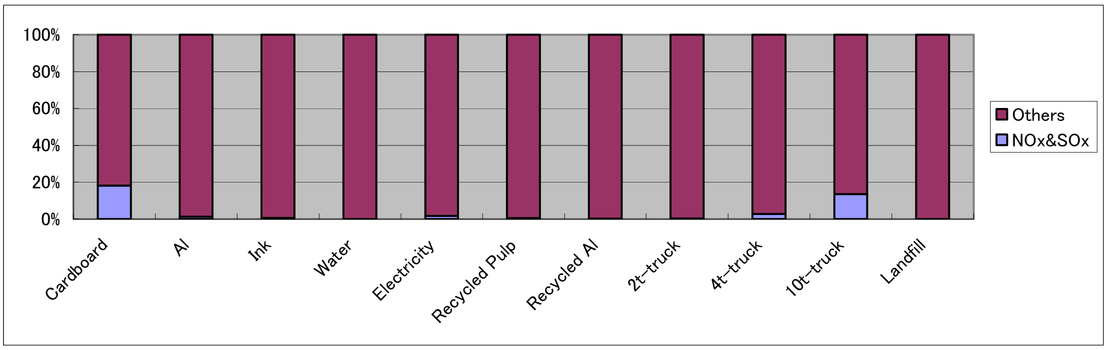


Figure 4.8 NOx and SOx proportion in ELP

Absolute fact of influence from paper is shown, production of cardboard and transportation of cardboard account 31.8% in all, namely take over 80% of the load from NOx and SOx.

As a consequence of driving factor analysis of printing production, NOx and SOx are detected to be the most influential factors and evaluated precisely by ELP to the fullest.

Five different Integrated LCA approaches are compared by package and book productions and pros and cons of each method were evaluated. Some of those methods show unfavorable characteristics for comparative analysis of Physical Printing Service.

As a result of comparison of five different Integrated LCA methods from the different viewpoints, it is concluded that ELP is the best choice. The reasons why ELP is selected as the best method is that it can estimate severe impact from waste disposal which is critical factor for both package and book productions and can be evaluated by four different impact categories nonetheless other methods cannot be. Additionally, it can verify the influence from NOx and SOx which are main effect parameters, so is sensitized to increase or decrease of NOx and SOx. Therefore, it is concluded that ELP is the most well balanced Integrated LCA approach among five different methods.

Application of Integrated LCA is useful approach to evaluate Printing Service from variety points of views. Not only case studies are analyzed, but also practical jobs should be evaluated by Integrated LCA to show its real usefulness. In the concrete manner, effectiveness of Integrated LCA should be shown to indicate its possibility in practical use.

CHAPTER 5

PRACTICAL IMPROVEMENTS

BY PRINTING SERVICE LCA

ABSTRACT

Establishment of Printing Service LCA, namely multilateral approaches by different kinds of LCA methods are completed and ready for practical use. In order to prove that multilateral LCA methods are something more than desk theory, case studies for both Packaging Printing Service and Information Printing Service are verified to demonstrate multilateral LCA methods are operationally-oriented ones. For Packaging Printing Service, as only one sector which has shown positive growth among other sectors such as commercial printing and publishing printing, environmental load is calculated by both $LCCO_2e$ and Integrated LCA to compare different patterns of recycling percentage ranging from 0% to 100% to reduce the load. Questioning whether recycling is the best way or not for environmental reduction is always controversial issue. The result for a case study has two different aspects when evaluated by different Integrated LCA approaches, most of those show wasting is better than recycling except for ELP method. After all, recycling concept is emphasized and “Easy-dismantled package” is created based on Eco-design concept to improve in both Environmental and Economical Factors. On the other hand, Information Printing Service focuses on comparison of Physical Book and E-Book. Comparison is possible but there are still uncertainties to come to final conclusion if E-Book has less environmental impact or not. The load for E-Book will be clarified by large scale of survey asking about reading behavior in the future.

5.1 INTRODUCTION

Quantitative assessment for Printing Service is completed and environmental load for every single process is illustrated in Chapter 3. For Printing Service which requires paper usage, Integrated LCA approaches invented in Japan and in Europe are utilized to focus not only on paper reduction, but also on other factors which necessitate improvement. A major reason of environmental load arising from paper usage is not only the issue; other things on which to be consulted come into view by the analysis of Integrated LCA result in Chapter 4.

As of this moment, verification for Printing Service can be conducted by variety kinds of LCA methods which are developed in many countries deriving not only from $LCCO_2e$ but also from wide range of impact categories.

5.2 PURPOSE OF THE STUDY

Broad range of verification patterns by LCA methods is established. It should prove that it is useful to utilize LCA methods applying for realistic applications in the real world. By validating case studies fitting reality for Packaging Printing Service and Information Printing

Service, it should be figured out whether beneficial effect from Printing Service LCA is real or not.

5.3 BACKGROUND OF THE STUDY

5.3.1 General trend for Packaging Printing Service

Printing statistics consists of Commodity statistics and Labor statistics, printing related data has been accumulated for many years by Ministry of Economy, Trade and Industry (METI).

The aim of this yearbook is to summarize and publish the result of designated year concerning not only printing but also paper and plastic related production, which is conducted under the METI's Regulations for the Current Survey of Production (Fundamental Statistics) based on the Statistics Law. Data is based on business establishments with 100 or more employees excluding business establishments under the direct management and newspaper companies, so data for small businesses are not included.

Commodity statistics is further segmented into two categories, one is Yearly commodity and the other is Chronological data by commodity, organized in temporal sequence. Those have same two types of data such as Item by the product and Item by the printing form individually.

Packaging Printing Service is generally defined as one of seven different items in printing overall. Production values of different items are summarized in Figure 5.1.

Year	Currency	Production value														
		Total	Publishing		Commercial		Security		Office work		Package		Decorative Material		Others	
2005	¥(million)	432,976	128,966	NA	139,179	NA	7,373	NA	61,505	NA	55,936	NA	13,489	NA	26,520	NA
	$(million)	5,094	1,517		1,637		87		724		658		159		312	
2006	¥(million)	446,458	139,508	8.2%	145,146	4.3%	7,026	-4.7%	57,534	-6.5%	56,571	1.1%	14,824	9.9%	25,849	-2.5%
	$(million)	5,252	1,641		1,708		83		677		666		174		304	
2007	¥(million)	453,929	143,019	10.9%	148,741	6.9%	5,602	-24.0%	55,774	-9.3%	57,953	3.6%	16,845	24.9%	25,995	-2.0%
	$(million)	5,340	1,683		1,750		66		656		682		198		306	
2008	¥(million)	429,785	122,674	-4.9%	141,988	2.0%	5,631	-23.6%	57,183	-7.0%	62,504	11.7%	15,299	13.4%	24,506	-7.6%
	$(million)	5,056	1,443		1,670		66		673		735		180		288	
2009	¥(million)	405,939	116,728	-9.5%	134,571	-3.3%	5,830	-20.9%	53,439	-13.1%	61,835	10.5%	12,494	-7.4%	21,044	-20.6%
	$(million)	4,776	1,373		1,583		69		629		727		147		248	

Reference: "Printing Statistics", Ministry of Economy, Trade and Industry

*Conversion rate: 1$=85 yen
*Business establishments with 100 or more regular employees (excluding business establishments under the direct management and newspaper companies.)

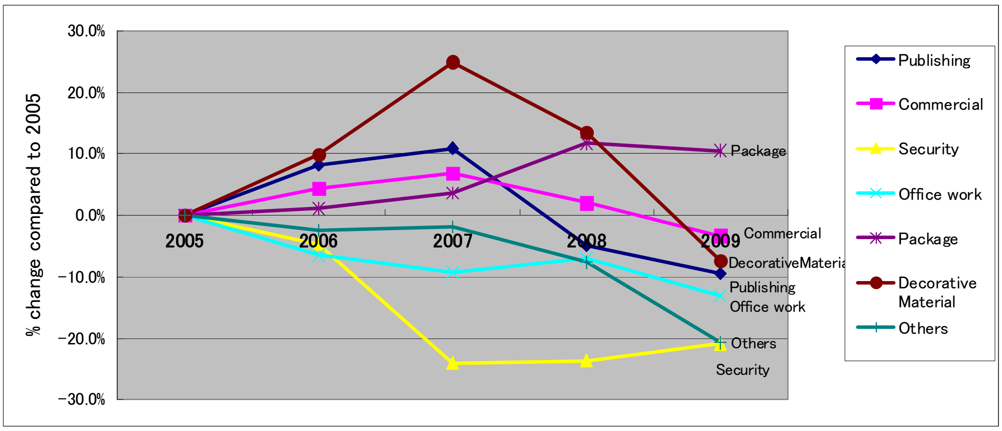


Figure 5.1 Production values for seven different items in printing industry (2005-2009)

As seen in sequential line graph, downtrend of printing industry is quite obvious for almost all segments. Total production value from seven segments cut narrowing at 6.2% from 2005 to 2009, but it is 10.6% declination from 2007 to 2009 in three years.

When looking at two big segments, Commercial sector occupying 33.2% of total production value decreased 3.3% in five years and Publishing sector occupying 28.8% of total production value decreased 9.5% in five years. Office work sector and Security sector are relatively small sectors compared to two major segments, but range of reduction is double digits, showing 13.1% down and 20.9% down respectively.

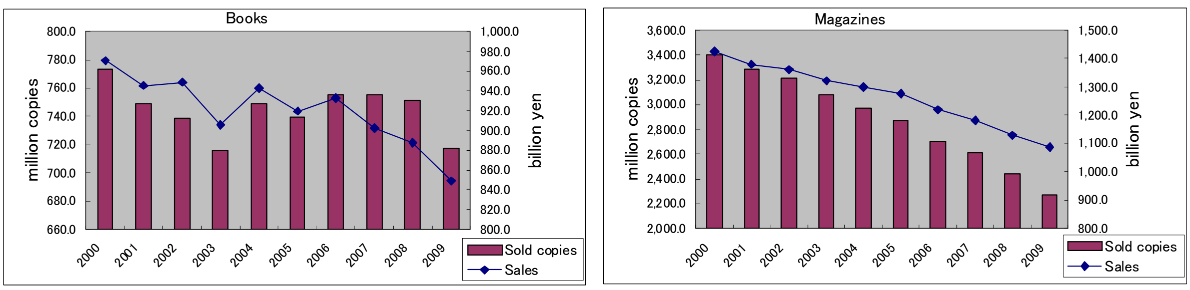
Steep downward across seven segments is recognized, but only Packaging sector is an exception. Although total production value decreases significantly, only Packaging sector increased 10.5% compared with 2005 casting skeptical gaze at other sectors. When printing industry is in such downturn, it is thought to be a rising star.

In order to grasp the details of Packaging Printing Service, it should be understood that Packaging sector is expanding steadily in the past five years.

5.3.2 General trend for Information Printing Service

Current situation of publishing industry should be overlooked; major indicators for both books and magazines such as estimated sales volume, estimated circulation and average unit price must be looked up to understand the essence of the industry. Detailed data is precisely shown in Figure 5.2.

Year	Books								Magazines								Books+Magazines			
	Issued number (Actual copies)	vs 2000 (%)	Sold copies (million copies)	vs 2000 (%)	Sales (billion yen)	vs 2000 (%)	price/copy (yen)	vs 2000 (%)	Issued number (Actual copies)	vs 2000 (%)	Sold (million copies)	vs 2000 (%)	Sales (billion yen)	vs 2000 (%)	price/copy (yen)	vs 2000 (%)	Sold (million copies)	vs 2000 (%)	Sales (billion yen)	vs 2000 (%)
2000	67,522	−	773.6	−	970.6	−	1,255		3,433	−	3,405.4	−	1,426.1	−	419	−	4,179.1	−	2,396.7	−
2001	69,003	102.2%	748.7	96.8%	945.6	97.4%	1,263	100.7%	3,460	100.8%	3,286.2	96.5%	1,379.4	96.7%	420	100.2%	4,034.9	96.6%	2,325.0	97.0%
2002	72,055	106.7%	739.1	95.5%	949.0	97.8%	1,284	102.3%	3,489	101.6%	3,217.0	94.5%	1,361.6	95.5%	423	101.1%	3,956.0	94.7%	2,310.6	96.4%
2003	72,608	107.5%	715.9	92.5%	905.6	93.3%	1,265	100.8%	3,554	103.5%	3,076.1	90.3%	1,322.2	92.7%	430	102.6%	3,792.0	90.7%	2,227.8	93.0%
2004	74,587	110.5%	749.2	96.8%	942.9	97.1%	1,259	100.3%	3,624	105.6%	2,971.5	87.3%	1,299.8	91.1%	437	104.5%	3,720.7	89.0%	2,242.7	93.6%
2005	76,528	113.3%	739.4	95.6%	919.7	94.8%	1,244	99.1%	3,642	106.1%	2,873.3	84.4%	1,276.7	89.5%	444	106.1%	3,612.7	86.4%	2,196.4	91.6%
2006	77,722	115.1%	755.2	97.6%	932.6	96.1%	1,235	98.4%	3,652	106.4%	2,699.0	79.3%	1,220.0	85.5%	452	107.9%	3,454.2	82.7%	2,152.6	89.8%
2007	77,417	114.7%	755.4	97.6%	902.6	93.0%	1,195	95.2%	3,644	106.1%	2,612.7	76.7%	1,182.7	82.9%	453	108.1%	3,368.1	80.6%	2,085.3	87.0%
2008	76,322	113.0%	751.3	97.1%	887.8	91.5%	1,182	94.2%	3,613	105.2%	2,438.7	71.6%	1,129.9	79.2%	463	110.6%	3,190.0	76.3%	2,017.7	84.2%
2009	78,555	116.3%	717.8	92.8%	849.2	87.5%	1,183	94.3%	3,539	103.1%	2,269.7	66.6%	1,086.4	76.2%	479	114.3%	2,987.5	71.5%	1,935.6	80.8%
2009−2000:	11,033	16.3%	−55.8	−7.2%	−121.4	−12.5%	−71.5	−5.7%	106	3.1%	−1,135.7	−33.4%	−339.7	−23.8%	59.9	14.3%	−1,191.6	−28.5%	−461.1	−19.2%



Reference: "2010 Annual Publishing Report", The Reserch Institute of Publications

Figure 5.2 Overall trends for Books and Magazines from 2000 to 2009

Estimated sales volume of books decreased from ¥970.6 bln. ($11,418.8 mil.) in 2000 to ¥849.2 bln. ($9,990.6 mil.) in 2009, dropped ¥121.4 bln. ($1,428.2 mil.) which is equal to 12.5% down over the decade. Estimated circulation of books slightly decreased from 773.6 million copies to 717.8 million copies, 55.8 million copies were published less, 7.2% down in ten years.

On the other hand, estimated sales volume of magazines decreased drastically from ¥1,426.1 bln. ($16,776.6 mil.) in 2000 to ¥1,086.4 bln. ($12,781.2 mil.) in 2009, dropped ¥339.7 bln. ($3,996.4 mil.) which is equal to 23.8% down over the decade. Estimated circulation of Books significantly decreased from 3,405.4 million copies to 2,269.7 million copies, 1,135.7 million copies were published less, 33.4% down in ten years amazingly.

Sharp reduction of total sales volume from ¥2.40 trillion ($28,196.5 mil.) to ¥1.94 trillion ($22,771.8 mil.) which goes beyond minimum sales level of ¥2.00 trillion ($5,424.7 mil.) is making market size shrunk almost 20% of scale-of-money base in the number which totals books and magazines. It is really amazing and great devastating matter to the industry and also printing industry since they have inseparable relationship mutually.

Unimaginable thing for publishing industry is that increasing price in increment for each magazine is 14.3% in ten years even though sales volume is on steep downhill run. Many industries are fighting against deflation for years, it is highly important to know that publishing industry can take unique position because of sufficient degree of protection by resale system which cannot be seen for other industry.

According to the forecast of publishing industry by Yano Research, total sales volume of books and magazines will be ¥1.79 trillion ($21,058.8 mil.) in 2012; it is ¥610 bln. ($7,176.5 mil.) decline from 2000 sales. Shrinking market size for Physical Books sold at bookstores all over Japan will be non-stop downtrend.

5.4 ANALYSIS BY CASE STUDY OF PACKAGING PRITNITNG SERVICE

5.4.1 Shifting to Eco-design for Packaging Printing Service

It is so important for Packaging Printing Service to concern Eco-design concept since structural design can support reducing environmental load from paper usage. Improvements for material volume, machine operation and method selection should be highlighted, it is considered as “Improvements in 3Ms”.

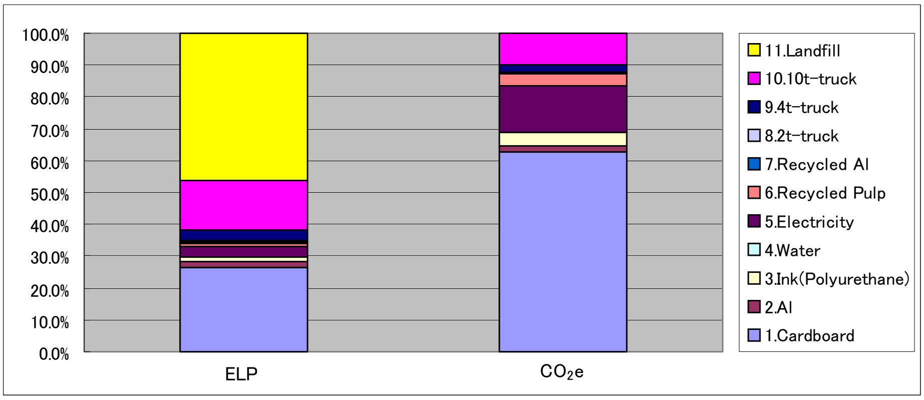
For real practice for package production here, material reduction which has immediate effectivity is adopted for entire environmental load reduction.

5.4.2 Evaluation difference between CO_2e oriented and Integrated LCA

In order to run through revalidating the difference of environmental impact by ELP which is selected as best Integrated LCA method and $LCCO_2$e which is normally considered as easy-to-use approach, the results of LCCO_2e and ELP is compared to know proportional breakout of environmental load from all processes. Figure 5.3 indicates relative proportional comparison of Best practice of package production.

Process	Input	ELF	CO_2e emission coefficient	ELP		CO_2e		⊿	%
1.Cardboard	1,783.089 kg	1.92E+03	6.37E-01	3.43E+06	26.5%	1.14E+03	62.7%	36.2%	136.3%
2.Al	2.500 kg	9.86E+04	1.43E+01	2.47E+05	1.9%	3.58E+01	2.0%	0.1%	3.5%
3.Ink(Polyurethane)	16.292 kg	1.15E+04	4.53E+00	1.88E+05	1.5%	7.38E+01	4.1%	2.6%	180.7%
4.Water	0.000 kg	1.59E-01	1.97E-04	0.00E+00	0.0%	0.00E+00	0.0%	0.0%	-
5.Electricity	617.720 kWh	6.49E+02	4.26E-01	4.01E+05	3.1%	2.63E+02	14.5%	11.4%	368.4%
6.Recycled Pulp	407.185 kg	2.39E+02	1.67E-01	9.73E+04	0.8%	6.80E+01	3.8%	3.0%	398.9%
7.Recycled Al	2.500 kg	2.43E+04	3.16E+00	6.06E+04	0.5%	7.90E+00	0.4%	0.0%	-7.0%
8.2t-truck	42.321 tkm	1.77E+03	2.09E-01	7.51E+04	0.6%	8.85E+00	0.5%	-0.1%	-16.0%
9.4t-truck	268.568 tkm	1.61E+03	1.43E-01	4.32E+05	3.3%	3.84E+01	2.1%	-1.2%	-36.6%
10.10t-truck	1,478.716 tkm	1.36E+03	1.21E-01	2.01E+06	15.6%	1.79E+02	9.9%	-5.7%	-36.6%
11.Landfill	167.860 kg*1	3.56E+04	3.49E-03	5.98E+06	46.3%	5.86E-01	0.0%	-46.2%	-99.9%
	Total ELP/CO_2e(kg-CO_2e):			1.29E+07		1.81E+03			

Reference(ELP): Nagata Laboratory at Waseda University
Reference(CO_2e): JEMAI "SimpleLCA"



*1: Weight of products × Landfill ratio(12.2%)

Figure 5.3 Comparison of CO_2e and ELP in Best practice

Evaluating environmental load by ELP is just conducted in last chapter and each process is compared with LCCO_2e in the viewpoints of proportions of items.

In LCCO_2e, impact from paper is totally different compared to ELP; it is estimated much less in ELP. On the other hand, negative impact from paper is dominant factor in the scale of CO_2e. It becomes clear and comprehensive by calculating numerical numbers and turns out that paper influence occupies almost two thirds of total CO_2e emission. Distributions by trucks of all sizes and electricity from facilities follow to the next and the third, three major processes occupy close to 90% of total CO_2e emission.

On other front, ELP does not really focuses on paper; proportion of environmental load is around one forth of total. Dominant factor is landfill occupying 46.3% of total, ELP concentrates on waste treatment.

It should be clearly expressed that environmental load from landfill has nearly no impact by the measure of CO_2e emission, but the load in ELP is ranked as ascendant element. It is outstandingly different characteristic when comparing two different methods.

As a consequence, reducing total input of paper is highly important issue; additionally reducing total amount of permanent disposal should be spotlighted. The concept of Reduce, Reuse and Recycle (3Rs) should be provided as backbone of Printing Service based on paper.

5.4.3 Comparison of package production by different recycle rates

Since it is understood that landfill in ELP has one of major negative impacts and has room for improvement not like paper and distribution, multi-pattern analysis is conducted to know the discrepancy when recycle percentage is changed on an ascending recycle percentage from 0% to 100% of recycle. There are only two scenarios for packages after use, namely those are wasted finally as landfill or recycled as pulp.

Simulated data is based on the precondition that all packages go straight to garbage boxes without being recycled. Here, recycle rate of 50.0% is set as central value. Recovery rate which includes recycled pulp from import and export is 79.7% in 2009, so lower recycle rate is fixed at 25.0% and highest one is fixed at 100% though it is not realistic.

Although it is changeless in total input of paper, while the amount of recycled pulp increases with the rise of recycling rate, landfill is decreased. Environmental load from distribution never be changed because collection for recycling and dampening of packages are handled by cleansing department of same local government.

Total value of ELP is certainly reduced by decrease in the amount of landfill which is 12.2 % of total weight though minor load of recycled pulp is surely increased. So, only two processes are changed by different recycle percentages; recycle pulp increases when recycle percentage goes up and landfill decreases when recycle percentage goes up. Total reduction in ELP is attained at 8.1% at 25% of recycle rate, 19.0% at 50% of recycle rate, 29.8% at 75% of recycle rate, 40.9% at 100% of recycle rate.

Striking improvement of ELP is accomplished when shifting from landfill to recycling of packages. Comparison of ELP at 0% and each quartile point is summarized in Figure 5.4.

Meanwhile, $LCCO_2e$ and other Integrated LCA such as LIME, Eco Indicator 95, Eco Point and EPS show totally opposite result compared to ELP.

$LCCO_2e$ indicates that environmental load from recycled pulp is larger than the one from landfill when recycling rate goes up, so final result is 3.1% increase at 25% of recycle rate, 6.2% increase at 50% of recycle rate, 9.3% increase at 75% of recycle rate, 12.4% increase at 100% of recycle rate. It shows that recycling pulp from wasted packages has negative impact. It is summarized in Figure 5.5.

By utilizing Integrated LCA, negative tendency of environmental load when recycling rate is rising up is tried to be answered in negative way. LIME, Eco Indicator 95, Eco Point and EPS are turned out to be the same as $LCCO_2e$ result.

Different versions of LIME show almost same tendency, marginal negative impacts varying from 0.5% to 1.2% at 50% of recycling rate are verified. At the same time, other Integrated

LCA methods such as Eco Indicator 95, Eco Point and EPS are validated in a same way as LIME and show certain level of negative impacts varying from 4.2% to 5.0% at 50% of recycling rate. Figure 5.5 and Figure 5.6 show opposite result compared to ELP.

Process	ELF		BestP. R0%		BestP. R25%		BestP. R50%		BestP. R75%		BestP. R100%	
			Input	ELP	Input	ELP	Input	ELP	Input	ELP	Input	ELP
1.Cardboard	1.92E+03	kg	1,783.089	3.43E+06	1,783.089	3.43E+06	1,783.089	3.43E+06	1,783.089	3.43E+06	1,783.089	3.43E+06
2.Al	9.86E+04	kg	2.500	2.47E+05	2.500	2.47E+05	2.500	2.47E+05	2.500	2.47E+05	2.500	2.47E+05
3.Ink(Polyurethane	1.15E+04	kg	16.292	1.88E+05	16.292	1.88E+05	16.292	1.88E+05	16.292	1.88E+05	16.292	1.88E+05
4.Water	1.59E-01	kg	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00
5.Electricity	6.49E+02	kWh	617.720	4.01E+05	617.720	4.01E+05	617.720	4.01E+05	617.720	4.01E+05	617.720	4.01E+05
6.Recycled Pulp	2.39E+02	kg	407.185	9.73E+04	751.161	1.79E+05	1,095.137	2.62E+05	1,439.113	3.44E+05	1,783.089	4.26E+05
7.Recycled Al	2.43E+04	kg	2.500	6.06E+04	2.500	6.06E+04	2.500	6.06E+04	2.500	6.06E+04	2.500	6.06E+04
8.2t-truck	1.77E+03	tkm	42.321	7.51E+04	42.321	7.51E+04	42.321	7.51E+04	42.321	7.51E+04	42.321	7.51E+04
9.4t-truck	1.61E+03	tkm	268.568	4.32E+05	268.568	4.32E+05	268.568	4.32E+05	268.568	4.32E+05	268.568	4.32E+05
10.10t-truck	1.36E+03	tkm	1,478.716	2.01E+06	1,478.716	2.01E+06	1,478.716	2.01E+06	1,478.716	2.01E+06	1,478.716	2.01E+06
11.Landfill	3.56E+04	kg*1	167.860	5.98E+06	125.895	4.49E+06	83.930	2.99E+06	41.965	1.50E+06	0.000	0.00E+00
	Total ELP:			1.29E+07		1.15E+07		1.01E+07		8.68E+06		7.27E+06
						89.1%		78.1%		67.2%		56.3%

Reference: Nagata Laboratory at Waseda University

*1: Weight of products × Landfill ratio(12.2%)
*Grey cells are chaged by switching over from Recycle 0% to 25%, 50%, 75% and 100%

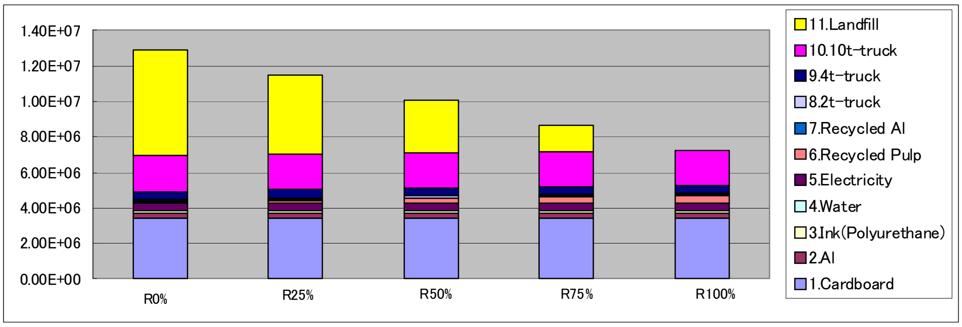


Figure 5.4 Comparison of ELP in Best practice at 0%/25%/50%/100% of recycle rate

Process	CO_2e emission coefficient		BestP. R0%		BestP. R25%		BestP. R50%		BestP. R75%		BestP. R100%	
			Input	CO_2e	Input	CO_2e	Input	CO_2e	Input	CO_2e	Input	CO_2e
1.Cardboard	6.37E-01	kg	1,783.089	1.14E+03	1,783.089	1.14E+03	1,783.089	1.14E+03	1,783.089	1.14E+03	1,783.089	1.14E+03
2.Al	1.43E+01	kg	2.500	3.58E+01	2.500	3.58E+01	2.500	3.58E+01	2.500	3.58E+01	2.500	3.58E+01
3.Ink(Polyurethane	4.53E+00	kg	16.292	7.38E+01	16.292	7.38E+01	16.292	7.38E+01	16.292	7.38E+01	16.292	7.38E+01
4.Water	1.97E-04	kg	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00
5.Electricity	4.26E-01	kWh	617.720	2.63E+02	617.720	2.63E+02	617.720	2.63E+02	617.720	2.63E+02	617.720	2.63E+02
6.Recycled Pulp	1.67E-01	kg	407.185	6.80E+01	751.161	1.25E+02	1,095.137	1.83E+02	1,439.113	2.40E+02	1,783.089	2.98E+02
7.Recycled Al	3.16E+00	kg	2.500	7.90E+00	2.500	7.90E+00	2.500	7.90E+00	2.500	7.90E+00	2.500	7.90E+00
8.2t-truck	2.09E-01	tkm	42.321	8.85E+00	42.321	8.85E+00	42.321	8.85E+00	42.321	8.85E+00	42.321	8.85E+00
9.4t-truck	1.43E-01	tkm	268.568	3.84E+01	268.568	3.84E+01	268.568	3.84E+01	268.568	3.84E+01	268.568	3.84E+01
10.10t-truck	1.21E-01	tkm	1,478.716	2.11E+02	1,478.716	2.11E+02	1,478.716	2.11E+02	1,478.716	2.11E+02	1,478.716	2.11E+02
11.Landfill	3.49E-03	kg*1	167.860	5.86E-01	125.895	4.39E-01	83.930	2.93E-01	41.965	1.46E-01	0.000	0.00E+00
	Total ELP:			1.84E+03		1.90E+03		1.96E+03		2.02E+03		2.07E+03
						103.1%		106.2%		109.3%		112.4%

Reference: JEMAI "Simple LCA"

*1: Weight of products × Landfill ratio(12.2%)
*Grey cells are chaged by switching over from Recycle 0% to 25%, 50%, 75% and 100%

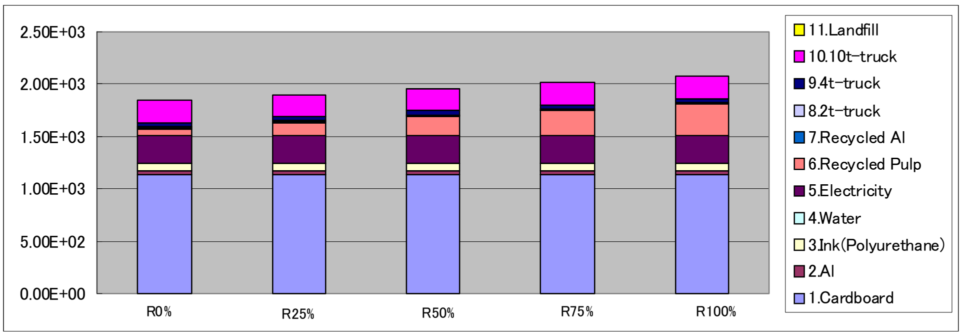


Figure 5.5 Comparison of CO_2e in Best practice at 0%/25%/50%/100% of recycle rate

Integrated LCA method	Unit	Recycle0%	Recycle25%		Recycle50%		Recycle75%		Recycle100%	
ELP	ELP	1.29E+07	1.15E+07	−10.9%	1.01E+07	−21.7%	8.65E+06	−32.9%	7.27E+06	−43.6%
LIME ver.1	Yen	7.82E+03	7.84E+03	0.3%	7.86E+03	0.5%	7.88E+03	0.8%	7.91E+03	1.2%
LIME ver.2	Points	5.20E+03	5.21E+03	0.2%	5.23E+03	0.6%	5.24E+03	0.8%	5.25E+03	1.0%
LIME ver.3	Points	5.85E+03	5.89E+03	0.7%	5.92E+03	1.2%	5.95E+03	1.7%	5.98E+03	2.2%
Eco Indicator 95	Points	1.65E+01	1.69E+01	2.4%	1.72E+01	4.2%	1.75E+01	6.1%	1.79E+01	8.5%
Eco Point	Points	6.74E+05	6.91E+05	2.5%	7.08E+05	5.0%	7.24E+05	7.4%	7.41E+05	9.9%
EPS	ELU	2.76E+02	2.82E+02	2.2%	2.88E+02	4.3%	2.94E+02	6.5%	3.00E+02	8.7%

Reference: Nagata Laboratory at Waseda University
LIME, Eco Indicator 95, Eco Point and EPS are calculated by JEMAI LCA Pro

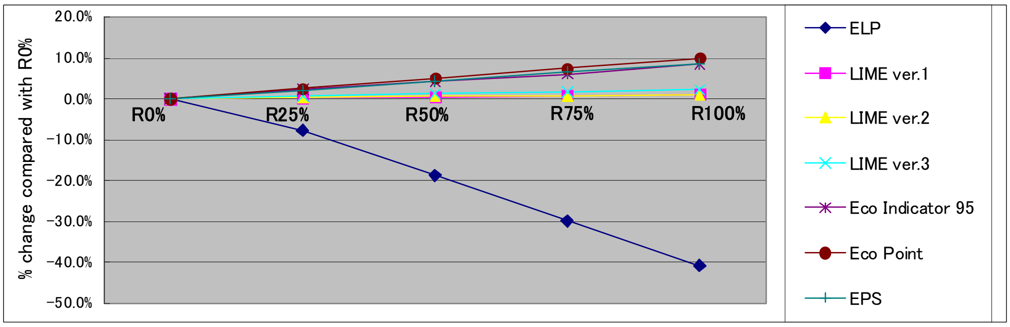


Figure 5.6 Comparison of Integrated LCA in Best practice at 0%/25%/50%/100% of recycle rate

It is understood that only ELP promotes recycling paper and other LCA methods do not from the result of evaluation. This result was led by minor negative impact from waste treatment which is represented by landfill.

If LCA methods answer in the negative for the necessity of recycling, production system goes opposite of government’s policy emphasizing “Building Recycling-oriented Society” which is concurrently promoted with “Building Low-carbon society”. Debating about the best recycling percentage of paper is understandable, but denying paper recycle itself is not acceptable. Here, ELP result is solely respected and promotion of Eco-design including recycling is thought to be correct answer.

5.4.4 Newly-developed package based on Eco-design concept

From ELP analyses covering environmental load from procurement to waste, it is understood that recycling should be encouraged since negative impact of landfill is notable in the view of ELP result as an Integrated LCA indicator.

Publications such as newspaper and books are frequently recycled by people who have strong recycling awareness. It also might be originated in easiness of banding stack. On the other hand, a package is thrown away after content is taken out because it is difficult to dismantle and make it flat for banding stack.

That is to say changing design concept from only eye-catching design to “Easy-Dismantling” design which is based on Eco-design concept is high-priority issue to reduce environmental load. So on that point, “Easy-Dismantling” design which can easily make packages bundled as garbage stack must be set forward for environmental-conscious manufacturing.

Case study for real package production based on the idea from this study is introduced here to combine theory with practice.

Before working on shifting to new design in practice, several important points in contention is reconfirmed as below.

- Recycle-oriented structure should be adopted to motivate consumers to dismantle packages for recycle after usage.
- Appearance of a package should not be featured too low on the list of priorities just to promote recycle since it is major factor to sell a product well.
- Production cost should not be higher than ever, ideally could be lower though capability of a package is better than current one.

First of all, in order to attain main purpose of a package design displacement, changing from solid lines to broken lines for folding comes under the careful review. Replacing to broken lines cuts two ways, namely easiness for tearing a package might influence load bearing in negative way. It also cares that minimizing number of broken lines should be considered to keep front appearance nice and avoid breakage. Developed view and photos showing how to be flat by broken lines for a package is illustrated in Figure 5.7.

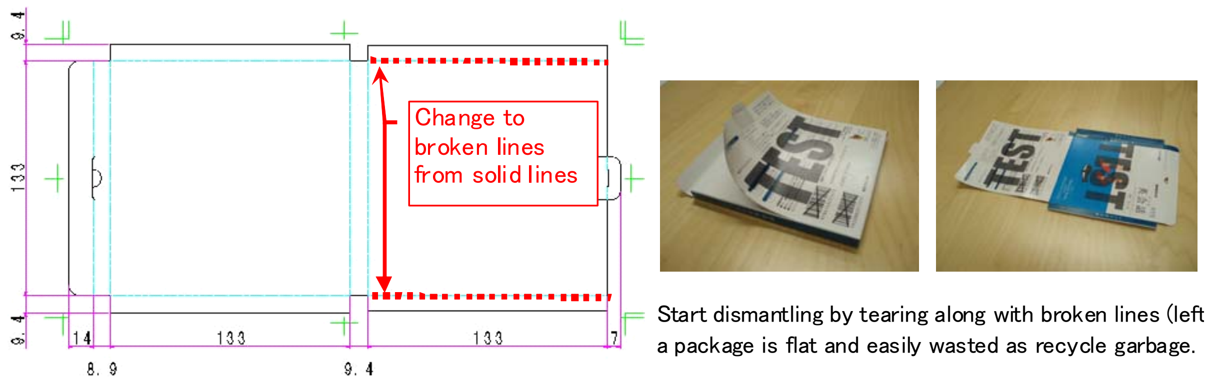


Figure 5.7　Developed view of a package with broken lines

As an arising from Eco-design trial for a package, the positive impact increasing maximum loading becomes apparent incidentally. Changing from solid lines to broken lines partially makes a package rigid square shape which can be subjected to a load evenly on any points of the surface; capability of a package against the load is extremely enhanced.

When comparing 2008 model with 0.47mm thickness to Advanced model with 0.36mm thickness, paper weight reduced 26% but load bearing decreased only 19%. Additionally, when comparing 2009 model with 0.40mm thickness to Advanced model with 0.36mm thickness, paper weight reduced 14% but load bearing decreased just 6%. Usually, relationship between paper weight and load bearing shows proportional ratio, comparison of

2008 model and 2009 model follows the tendency showing 14% decrease of paper weight results 14% weakened of load bearing. It is summarized in Figure 5.8.

Test method:	Paper packages are piled and applied by the load for one hour. Max. load is recorded when no destruction occurs after one hour.		
Model year:	2008 model	2009 model	Advanced model
Paper:	Cardboard-A*1	Cardboard-A*1	Cardboard-B*2
Paper mill:	Mitsubishi	Oji	Hokuetsu
Paper weight:	420g/m²	360g/m²	310g/m²
Paper thickness:	0.47mm	0.40mm	0.36mm
Max. load:	42kg	36kg	34kg

*1: No recycled pulp is contained

*2: Around 60% of recycled pulp is contained.

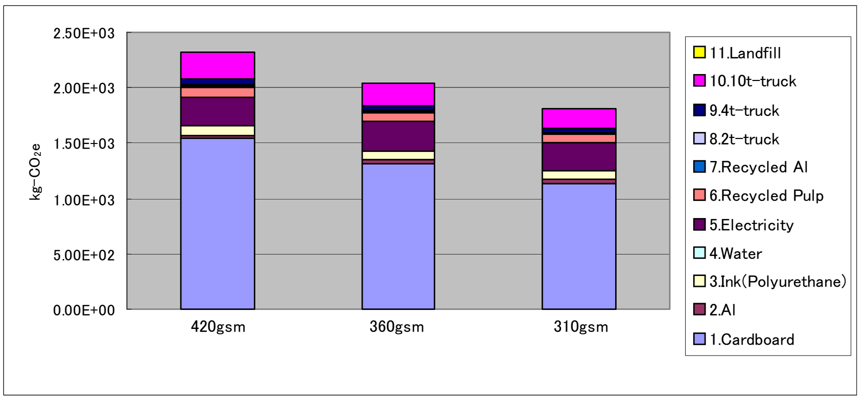
When 15 packages are piled, 2011 model (right) is piled more flatly since broken line helps making packages regular square shape. It increases max.load.

Figure 5.8 Maximum loads for different model year of packages

As a result of shifting from 2008 model to Advanced model is latest version by utilizing broken lines effectively, CO_2e emission is reduced 22.0% compared with 2008 model and is reduced 11.9% compared to 2009 model which is located at midpoint. In a similar way, ELP is reduced 24.9% compared to 2008 model and is reduced 13.5% compared to 2009 model; it is almost same level of improvement in numerical number in total even though breakout is totally different. Figure 5.9 and Figure 5.10 indicate respectively from maximum paper thickness to minimum paper thickness matching up to reality.

Process	CO2e emission coefficient	2008 model(420gsm)		2009 model(360gsm)		Advanced model(310gsm)	
		Input	CO2e	Input	CO2e	Input	CO2e
1.Cardboard	6.37E-01	2,415.798 kg	1.54E+03	2,070.684 kg	1.32E+03	1,783.089 kg	1.14E+03
2.Al	1.43E+01	2.500 kg	3.58E+01	2.500 kg	3.58E+01	2.500 kg	3.58E+01
3.Ink(Polyurethane)	4.53E+00	17.109 kg	7.75E+01	17.109 kg	7.75E+01	16.292 kg	7.38E+01
4.Water	1.97E-04	42.772 kg	8.43E-03	42.772 kg	8.43E-03	0.000 kg	0.00E+00
5.Electricity	4.26E-01	617.720 kWh	2.63E+02	617.720 kWh	2.63E+02	617.720 kWh	2.63E+02
6.Recycled Pulp	1.67E-01	551.670 kg	9.21E+01	472.860 kg	7.90E+01	407.185 kg	6.80E+01
7.Recycled Al	3.16E+00	2.500 kg	7.90E+00	2.500 kg	7.90E+00	2.500 kg	7.90E+00
8.2t-truck	2.09E-01	57.017 tkm	1.19E+01	49.037 tkm	1.02E+01	42.321 tkm	8.85E+00
9.4t-truck	1.43E-01	363.437 tkm	5.20E+01	311.719 tkm	4.46E+01	268.568 tkm	3.84E+01
10.10t-truck	1.21E-01	2,003.421 tkm	2.42E+02	1,717.218 tkm	2.08E+02	1,478.716 tkm	1.79E+02
11.Landfill	3.49E-03	227.420 kg*1	7.94E-01	194.935 kg*1	6.80E-01	167.860 kg*1	5.86E-01
		Total CO_2e:	2.32E+03		2.05E+03		1.81E+03
					-11.9%		-22.0%

Reference: JEMAI "Simple LCA"

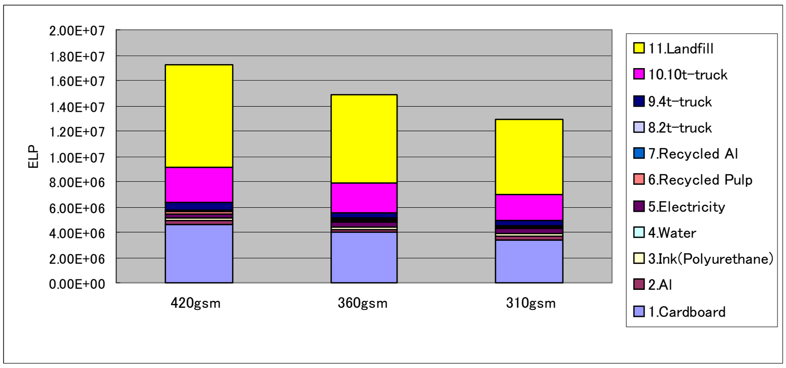


*1: Weight of products*Landfill ratio(12.2%)

Figure 5.9 Comparison of 2008 model, 2009 model and Advanced model by CO_2e

Process	ELF	2008 model(420gsm)		2009 model(360gsm)		Advanced model(310gsm)	
		Input	ELP	Input	ELP	Input	ELP
1.Cardboard	1.92E+03	2,415.798 kg	4.64E+06	2,070.684 kg	3.98E+06	1,783.089 kg	3.42E+06
2.Al	9.86E+04	2.500 kg	2.47E+05	2.500 kg	2.47E+05	2.500 kg	2.47E+05
3.Ink(Polyurethane)	1.15E+04	17.109 kg	1.97E+05	17.109 kg	1.97E+05	16.292 kg	1.87E+05
4.Water	1.59E-01	42.772 kg	6.80E+00	42.772 kg	6.80E+00	0.000 kg	0.00E+00
5.Electricity	6.49E+02	617.720 kWh	4.01E+05	617.720 kWh	4.01E+05	617.720 kWh	4.01E+05
6.Recycled Pulp	2.39E+02	551.670 kg	1.32E+05	472.860 kg	1.13E+05	407.185 kg	9.73E+04
7.Recycled Al	2.43E+04	2.500 kg	6.08E+04	2.500 kg	6.08E+04	2.500 kg	6.08E+04
8.2t-truck	1.77E+03	57.017 tkm	1.01E+05	49.037 tkm	8.68E+04	42.321 tkm	7.49E+04
9.4t-truck	1.61E+03	363.437 tkm	5.85E+05	311.719 tkm	5.02E+05	268.568 tkm	4.32E+05
10.10t-truck	1.36E+03	2,003.421 tkm	2.72E+06	1,717.218 tkm	2.34E+06	1,478.716 tkm	2.01E+06
11.Landfill	3.56E+04	227.420 kg*1	8.10E+06	194.935 kg*1	6.94E+06	167.860 kg*1	5.98E+06
		Total CO2e:	1.72E+07		1.49E+07		1.29E+07
					-13.5%		-24.9%

Reference: Nagata Laboratory at Waseda University



*1: Weight of products*Landfill ratio(12.2%)

Figure 5.10　Comparison of 2008 model, 2009 models and Advanced model by ELP

Different types of packages are re-designed based on Eco-design concept other than "Easy-Dismantling".

Previous design was changed in the range of same figure, but other types are under the reviews without considering biased view points. Environmental impacts are summarized by the scale of CO_2e and ELP in Figure 5.11 and Figure 12 respectively.

One is the package which is exactly the same as base model in terms of appearance, but printed colors are changed to 4-color to 1-color without making consideration of appeal power by full range of colors. When shifting to 1-color, amount of ink and plate are reduced including transportation.

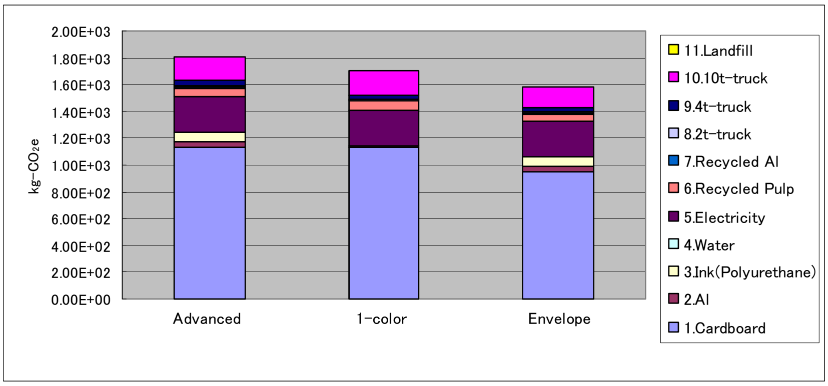
The other is the package which is totally different from base model in terms of appearance, has no spine and is simply folded into two to be envelope shaped one. In order to be folded, paper is too thick, so grammage is reduced from 310gsm to 260gsm. When changing to different type of a package, amount of paper which has biggest impact is reduced more than usual, and paper related transportations including recycling and delivery also reduced involving effects on total load.

As results of CO_2e and ELP comparisons, the load of 1-color package is reduced 5.9% in CO_2e and 3.3% in ELP discretely. On the other hand, the load of envelope type of package is reduced 12.7% in CO_2e and 15.0% in ELP individually, it is drastic reduction compared to

1-color package.

Process	CO_2e emission coefficient	Advanced model(310gsm)		Advanced model(310gsm) (1color printing)		Advanced model(260gsm) (Envelope type of package)	
		Input	CO_2e	Input	CO_2e	Input	CO_2e
1.Cardboard	6.37E-01	1,783.089 kg	1.14E+03	1,783.089 kg	1.14E+03	1,495.494 kg	9.53E+02
2.Al	1.43E+01	2.500 kg	3.58E+01	0.500 kg	7.15E+00	2.500 kg	3.58E+01
3.Ink(Polyurethane)	4.53E+00	16.292 kg	7.38E+01	0.592 kg	2.68E+00	16.292 kg	7.38E+01
4.Water	1.97E-04	0.000 kg	0.00E+00	0.000 kg	0.00E+00	0.000 kg	0.00E+00
5.Electricity	4.26E-01	617.720 kWh	2.63E+02	617.720 kWh	2.63E+02	617.720 kWh	2.63E+02
6.Recycled Pulp	1.67E-01	407.185 kg	6.80E+01	407.185 kg	6.80E+01	341.510 kg	5.70E+01
7.Recycled Al	3.16E+00	2.500 kg	7.90E+00	0.500 kg	1.58E+00	2.500 kg	7.90E+00
8.2t-truck	2.09E-01	42.321 tkm	8.85E+00	41.315 tkm	8.63E+00	35.716 tkm	7.46E+00
9.4t-truck	1.43E-01	268.568 tkm	3.84E+01	267.638 tkm	3.83E+01	225.437 tkm	3.22E+01
10.10t-truck	1.21E-01	1,478.716 tkm	1.79E+02	1,478.716 tkm	1.79E+02	1,240.213 tkm	1.50E+02
11.Landfill	3.49E-03	167.860 kg*1	5.86E-01	167.860 kg*1	5.86E-01	140.788 kg*1	4.91E-01
		Total CO_2e:	1.81E+03		1.70E+03		1.58E+03
					-5.9%		-12.7%

Reference: JEMAI "Simple LCA"

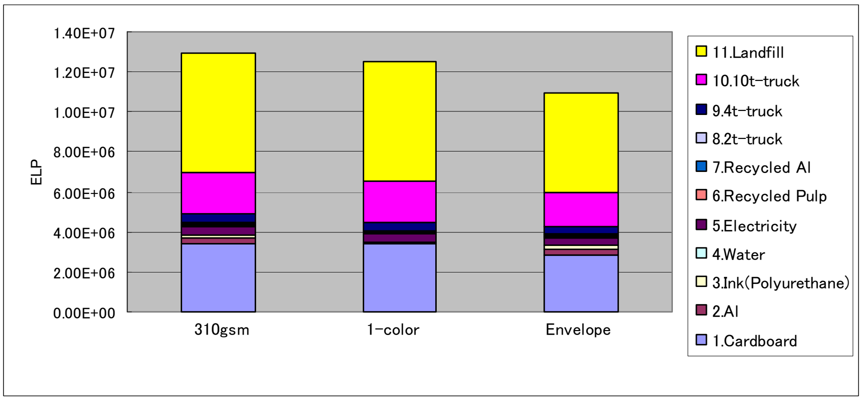


*1: Weight of products*Landfill ratio(12.2%)

Figure 5.11 Comparison of Advanced model , 1-color package and Envelope type package by CO_2e

Process	ELF	Advanced model(310gsm)		Advanced model(310gsm) (1color printing)		Advanced model(260gsm) (Envelope type of package)	
		Input	ELP	Input	ELP	Input	ELP
1.Cardboard	1.92E+03	1,783.089 kg	3.42E+06	1,783.089 kg	3.42E+06	1,495.494 kg	2.87E+06
2.Al	9.86E+04	2.500 kg	2.47E+05	0.500 kg	4.93E+04	2.500 kg	2.47E+05
3.Ink(Polyurethane)	1.15E+04	16.292 kg	1.87E+05	0.592 kg	6.81E+03	16.292 kg	1.87E+05
4.Water	1.59E-01	0.000 kg	0.00E+00	0.000 kg	0.00E+00	0.000 kg	0.00E+00
5.Electricity	6.49E+02	617.720 kWh	4.01E+05	617.720 kWh	4.01E+05	617.720 kWh	4.01E+05
6.Recycled Pulp	2.39E+02	407.185 kg	9.73E+04	407.185 kg	9.73E+04	341.510 kg	8.16E+04
7.Recycled Al	2.43E+04	2.500 kg	6.08E+04	0.500 kg	1.22E+04	2.500 kg	6.08E+04
8.2t-truck	1.77E+03	42.321 tkm	7.49E+04	41.315 tkm	7.31E+04	35.716 tkm	6.32E+04
9.4t-truck	1.61E+03	268.568 tkm	4.32E+05	267.638 tkm	4.31E+05	225.437 tkm	3.63E+05
10.10t-truck	1.36E+03	1,478.716 tkm	2.01E+06	1,478.716 tkm	2.01E+06	1,240.213 tkm	1.69E+06
11.Landfill	3.56E+04	167.860 kg*1	5.98E+06	167.860 kg*1	5.98E+06	140.788 kg*1	5.01E+06
		Total CO_2e:	1.29E+07		1.25E+07		1.10E+07
					-3.3%		-15.0%

Reference: Nagata Laboratory at Waseda University



*1: Weight of products*Landfill ratio(12.2%)

Figure 5.12 Comparison of Advanced model , 1-color package and Envelope type package by ELP

Sensitivity analysis by improvements of materials and processes are conducted in previous chapter, so improvements by eco-conscious standpoint are compared to know the difference here.

5.4.5 Environmental Factor and Economical Factor analysis

Each model should be scrutinized carefully in the standpoint of production cost. Cost breakdown structures for all models are shown in Figure 5.13.

Process	2008 model (420gsm)	2009 model (360gsm)	Advanced model (310gsm)
1.Design	46,425	46,425	46,425
2.Cardboard	313,928	266,156	232,033
3.Ink	22,565	22,565	21,807
4.Water	1	1	0
5.Plate	6,797	6,797	7,261
6.Press	32,747	32,747	32,747
7.Postpress	222,340	222,340	222,340
8.Delivery	46,425	46,425	46,425
Total cost:	691,228	643,456	609,038
compared to 2008 model:		−6.9%	−11.9%

*Numerical numbers are not real value in money

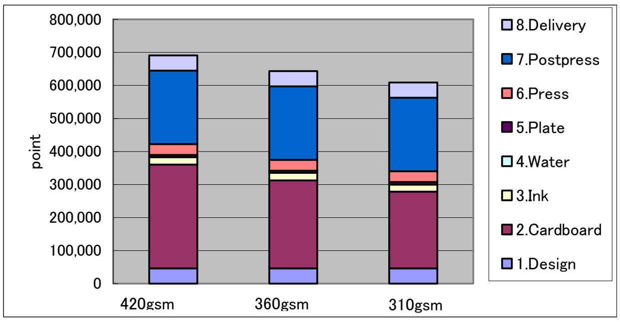


Figure 5.13 Cost breakdown structures for 2008 model, 2009-2010 models and Advanced model

Disclosure about cost breakdown is a susceptive issue, so numerical numbers shown in Figure 5.13 are hypothetical ones assuming lowest cost item which is for water and additives as one. It is perfectly clear that paper is a major factor in terms of the cost, so using thinner paper has critical impact.

As a consequence of shifting from 2008 model to 2009 models, total cost is cutback 6.9% for changeover. Shifting from 2008 model to Advanced model drives cost-cutting of 11.9%; it is drastic cost saving by the idea based on Eco-design.

At this point, environmental factors such as $LCCO_2e$ and ELP, quality factors such as Life Cycle Costing (LCC) are performed; those comparative data for 2008 model, 2009 models and Advanced model are summarized in Figure 5.14.

Factor	Item	2008 model	2009 model	Advanced model
Environmental Factor	CO_2e	100.0%	88.1%	78.0%
	ELP	100.0%	86.5%	75.1%
Economical Factor	Cost	100.0%	93.1%	88.1%

Reference(ELP): Nagata Laboratory at Waseda University
Reference(CO_2e): JEMAI "Simple LCA"

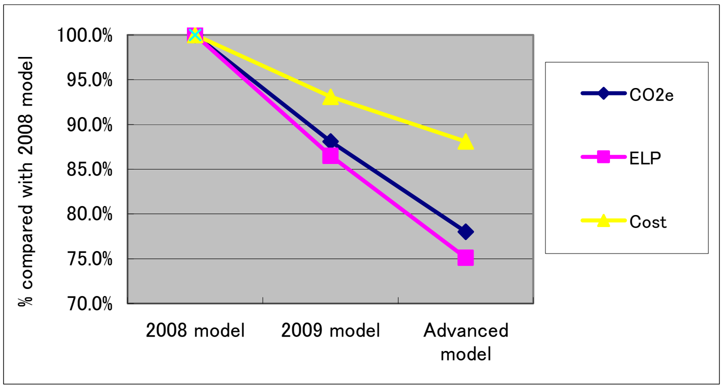


Figure 5.14 Environmental Factor and Economical Factor analysis

Environmental factors show significant reduction of environmental load when shifting to Advanced model which is improved based on Eco-design; both items indicate more than 20% reduction respectively. On another front, LCC representing quality factor demonstrates almost 12% cost reduction.

According to both factors analysis, it is understood that reduction of environmental load can lead to satisfactory level of cost reduction.

5.5 ANALYSIS BY CASE STUDY OF INFORMATION PRITNITNG SERVICE

5.5.1 Shifting to Eco-design for Information Printing Service

Information Printing Service is totally different from Packaging Printing Service since it can be substituted for digital media without constraint. Books, magazines, newspapers, brochures and leaflets representing Information Printing Service can change their configurations, namely can shift to digital media from current media which is based on paper. When looking at current state of newspapers and magazines which require immediate information updates, replacement of paper media by digital media is ongoing transformation.

In terms of environmental load reduction, it should be verified whether digital media can outperform paper media or not by comparing based on well-conceived different scenarios.

5.5.2 Evaluation difference between CO_2e oriented and Integrated LCA

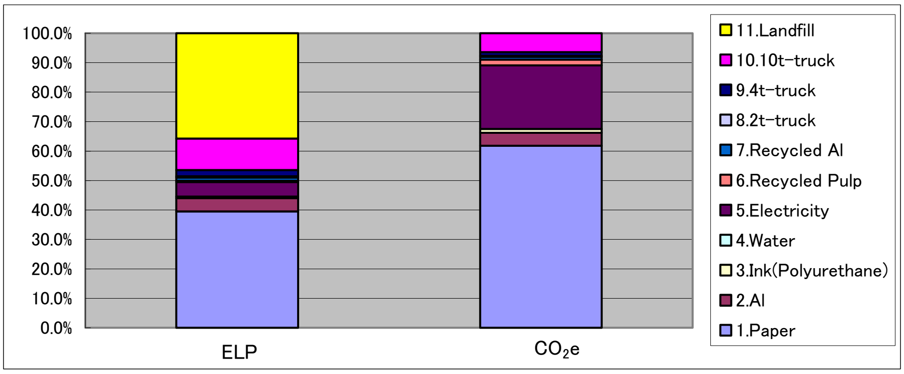
Proportions of each process for Integrated LCA and $LCCO_2e$ are compared in the same as Packaging Printing Service by the scale of ELP and CO_2e.

For Information Printing Service, points of changing emission factors of ELP and $LCCO_2e$ are the ones for paper which are changed from cardboard to normal paper which is commonly used for book production. Generally speaking, environmental load for producing normal paper has more negative impacts compared to cardboard, so ELF which is an emission factor for ELP is more than two times as high as the one for cardboard and CO_2e emission factor is more than one and a half times as high as the one for cardboard. Input for each process is all the same as ELP comparison in previous chapter.

Figure 5.15 shows comparison of ratios for processes.

Process	Input	ELF	CO_2e emission coefficient	ELP		CO_2e		⊿	%
1.Paper	2,043.913 kg	4.18E+03	9.75E−01	8.54E+06	39.5%	1.99E+03	61.8%	22.3%	56.4%
2.Al	10.000 kg	9.86E+04	1.43E+01	9.86E+05	4.6%	1.43E+02	4.4%	−0.1%	−2.9%
3.Ink(Polyurethane)	9.222 kg	1.15E+04	4.53E+00	1.06E+05	0.5%	4.18E+01	1.3%	0.8%	163.4%
4.Water	0.000 kg	1.59E−01	1.97E−04	0.00E+00	0.0%	0.00E+00	0.0%	0.0%	−
5.Electricity	1,636.630 kWh	6.49E+02	4.26E−01	1.06E+06	4.9%	6.97E+02	21.6%	16.7%	339.6%
6.Recycled Pulp	367.672 kg	2.39E+02	1.67E−01	8.78E+04	0.4%	6.14E+01	1.9%	1.5%	368.3%
7.Recycled Al	10.000 kg	2.43E+04	3.16E+00	2.43E+05	1.1%	3.16E+01	1.0%	−0.1%	−12.7%
8.2t−truck	53.702 tkm	1.77E+03	2.09E−01	9.53E+04	0.4%	1.12E+01	0.3%	−0.1%	−21.1%
9.4t−truck	288.840 tkm	1.61E+03	1.43E−01	4.65E+05	2.2%	4.13E+01	1.3%	−0.9%	−40.5%
10.10t−truck	1,695.089 tkm	1.36E+03	1.21E−01	2.31E+06	10.7%	2.05E+02	6.4%	−4.3%	−40.5%
11.Landfill	216.701 kg*1	3.56E+04	3.49E−03	7.72E+06	35.7%	7.56E−01	0.0%	−35.7%	−99.9%
	Total ELP/CO_2e:			2.16E+07		3.23E+03			

Reference(ELP): Nagata Laboratory at Waseda University
Reference(CO_2e): JEMAI "SimpleLCA"



*1: Weight of products × Landfill ratio(12.2%)

Figure 5.15 Comparison of CO_2e and ELP in Best practice

The result from comparison of each process proportion to the total is almost the same as Packaging Printing Service, that is to say that printed media based on paper usage is not influenced much by the difference of Printing Services. Still, paper is major obstacle when reducing environmental load.

Information Printing Service should take a different approach from Packaging Printing Service, changing media from analog to digital which is totally different from physical approach based on recycling oriented thought. Drastic reduction is expected in this field.

5.5.3 Comparison of Physical Book and Electronic Book

Specification for Best practice of Physical Book is cited continuously and Electronic Book (E-Book) is assumed that digital version of the same book is read by kindle software on iPad which is commonly used as E-Book reading device. Physical book and E-Book are shown in

Figure5.16

Physical Books are produced 5,000 copies and sold only 3,000 copies at sales rate is 60% which is the same scenario before, whereas E-Book is sold 3,000 copies which means 3,000 downloads from server to iPad, one full day is used for reading a book. Scenario for E-Book might be precisely set, such as three hours of reading a book a day or one hour of reading for three days, but it is fixed one full day for downloading and reading since consumers' behaviors are not surveyed in detail. Period covered for data collection is one year.

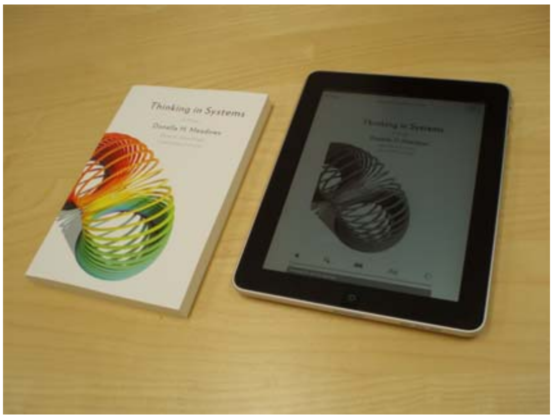


Figure 5.16 Physical Book and E-Book on iPad

5.5.3.1 Electricity usage monitoring of server and peripheral devices

Whenever electricity usage for computer and related devices need to be estimated, it is common to calculate based on rated output. It always prompts questions whether multiplication of rated output and working hour is without credibility or not, so electricity monitoring device for servers and peripherals is attached to electrical power supply to know actual condition. Figure 5.17 shows server components consisting mainly of two servers, hub and router.

Figure 5.17 Small component of server and peripherals

At first, data was monitored for a week, and then monitored for another week to confirm if specific trend is followed or not. Monitoring record for servers and peripherals are summarized in Figure 5.18.

Date	Avg. kW/h a day
2010/10/18 Mon	0.402
2010/10/19 Tue	0.403
2010/10/20 Wed	0.402
2010/10/21 Thu	0.401
2010/10/22 Fri	0.399
2010/10/23 Sat	0.400
2010/10/24 Sun	0.402
2010/10/25 Mon	0.400
2010/10/26 Tue	0.401
2010/10/27 Wed	0.398
2010/10/28 Thu	0.399
2010/10/29 Fri	0.399
2010/10/30 Sat	0.398
2010/10/31 Sun	0.398
Avg. kW/h for 2-week:	0.400

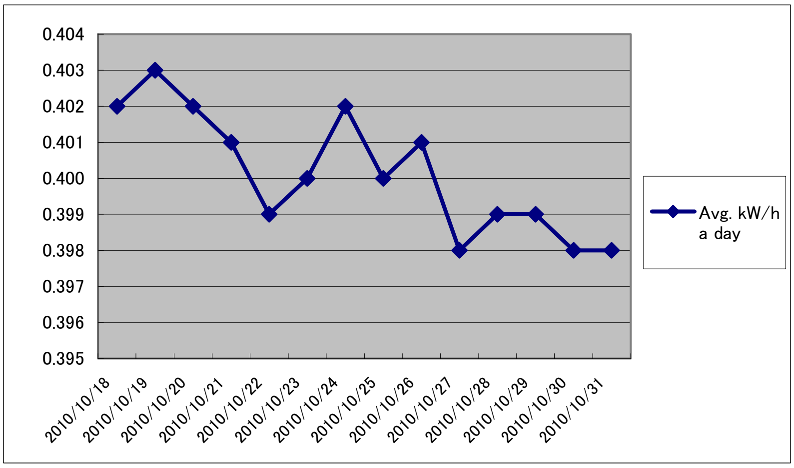


Figure 5.18 Electricity monitoring data for server and peripherals

Monitoring data ranges from 398W to 403W which is around one third of rated output, difference from the lowest to the highest is just 5W which is only 1.2% of the highest value. Even though CPU is working busy or amount of data transmission is frequent, it leads to further understanding of consistent electricity usage for servers and peripherals. It is understood that one time of electricity monitoring should be sufficient.

5.5.3.2 $LCCO_2e$ for E-Book

$LCCO_2e$ from each process of E-Book is summarized in Table 5.1.

Table 5.1 $LCCO_2e$ summary for E-Book production

Data creation	6.374 kW*1	*	100 hours	*	0.426 kg-CO2e/kWh	/	3000 copies	=	0.091 kg-CO2e							
Server:	0.400 kW*2 by 2-server and peripherals	*	24 hour	*	365 days	*	0.462 kg-CO2e/kWh	*	2.460 MB	/	51,200 MB	=	0.078 kg-CO2e/yr.			
Server Air cond.:	2.500 kW*3	*	18.2% (loading f.)	*	24 hour	*	365 days	*	0.462 kg-CO2e/kWh	*	2.460 MB	/	51,200 MB	=	0.088 kg-CO2e/yr.	
Data download:	1012 kg-CO2e/¥ million(3EID)*4	/	1,000,000 yen	*	24,000 yen/yr.	/	365 days	=	0.067 kg-CO2e/d.							
iPad(usage)*5	39 kg-CO2e/3yr.	/	3 years	/	365 days	=	0.036 kg-CO2e/d.									
iPad(production and others)*5	91 kg-CO2e/3yr.	/	3 years	/	365 days	=	0.083 kg-CO2e/d.									
							0.442 kg-CO2e/book in an year									

*1: PC 0.06kW+Air condition 5.930kW+Lighting 0.384kW=6.374kW, it is just the same as Physical book

*2: Average electricity consumption for two servers is calculated based on 2-week monitoring, see Table 5.13

*3: Electricity of air conditioning is calculated based on MSG-GV220 (Mitsubishi Electronic), so loading factor of air conditioning is 455W÷2.5kW=18.2%

*4: "Other services relating to communication(1.102t-CO2)", Embodied Energy and Emission Intensity Data for Japan Using Input-Output Tables, The National Institute for Environmental Studies (NIES)

*5: "iPad Environmental Report", Apple

Data creation is exactly the same as Physical Book because of core data for physical book or digital is all the same. In a strict sense, it might take time for data conversion for E-Book format, but it is estimated as pint-sized load and ignored here in this case study. Calculating formula is;

6.374kW(PC+air-con.+lighting)*100h*0.426kg-CO_2e/3,000download=0.091kg-CO_2e/copy

Two servers and peripherals are monitored as shown above and each copy of E-Book is calculated based on the memory occupancy of total storage which is around 50GB. Calculating formula is;

0.400kW*24h*365-day*0.462 kg-CO_2e*2.460MB/51,200MB＝0.078 kg-CO_2e/copy

Air-conditioning for a server room (18 cubic-meters) should be key factor, so it is calculated based on specific equipment. Division process of air-conditioning (2.5kW) and loading factor of 18.2% and can lead energy consumption (455W). Calculating formula is;

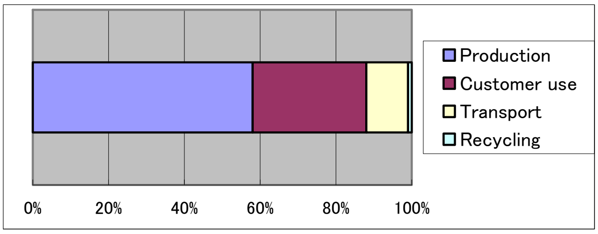
0.455kW*24h*365-day*0.462kg-CO_2e*2.460MB/51,200MB＝0.088 kg-CO_2e/copy

Data download which starts from server center to iPad cannot show true figure of environmental load, so the item named “Other services relating to communication” in Japanese Input-Output table is utilized for calculation. Assumptive story is based on spending 2,000 yen a month for internet access service, namely 24,000 yen per year all totaled. Environmental load is calculated for data transmission for full day. Calculating formula is;

1,012 kg-CO_2e/1 million yen*24,000 yen/365-day=0.067 kg-CO_2e/copy

Apple publicizes environmental load of iPad, it is shown in Figure 5.19.

Stages	iPad	
	kg-CO_2e	%
Production	75	58%
Customer use	39	30%
Transport	14	11%
Recycling	1	1%
Total(kg-CO_2e):	130	



Reference: "iPad Environmental Report", Apple

・Greenhouse gas emissions: Estimated emissions are calculated in accordance with guidelines and requirements as specified by ISO 14040 and ISO 14044. Calculation includes emissions from the following life-cycle phases contributing to Global Warming Potential (GWP 100 years) in CO_2 equivalency factors (CO_2e)

・Production: Includes the extraction, production, and transportation of raw materials as well as the manufacture, transport, and assembly of all parts and product packaging.

・Transport: Includes air and sea transportation of the finished product and its associated packaging from manufacturing site to continental distribution hubs. Transport of products from distribution hubs to end customer is not included.

・Use: User power consumption assumes a three-year period. Product use scenarios are modeled on data that reflects intensive daily use of the product. Geographic differences in the power grid mix have been accounted for at a continental level.

・Recycling: Includes transportation from collection hubs to recycling centers and the energy used in mechanical separation and shredding of parts

Figure 5.19 iPad Environmental Report by Apple

LCCO_2e is precisely done by Apple showing absolute amount and proportion of environmental load in three years at each stage such as production, customer use, transport and recycling. All stages are divided into two parts, one is customer usage which is electricity use weighting 30% of total load and others including production, transport and recycling. It is presupposed that iPad is used 365 days a year, so calculation formula is;

39kg-CO_2e/3-year/365-day=0.036 kg-CO_2e/day (usage)

91kg-CO_2e/3-year/365-day=0.083 kg-CO_2e/day (production, transport and recycling)

Calculated environmental load is accumulated one full day of reading a book. There could be so many scenarios about years of use, days of use and reading time for a book. These factors definitely influence total load for E-Book, so consider several different usage patterns partly for sensitivity analysis later.

When getting down to a core part of E-Book calculation, there is a point in controversy to decide if iPad's environmental load except from electricity should be calculated or not. Generally, product focused LCA method does not include property and machines for production such as printing machine and book binding machine are not included to be calculated. It could be thought however that iPad is part of E-Book since it is necessary as reading device, so it is included here in this case study.

5.5.3.3 LCCO_2e comparison of E-Book and Physical Book

Before comparing E-Book with Physical Book, imaginable patterns for E-Book based on different scenario are considered. The result is shown in Figure 5.20.

Item	365-day of iPad use		250-day of iPad use		183-day of iPad use		122-day of iPad use		73-day of iPad use	
	CO_2e-kg/book	%	CO_2e-kg/book	%	CO_2e-kg/book	%	CO_2e-kg/book	%	CO_2e-kg/book	%
Data creation	0.091	20.5%	0.091	17.2%	0.091	14.4%	0.091	11.1%	0.091	7.6%
Server	0.078	17.6%	0.078	14.8%	0.078	12.4%	0.078	9.6%	0.078	6.6%
Server Air cond.	0.088	20.0%	0.088	16.8%	0.088	14.1%	0.088	10.9%	0.088	7.5%
Data download	0.067	15.0%	0.097	18.4%	0.133	21.2%	0.199	24.5%	0.333	28.1%
iPad(usage)	0.036	8.1%	0.052	9.9%	0.071	11.3%	0.107	13.2%	0.178	15.0%
iPad(production and others)*1	0.083	18.8%	0.121	23.0%	0.166	26.5%	0.249	30.7%	0.416	35.1%
Total CO_2e:	0.442		0.527		0.627		0.812		1.184	

Reference: "iPad Environmental Report", Apple

*1: Production(58%), Transport(11%) and Recycling(1%) are included.

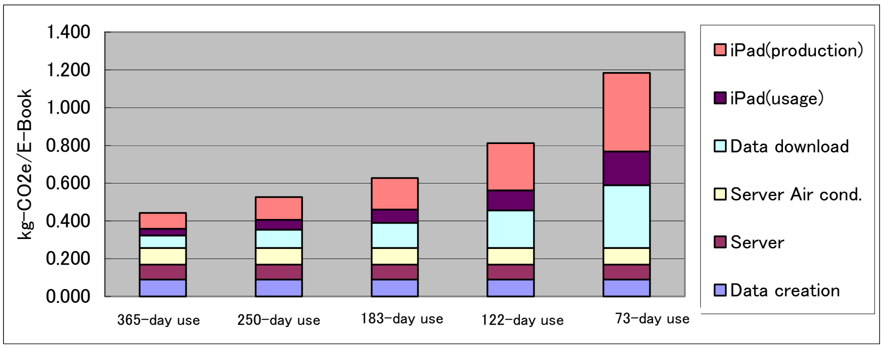


Figure 5.20　E-Book 5-pettern scenario based on different iPad usage

Primary scenario for E-Book is based on 365-day use of iPad, so days of iPad usage is changed to 250-day (usual business days a year), 183-day (once every other day), 122-day (once every three days) and 73-day (once every five days) to know the difference of environmental load based on different scenarios.

Four items such as Data creation, Server, Server air-conditioning and usage of iPad are fixed. Only items which are related to iPad, such as its production, transportation and recycling are changed by scenarios. Electricity usage for iPad should be changed by scenarios, but cannot be estimated since information source is limited.

As a result of comparison, environmental load per E-Book varies from 0.442kg-CO2e to 1.184kg-CO2e, highest value is more than 2.5 times as high as lowest one.

Other scenarios are changed by loading factor from 10% to 50% of server air-conditioning showing in Figure 5.21.

Item	L.F.=10.0%		L.F.=18.2%		L.F.=30.0%		L.F.=40.0%		L.F.=50.0%	
	CO_2e-kg/book	%	CO_2e-kg/book	%	CO_2e-kg/book	%	CO_2e-kg/book	%	CO_2e-kg/book	%
Data creation	0.091	22.5%	0.091	20.5%	0.091	18.1%	0.091	16.5%	0.091	15.2%
Server	0.078	19.3%	0.078	17.6%	0.078	15.6%	0.078	14.2%	0.078	13.0%
Server Air cond.	0.049	12.2%	0.088	19.9%	0.146	29.2%	0.194	35.4%	0.243	40.7%
Data download	0.067	16.5%	0.067	15.1%	0.067	13.3%	0.067	12.1%	0.067	11.1%
iPad(usage)	0.036	8.9%	0.036	8.1%	0.036	7.2%	0.036	6.6%	0.036	6.0%
iPad(production and others)	0.083	20.6%	0.083	18.8%	0.083	16.6%	0.083	15.2%	0.083	13.9%
Total CO_2e:	0.403		0.442		0.500		0.548		0.597	

Reference: "iPad Environmental Report", Apple

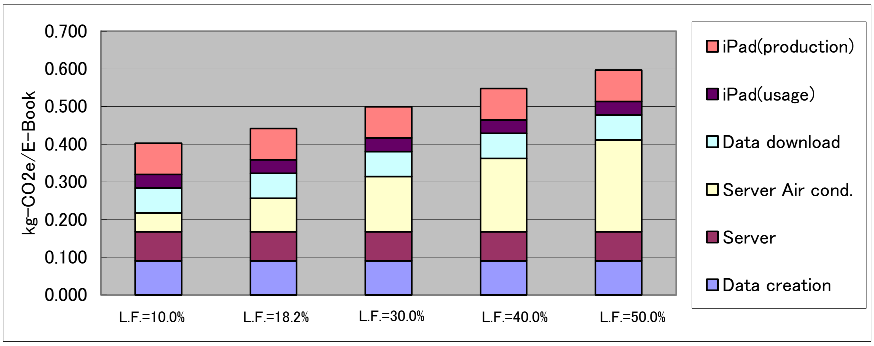


Figure 5.21 E-Book 5-pettern scenario based on different air-conditioning loading factor

Two different scenarios based on different time period of iPad usage and different loading factor of server air-conditioning is completed, then compared to Physical Book showing in Figure 5.22.

Scenario	365-day of iPad use		250-day of iPad use		183-day of iPad use		122-day of iPad use		73-day of iPad use	
	CO_2e-kg/book	%	CO_2e-kg/book	%	CO_2e-kg/book	%	CO_2e-kg/book	%	CO_2e-kg/book	%
Scenario-A	0.442		0.527	119.2%	0.627	141.9%	0.812	183.7%	1.184	267.9%

Scenario	L.F.=10.0%		L.F.=18.2%		L.F.=30.0%		L.F.=40.0%		L.F.=50.0%	
	CO_2e-kg/book	%	CO_2e-kg/book	%	CO_2e-kg/book	%	CO_2e-kg/book	%	CO_2e-kg/book	%
Scenario-B	0.403		0.442	109.7%	0.500	124.1%	0.548	136.0%	0.597	148.1%

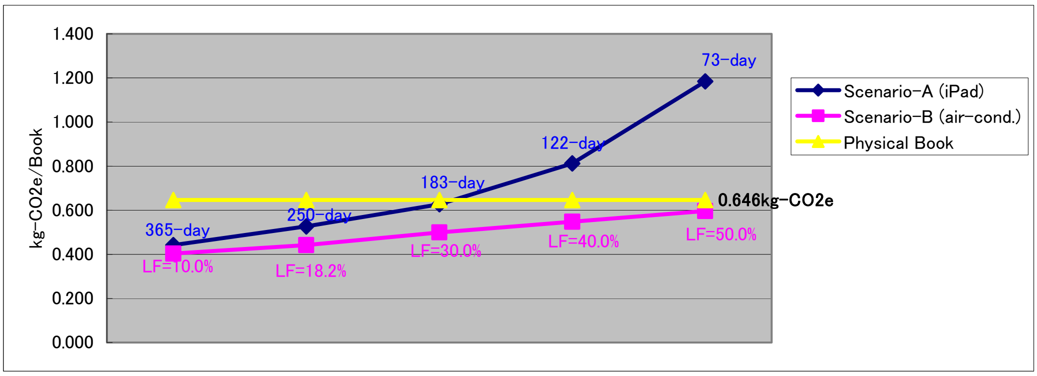


Figure 5.22 E-Book vs. Physical Book

Scenario A is based on iPad usage days an year, whereas Scenario B is based on different patterns of server air-conditioning loading factors; both scenarios are compared to environmental load of Physical book which is calculated referring from Table 5.12.

The loads for Scenario B gradually increase and never hit the load of Physical book, but the ones for Scenario A increase drastically and exceed when iPad is used once every three days.

In the past, it is thought that E-Book is much more eco-friendly alternative to read a book, but it is strongly influenced by how frequently the device is used.

Another sensitivity analysis is conducted to know the environmental load by different number of downloads for E-Book and copies for Physical Book.

Based on the assumption that number of returned books are 40% of total production volume, so number of E-Book downloads are exactly 60% compared with the one of Physical Book. It is indicated in Figure 5.23.

There is a big difference when production volume is small, especially from 500 downloads to 1000 downloads (834 copies to 1667 copies). Publishing business has been shrunk year by year, so lot size is smaller and smaller; shifting from Physical Book to E-Book is recommended when considering structural recession in publishing sector.

Scenario for E-Book	500 downloads		1000 downloads		3000 downloads		5000 downloads		10000 downloads	
	CO_2e-kg /book	%	CO_2e-kg /book	%	CO_2e-kg /book	%	CO_2e-kg /book	%	CO_2e-kg /book	%
365-day of iPad use	0.895	202.5%	0.623	141.0%	0.442	－	0.406	91.9%	0.379	85.7%

Scenario for Physical Book	834 copies		1667 copies		5000 copies		8334 copies		16667 copies	
	CO_2e-kg /book	%	CO_2e-kg /book	%	CO_2e-kg /book	%	CO_2e-kg /book	%	CO_2e-kg /book	%
E-Book is 60% of Physical Book*1	1.415	219.0%	0.938	145.2%	0.646	－	0.588	91.0%	0.540	83.6%

*1: Production volume of E-Book is 60% basd on the facthat average number of returned book of Physical Book is 40%

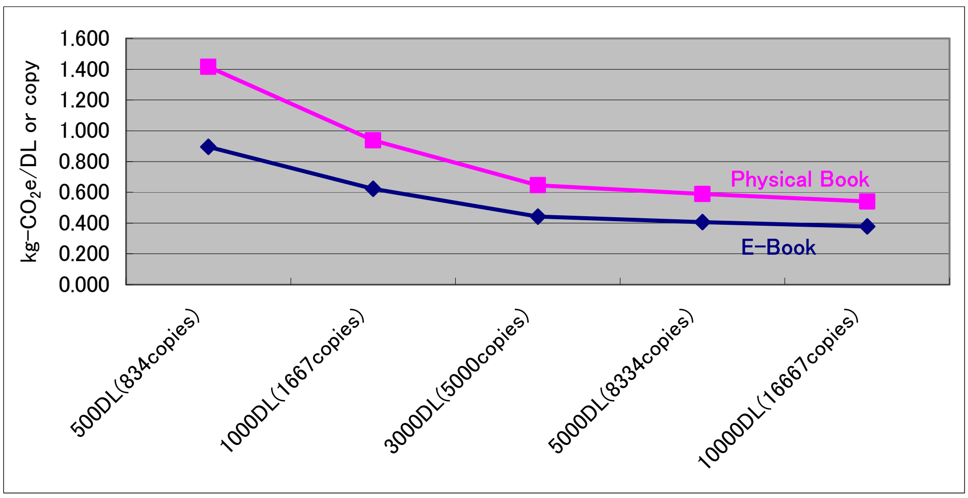


Figure 5.23 E-Book vs. Physical Book by different downloads and copies

5.5.4 Environmental factor and economical Factor analysis

Cost analysis of Physical Book and E-Book is reviewed in terms of production cost. Cost breakouts for both types of books are indicated in Figure 5.24.

	Physical Book		E-Book	
Paper	263	8.8%	0	0.0%
Ink	10	0.3%	0	0.0%
Plate	38	1.3%	0	0.0%
Prepress	1,847	61.6%	1,847	91.9%
Press	101	3.4%	0	0.0%
Postpress	120	4.0%	0	0.0%
Delivery	618	20.6%	0	0.0%
Server related	0	0.0%	162	8.1%
	2,996		2,009	
			67.0%	

*Numerical numbers are not real ones.

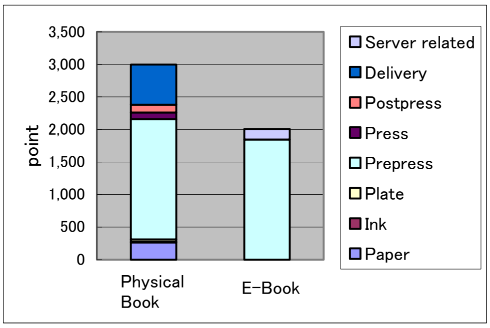


Figure 5.24 Cost breakdown structure for Physical Book and E-Book

Open disclosure of cost breakdown is touchy issue, so all figures shown in Table 5.20 is different from real ones, but only ratio of total cost is indicated without being distorted.

Prepress cost consisting of text input and editing work is common cost for both types of books, it is prime cost driver. The distinct points between Physical Book and E-Book are that no tangible things such as paper, ink, plate and logistics exist for E-Book, instead running cost for server components such as server, switching hub, routers and monitor is additional cost. As a result of shifting to E-Book, over one third of cost reduction could be achieved.

In order to compare environmental factor and economical factor, $LCCO_2e$ and LCC are performed and shown in Table 5.25 for Scenario-A which is based on different patterns of iPad used hours and Figure 5.26 for Scenario-B which is based on different patterns of server air-conditioning loading factors.

Factor	Item	Physical Book	E-Book iPad(365-day)	E-Book iPad(250-day)	E-Book iPad(183-day)	E-Book iPad(122-day)	E-Book iPad(73-day)
Environmental Factor	CO_2e	100.0%	68.4%	81.6%	97.1%	125.7%	183.3%
Economical Factor	Cost	100.0%	67.0%	67.0%	67.0%	67.0%	67.0%

Reference(CO_2e): JEMAI "Simple LCA"

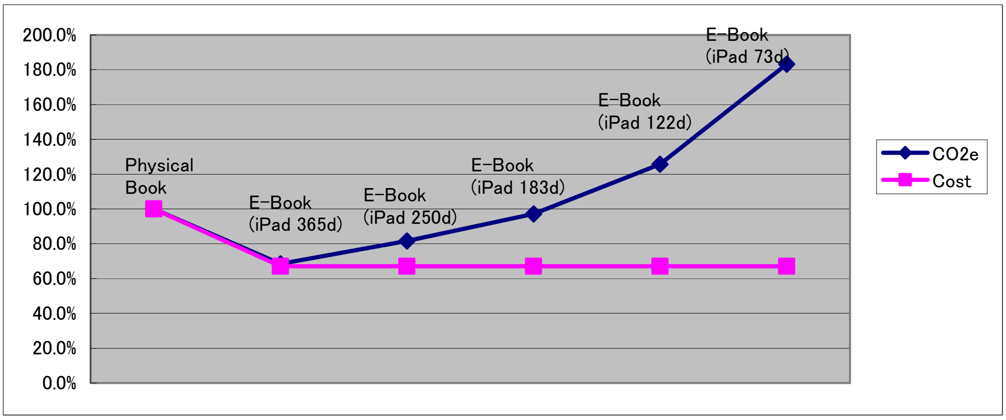


Figure 5.25 Environmental factor and economical factor analysis based on Scenario-A

Factor	Item	Physical Book	Air cond. L.F.=10.0%	Air cond. L.F.=18.2%	Air cond. L.F.=30.0%	Air cond. L.F.=40.0%	Air cond. L.F.=50.0%
Environmental Factor	CO_2e	100.0%	62.4%	68.4%	77.4%	84.8%	92.4%
Economical Factor	Cost	100.0%	65.7%	67.0%	68.9%	70.5%	72.1%

Reference(CO_2e): JEMAI "Simple LCA"

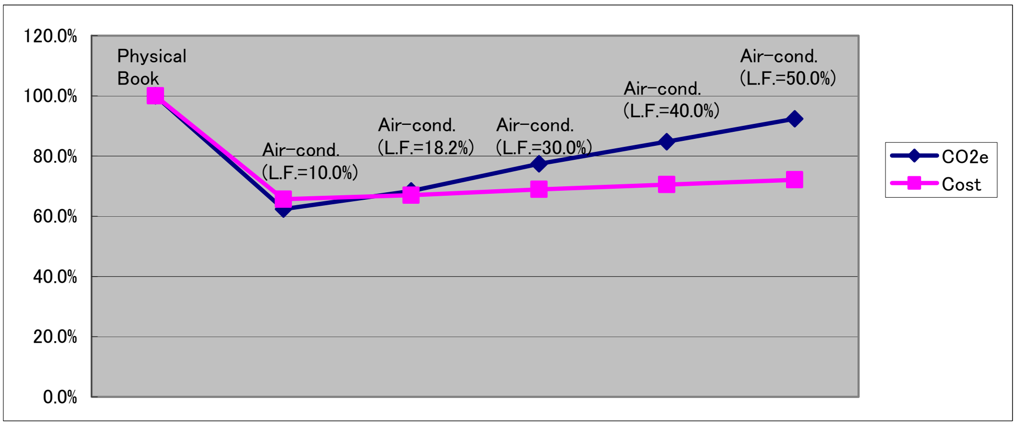


Figure 5.26 Environmental factor and economical factor analysis based on Scenario-B

One item is selected for each factor, CO_2e for environmental factor and cost for economical factor.

In Figure 5.25, both factors dropped over 30% in parallel when shifting to E-Book, then economical factor keeps same reduction percentage since iPad usage hours is not related to production cost at all. On the other hand, environmental factor gradually rises up with the increase of iPad usage hours, peak of CO_2e emission is more than 60% increase compared to Physical Book.

In Figure 5.26, by shifting to E-Book, both factors dropped almost same percentage as

Scenario-A. Environmental factor rises up because loading factor changes in upward trend, but CO_2e never be more than Physical Book like Scenario-A. Cost is detailed its trend and is realized that small amount of cost overrun is seen since electricity of air-conditioning in a server room increases when loading factor rises.

5.6 CONCLUSION

For Package Printing Service, environmental load is decreased by reducing total amount of paper usage based on utilization of Eco-design concept. Changing weight of paper and basic structure of package design can achieve certain level of the load reduction as benefit of real world practices.

As long as material is used for production, it should be recycled materially. There are different kinds of recycle patterns such as material, thermal and chemical recycles, but this case study is strictly persist in material recycle. The load for recycling is evaluated by $LCCO_2$e and several different Integrated LCA methods and only ELP suggests that recycling can bring forward environmental load reduction.

All LCA methods show that certain amount of increase in terms of the load when recycling, but it is very difficult to follow the result since national goal to reduce the load is clarified as “Reduce, Reuse and Recycle”. Alternatives for analytical methods should not be only one, should be chosen from multilateral LCA methods to know different viewpoints of ideas to evaluate for due recognition.

Total production cost can follow reduction of environmental load at around half proportional amount. When reduction of the load is successfully achieved, some extent of cost reduction is also achieved as usual.

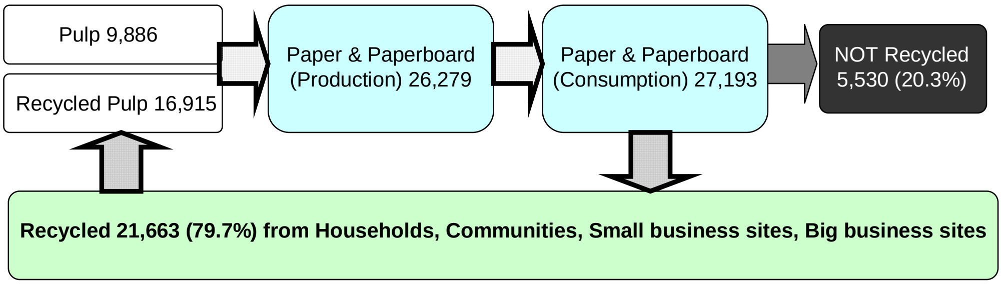
For Information Printing Service, environmental load is drastically decreased not by reducing total amount of material and energy, but by changing media from paper media to digital media although the load from E-Book reader is not perfectly investigated. Digital media does not require materials such as paper, ink and plates. Additionally, logistics does not exist, namely no transportation by trucks for material and completed products.

Cost reduction is attained in more drastic way than Package Printing Service. Rethinking media itself and shifting from tangible to intangible are fundamental change. Reductions of environmental load and production cost always hit the target not by commonly-used approach but by innovative approach.

LCA methods such as $LCCO_2$e and Integrated LCA can be utilized for Packaging Printing Service and Information Printing Service in the real world to know how much of environmental load could be reduced by numerical number; it can lead to the best practice concerning comparison of current practice and ideal practice.

For Package Printing Service, increasing recycle rate for paper packages is very important.

But, it seems quite difficult when looking at entire picture shown in Figure 5.24 because of quite high recovery rate for paper and paperboard. Additionally, Table 5.2 shows the proof convincing recycling of paperboard is difficult issue to be contended.



*Numerical numbers are rounded to the nearest 1000-ton

Reference: Emergence and circulate route of recycled paper in 2009, Ministry of Environment

Figure 5.27 Emergence and circulate route of recycled paper in 2009

Table 5.2 Recycled proportion for each grade of paper and paperboard

	Grades	Shipment	%	Grades	Consumption as recycled	%	Recycle%
Paper	Newsprint	3,475,521	13.1%	Old newsprints, Old magazines, Fine paper printed (incl. coated paper)	8,713,351	51.9%	68.6%
	Printing paper, writing paper	9,223,243	34.9%				
	Packaging paper	809,881	3.1%	Kraft browns, Quires woody paper printed	225,186	1.3%	6.8%
	Household tissue	1,775,006	6.7%				
	Other paper	708,536	2.7%				
	Sub total of Paper:	15,992,187	60.5%	Sub total of Recycled Paper:	8,938,537	53.2%	55.9%
Paperboard	Liner and medium	8,232,365	31.1%	Old corrugated containers	7,341,009	43.7%	89.2%
	White paperboard	1,475,901	5.6%	Hard white savings, white cards,White woody shavings, white manilas,Box board cuttings	512,118	3.0%	23.0%
	Patent coated paperboard	150,454	0.6%				
	Building board	182,322	0.7%				
	Other paperboard	415,718	1.6%				
	Sub total of Paperboard:	10,456,760	39.5%	Sub total of Recycled Paper:	7,853,127	46.8%	75.1%
	Grand Total:	26,448,947		Grand Total:	16,791,664		63.5%

(ton/year)

Reference: "Statistics of Recovered Paper in Japan", Paper Recycling Promotion Center

According to Table 5.2, consumption of paperboard occupies almost 40% of total, but mostly from "Liner and medium" which are material for corrugated containers. Proportion of paperboard for paper packages is categorized in "White paperboard" and is less than 6% of total. When recycling for paper packages is promoted and achieve 75% recycling rate, recycling rate for paperboard is 57.5% which is more than double compared to 23.0%. Increasing recycling percentage for "White paperboard" has significant impact on total recycling percentage; it has upward force almost 3% and will be 66.4% from 63.5%.

Conflicts always develop when pursuing of eye-filling and easiness of dismantling at the same time. For example, when priority of package design is set based on dismantling, sides of a package should be partly broken lines, then its appearance will be worsen. But a weak point could be improved with devising of industrial or graphic design.

Additionally, there may be no space on a package for text line which explains how to dismantle and appeals importance of recycling since it attaches importance of appearance too much. If there is no space for explanation, practical use of a small logo mark instead of written instruction might be substituted.

Both consumers and suppliers must change their attitudes of minds, so package design should be changed based on the point of recycling as long as paper usage continues to construct Recycling-oriented society based on the idea of “Reduce, Reuse and Recycle”.

For Information Printing Service, there are challenging issues to be solved when comparing Physical Book and E-Book in detail. Part of calculation for E-Book cannot go beyond the compass of estimation.

Environmental load from server related components for case study here is researched based on one set of small server system since gigantic server center could not be researched. Generally, buying E-Book through gigantic server center is common because small publishing companies cannot start their own business on the web without relying on it. Electricity usage for server related components and air-conditioning devices should be investigated to know actual load from gigantic server center.

There is almost no data for the load of data download from a server center to an iPad. Here in this case study, Japanese Input and Output Table is utilized to calculate the load for downloading E-Book from a web site to iPad. When calculation is done based on Input and Output Table, though it is small portion compared with all, is considered that it has uncertain part in it.

Behavior pattern for using iPad is drawn from a scenario based on downloading and reading E-Book in one day. It is very rough estimation, so survey for E-Book readers by iPad should be conducted to know their behavioral rule when reading E-Books. Additionally, behavior pattern of using iPad should be known since the load for iPad itself is included in E-Book calculation. So on that point, survey should be done to make clear that how many days a year for using iPad and how many hours a year for reading E-Book.

For both Package Printing Service and Information Printing Service, there are still agendas in real practices to be solved when utilizing LCA methods to improve in terms of environmental load reduction in further detail.

CHAPTER 6

LOCALIZATION OF PRINTING SERVICE LCA IN EMERGING COUNTRIES

ABSTRACT

In most of emerging countries in Asia, such as Thailand, Printing Service LCA is not well organized even though the country is already working on Carbon Footprint of Products (CFP), so schematization and localization of practical methodology is established by joint research project with Chulalongkorn University. Firstly, Production of 500 copies of textbook at university is selected as case study to establish the method and to know the difference of CO_2e emission from Printing Service between Thailand and Japan. Printing method and CO_2e emission factors are different in both countries; clear difference is emerged from actual calculation of CO_2e emission. Secondly, in order to perceive the recognition degree of CFP in Thailand, questionnaire research is conducted. More than half of the interviewees do not know about CFP even at the university, so much more than half of people in the town are expected not to know about it. But, after explaining the concept of CFP, almost all interviewees can understand it and show very positive attitude. They can see strong positive potential for CFP to assist constructing Low-carbon society in the future. Thirdly, as a result of demand toward establishing Integrated LCA method, Environmental Load Point (ELP) is upgraded exclusively for Thailand. There are some difficulties since data from annual consumption of all items are usually limited in emerging countries, but ELP is finally streamlined based on different category groups at satisfactory level. The findings here is that Printing Service LCA can take root in emerging countries to promote CFP and reduce overall environmental load by ELP representing Integrated LCA method.

6.1 INTRODUCTION

Quantification of environmental load for Printing Service is well organized, namely Printing Service LCA which covers from data collection to assessment of the load is precisely schematized in Japan. But, printing industries in many emerging countries in Asia do not have clues of quantitative assessment methods yet and feel rushed to establish localized Printing Service LCA since some of their business model can work out by exporting related business.

Thailand which is located in the center of Southeast Asia is covered here at first in this chapter to validate Printing Service LCA. Possibility of localizing quantification method fitting in Thai printing industry is provided.

In order to promote diffusion of Printing Service LCA concept, joint research study is conducted with an academic organization to avoid know-how monopolization at private companies. Department of Imaging and Printing at Chulalongkorn University (CU) is a pillar of the kingdom and the most influential printing related academic institution in Thailand, so unbiased expanding of practical use of Printing Service LCA is expected in the future.

6.2 PURPOSE OF THE STUDIES

Printing Service LCA is localized in Thailand in response to the request from the industry.

Firstly, Practical quantification method covering from primary data collection to assessment of environmental load should be localized firstly at Chulalongkorn University Printing House (CUPH). Textbook for students which is a case study here should be certified as CFP at first, and then will be predominant factor to generalize Printing Service LCA in emerging country. It should be proposed to establish Printing LCA method.

Secondary, CFP seems to be known to the public slowly in Thailand, but recognition degree is still unknown. It should be known at certain degree to take appropriate action for people to promote CFP. Grasping the detailed concept of CFP is important to shift their life style to Low-carbon one. Survey for CFP is conducted to figure out correlative relationship of CFP related variables in statistical way to show the channel for promotion.

Thirdly, “Carbon centered evaluation method for environmental load” might not be perfect even in emerging countries, not only in Thailand, so survey for people’s environmental consciousness is conducted to find out what is the most anxious issue in impact categories. Then, Environmental Load Point (ELP) which is Integrated LCA and is utilized for analysis in previous chapter should be verified if it can perform effectively or not in different countries.

Successful schematization of this study could be utilized when establishing Printing Service LCA in different emerging countries. It is strived to be ideal model when transferring and localizing Japanese quantification scheme to emerging countries.

6.3 GENERAL OUTLOOK OF THAILAND

Thailand is truly at the heart of Southeast Asia having the shape of an elephant’s head. Geographically, Thailand has natural borders with neighbors with Myanmar (Burma) on the northwest; Laos on the north east; and Cambodia on the east. It is shown in Figure 6.1.

Reference: The World Bank

Figure 6.1 Geographical location of Thailand

The weather is usually very hot and very humid throughout the year because of the location of the tropics. It is often said that Thailand is divided into three different seasons; “hot, hotter and hottest”.

The majority, roughly 80% of citizens are ethnically local Thai. The rest consists of Chinese, Indian and Malay. Bangkok is a capital city of the nation and is diversified ethnically; there are many expatriate residents for international business coming from all over the world.

Table 6.1 shows key indicators of Thailand and also the ones of Japan to have an idea by contrasting with familiar figures.

Table 6.1 Key indicators of Thailand and Japan

Item	Thailand		Japan		TH/JP
	Data	Year	Data	Year	
<World view>					
Population, total (millions)	67.76	2009	127.56	2009	53.1%
Surface area (sq.km, thousands)	513.1	2008	377.9	2008	135.8%
<People>					
Life expectancy at birth, total (years)	69	2008	83	2008	83.1%
Fertility rate, total (birth per woman)	1.8	2008	1.3	2008	138.5%
Mortality rate, under-5 (per 1000)	14	2009	3	2009	466.7%
<Environment>					
Forest area (sq.km, thousands)	145.2	2005	248.7	2005	58.4%
Agiricultural land (% of land area)	38.4	2005	12.9	2005	297.7%
Improved water source (% of population with access)	96	2008	100	2008	96.0%
CO2 emission (metric tons per capita)	4.1	2005	9.7	2005	42.3%
Electric power consumption (kWh per capita)	1899	2005	8201	2005	23.2%
<Economy>					
GDP (current US$, billions)	263.77	2009	5069.00	2009	5.2%
Agiricultural, value added (% of GDP)	12	2009	1	2008	1200.0%
Industry, value added (% of GDP)	43	2009	28	2008	153.6%
Service, etc., value added (% of GDP)	45	2009	71	2008	63.4%
Exports of goods and services (% of GDP)	68	2009	13	2009	523.1%
Imports of goods and services (% of GDP)	58	2009	12	2009	483.3%
<States and markets>					
Mobile cellular subscriptions (per 100 people)	92	2008	86	2008	107.0%
Internet users (per 100 people)	23.9	2008	75.2	2008	31.8%

Reference: The World Bank

Population in Thailand is almost half of Japan, but the land area is around 1.4 times as big as Japan. Average residents per square kilometer are 132 residents in Thailand and 338 residents in Japan, so it is concluded that Japan is around 2.6 times as congested as Thailand.

According to life expectancy at birth and mortality rate, it is inferable that Thailand is still typical emerging country, but it might not be correct since fertility rate looks like the one like advanced country.

Exports of goods and services in Thailand accounts 68% of GDP since domestic consumption is not really strong, it is extremely higher compared with the one in Japan.

Adoption rate of cellular phone in Thailand is higher than Japan, but the one of internet is still on the way. Accessibility of internet is extremely important when considering digital shift of Information Printing Service in the near future.

6.4 ECONOMICAL OUTLOOK OF THAILAND

Economical magnitude in Thailand is imagined from temporal sequence of GDP. Figure 6.2 indicates that GDP of Thailand and Japan to compare the scale and the proportion based on percent change based on year 2000.

Country	Item	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Thailand	Nominal GDP (billion USD)	122.73	115.54	126.88	142.64	161.34	176.35	207.09	246.98	272.58	263.71
	% increase vs 2000	–	−5.9%	3.4%	16.2%	31.5%	43.7%	68.7%	101.2%	122.1%	114.9%
	Population(million)	62.40	62.94	63.46	64.01	65.08	65.11	65.28	65.74	66.32	66.98
	Nominal GDP per capita	1,966.75	1,835.66	1,999.32	2,228.40	2,479.10	2,708.52	3,172.32	3,756.87	4,110.04	3,937.16
Japan	Nominal GDP (billion USD)	4667.45	4095.48	3918.33	4229.10	4605.94	4552.19	4362.55	4377.96	4866.95	5068.89
	% increase vs 2000	–	−12.3%	−16.0%	−9.4%	−1.3%	−2.5%	−6.5%	−6.2%	4.3%	8.6%
	Population(million)	126.83	127.13	127.4	127.63	127.73	127.75	127.75	127.76	127.69	127.55
	Nominal GDP per capita	36,800.84	32,214.90	30,756.12	33,135.63	36,059.97	35,633.58	34,149.12	34,267.06	38,115.36	39,740.42

Reference: IMF World Economic Outlook

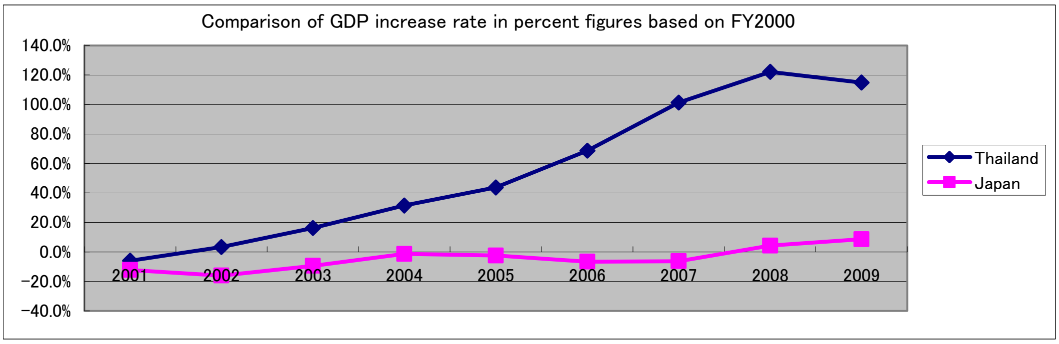


Figure 6.2 GDP comparison of Thailand and Japan

Nominal GDP is traced from 2000 to 2009 and 10 years of peaks and valleys are shown. The difference between Thailand and Japan used to be huge but is shrunk; Thailand is just 2.6 % of Japan by the scale of GDP in 2000, but is 5.2% in 2009. GDP in Thailand increased from 122.7 billion USD to 263.7 billion USD, so the rate of increase is more than double in a decade. On the other hand, the one in Japan is struggling for seven years and shows only 8.6% increase in a decade. When comparing absolute figure, Japan is almost 20 times as big as Thailand, but increased percentage is totally different. Japan experienced seven times negative growth rate in seven straight years, but Thailand experienced only one negative growth rate when currency crisis hit the nation in 2001.

As explained above, the scale of GDP in Thailand is around one twentieth compared with Japan, but GDP per capita is almost 10% compared with Japan in 2009. Population in Thailand increased 7.3% in ten years, but the one in Japan slightly increased at 0.6%.

In order to know the size of printing industry and paper related industry, shipment value and added value of each manufacturing industry are compared in Table 6.2.

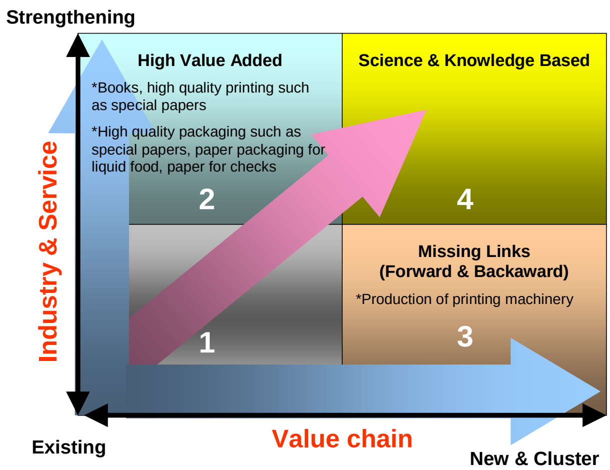
Table 6.2 Shipping values and added values in manufacturing industry in Thailand

Industry	Shipment value(2006) A		Added value(2006) B		B/A(%)
Food & beverage	33,866.7	15.5%	7,359.1	13.9%	21.7%
Tabacco	1,390.7	0.6%	922.3	1.7%	66.3%
Textile	8,429.3	3.8%	1,999.7	3.8%	23.7%
Apparel	6,049.1	2.8%	1,818.3	3.4%	30.1%
Leather & footwear	2,719.0	1.2%	832.1	1.6%	30.6%
Wood & wood product	2,302.9	1.1%	619.8	1.2%	26.9%
Paper & paper product	5,170.7	2.4%	1,103.2	2.1%	21.3%
Printing & publishing	2,501.0	1.1%	725.9	1.4%	29.0%
Petroleum product	10,984.8	5.0%	985.3	1.9%	9.0%
Chemical product	15,734.7	7.2%	3,335.1	6.3%	21.2%
Rubber & plastic	15,721.2	7.2%	3,677.7	7.0%	23.4%
Other non-ferrous metal	7,435.1	3.4%	1,969.6	3.7%	26.5%
Metal	8,693.2	4.0%	1,606.7	3.0%	18.5%
Assembled metal product	11,003.0	5.0%	2,835.2	5.4%	25.8%
Machinery	12,505.8	5.7%	2,888.6	5.5%	23.1%
Office machinery	1,876.3	0.9%	532.6	1.0%	28.4%
Electronic machinery	6,849.2	3.1%	1,639.8	3.1%	23.9%
Radio, TV, communication device	28,112.1	12.8%	7,766.8	14.7%	27.6%
Medical, precision, optical, watch	2,111.8	1.0%	740.3	1.4%	35.1%
Automobile	24,459.8	11.2%	6,475.3	12.3%	26.5%
Other transportation	4,639.1	2.1%	1,033.5	2.0%	22.3%
Furniture & others	6,492.4	3.0%	1,871.9	3.5%	28.8%
Recycle	87.5	0.0%	23.9	0.0%	27.3%
Total:	219,135.4		52,762.7		

(million USD)
Reference: National Statistical Office; The 2007 Industrial Census Whole Kingdom

Manufacturing industry which is non agricultural industry is summarized above, printing related industry including paper and publishing is relatively small since sum of printing and publishing industry is one forth of Japan. Paper industry in Thailand is comparatively small, it is only 5.9% compared to the one in Japan.

Even though the industry is not so strong, Thai printing industry is setting out to go on to the next step, polish value added strategic plan for the future; it is summarized in Figure 6.3.



Reference: Thailand Board of Investment

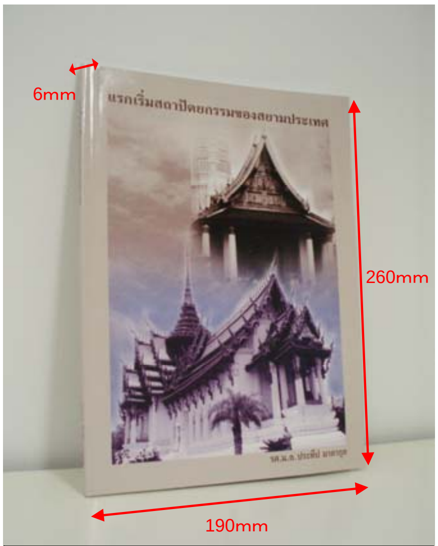
Figure 6.3 Value added strategic plan for Thai Printing Industry

The characteristic of printed matters in Thailand used to be cheap price oriented by cheap labors, but they now try to move forward to high quality printed matters. For Information Printing Service, they try to handle high quality of special papers, whereas for Packaging Printing Service, try to focus on special packaging relating to food industry for exporting. In the future, they can move to unexploited new stage which is explained as "Science & Knowledge based" printing jobs, such as electronic components of electrical goods. They are preparing to move forward from current position.

6.5 LOCALIZING OF PRINTING SERVICE LCA FOR CARBON FOOTPRINT

6.5.1 Specification of case study

Case study here is a textbook for students at Architecture department of CU, its appearance and specification is shown in Figure 6.4.



Title:	The beginning of Siam Architecture Arts
Author:	ML Prateep Malakul
Size(mm):	190*260*6
Copies:	500
Pages:	Cover 4P + Text 128P

Figure 6.4 Textbook "The beginning of Siam Architecture Arts"

6.5.2 Printing Service LCCO$_2$e by Thai and Japanese methods

6.5.2.1 Difference of workflow

Procurements of paper, ink and printing plate are all the same everywhere, but production process at prepress is different between emerging country and advanced country.

By old-fashioned method, plastic film (polypropylene) which has printed image should be developed at first, and then it is exposured on the plate and developed again as printing plate to be ready for printing. This method, called Computer to Film (CtF), used to be employed in Japan during 1990s. But, its system is currently difficult to be seen in Japan.

Nowadays, Computer to Plate (CtP) which does not require film output because of direct printing image transmission on the plate from computer becomes ubiquitous contrastingly in Japan, its occupancy state is over 80%. Advantage of CtP is to avoid consuming plastic film.

In Thailand, some printers utilize CtP system, but this case study is done by CtF. The difference between CtF and CtP is illustrated in Figure 6.5 and Table 6.3.

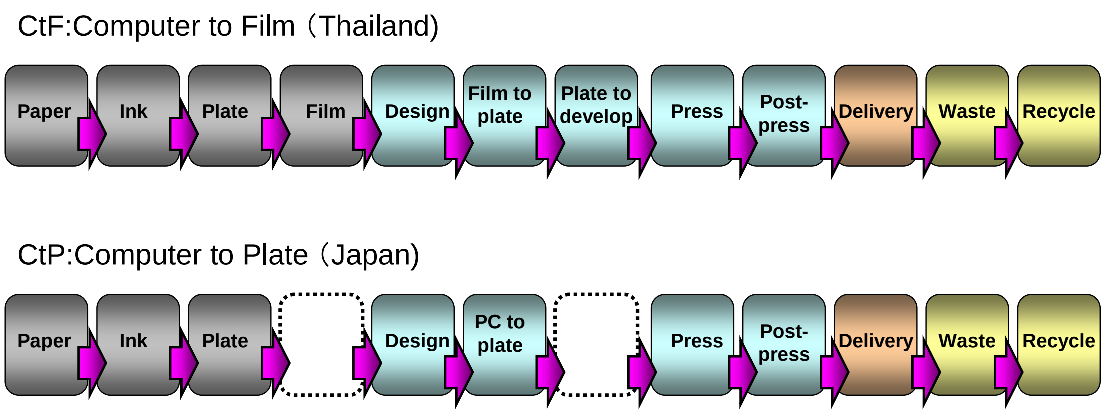


Figure 6.5　Difference of production process at prepress (CtF vs. CtP)

Table 6.3　Difference of CO_2e emission between CtF and CtP

<Calculation for Computer to Film based on TH secondary data>

Process	Computer to Plate(TH)	Computer to Film (TH)
Plate-setter	12.0 kW * 4 h * 0.561 kg-CO_2e/kWh = 26.928 kg-CO_2e	
Film-PP		3.4 kg (20 films) * 1.870 kg-CO_2e/kg = 6.367 kg-CO_2e
Film-PP transportation		3.4 kg * 18 km * 0.397 kg-CO_2e/tkm = 0.024 kg-CO_2e
Film-setter		40.0 kW * 2 h * 0.561 kg-CO_2e/kWh = 44.880 kg-CO_2e
Plate-exposure		12.0 kW * 2 h * 0.561 kg-CO_2e/kWh = 13.464 kg-CO_2e
Plate-developer		0.9 kW * 1 h * 0.561 kg-CO_2e/kWh = 0.505 kg-CO_2e
Air-conditioning	7.0 kW * 4 h * 0.561 kg-CO_2e/kWh = 15.748 kg-CO_2e	7.0 kW * 5 h * 0.561 kg-CO_2e/kWh = 19.685 kg-CO_2e
Lighting	1.5 kW * 4 h * 0.561 kg-CO_2e/kWh = 3.447 kg-CO_2e	1.5 kW * 5 h * 0.561 kg-CO_2e/kWh = 4.308 kg-CO_2e
Total:	46.123 kg-CO_2e	89.235 kg-CO_2e
		% compared to CtP: 193.5%

<Calculation for Computer to Film based on JP secondary data>

Process	Computer to Plate(JP)	Computer to Film (JP)
Plate-setter	12.0 kW * 4 h * 0.426 kg-CO_2e/kWh = 20.448 kg-CO_2e	
Film-PP		3.4 kg (20 films) * 1.870 kg-CO_2e/kg = 6.367 kg-CO_2e
Film-PP transportation		3.4 kg * 18 km * 0.209 kg-CO_2e/tkm = 0.013 kg-CO_2e
Film-setter		40.0 kW * 2 h * 0.426 kg-CO_2e/kWh = 34.080 kg-CO_2e
Plate-exposure		12.0 kW * 2 h * 0.426 kg-CO_2e/kWh = 10.224 kg-CO_2e
Plate-developer		0.9 kW * 1 h * 0.426 kg-CO_2e/kWh = 0.383 kg-CO_2e
Air-conditioning	7.0 kW * 4 h * 0.426 kg-CO_2e/kWh = 11.959 kg-CO_2e	7.0 kW * 5 h * 0.426 kg-CO_2e/kWh = 14.948 kg-CO_2e
Lighting	1.5 kW * 4 h * 0.426 kg-CO_2e/kWh = 2.617 kg-CO_2e	1.5 kW * 5 h * 0.426 kg-CO_2e/kWh = 3.272 kg-CO_2e
Total:	35.024 kg-CO_2e	69.288 kg-CO_2e
		% compared to CtP: 197.8%

6.5.2.2 Difference of primary and secondary data

Data collection of primary data is learned by following Japanese method, how to calculate paper for products/for waste/for recycle, ink usage, water usage, plate usage, running hours of production facility, delivery, and scenario creation for disposal/recycle.

The most complicated and uncertain data among primary data is the ratio of water and ink usage, so it is reconfirmed at CU Printing House. It is summarized in Table 6.4.

Table 6.4 Ratio of water usage and ink usage

Job	Black	Cyan	Magenta	Yellow	Total ink usage (kg)	Water+additives (kg)	Ratio=Water/Ink
1	0.40	0.07	0.66	0.60	1.73	5.00	2.89
2	0.00	0.50	0.56	0.00	1.06	3.60	3.40
3	0.10	0.50	0.60	0.50	1.70	3.80	2.24
4	0.05	0.15	0.10	0.10	0.40	1.50	3.75
5	0.90	0.14	0.16	0.20	1.40	2.00	1.43
6	0.10	0.26	0.41	0.14	0.91	1.70	1.87
7	0.15	0.13	0.21	0.10	0.59	1.20	2.03
8	0.09	0.10	0.05	0.08	0.32	1.00	3.13
9	0.15	0.50	0.40	0.12	1.17	4.00	3.42
Average ratio (Water+additives/Total Ink usage):							2.68

Reference: Chulalongkorn University Printing House

Secondary data in Japan is authoritatively organized by Japanese government related institutions, but the one in Thailand is in the course of upgrading now.

In Thailand, National Metal and Materials Technology Center (MTEC) is developing Thai secondary data as national database, but many of printing service relating materials and chemicals are not on the list of it yet. Match-up of it is indicated in Table 6.5.

Table 6.5 Comparison of TH secondary data and JP secondary data

Item	Japan		Thailand	
	CO2e Emission Factor	Reference	CO2e Emission Factor	Reference
Cardboard	0.637 kg-CO_2e/kg	JLCA-LCA database 4th edition	0.843 kg-CO_2e/kg	LCI database for liquid packaging board production
Fine paper	0.975 kg-CO_2e/kg	JLCA-LCA database 4th edition	0.843 kg-CO_2e/kg	LCI database for liquid packaging board production
Ink (average)	3.393 kg-CO_2e/kg	Ink manufacturer	→	
Plate	14.312 kg-CO_2e/kg	Plate manufacturer	→	
Water	0.197 kg-CO_2e/m^3	Simple LCA, JEMAI	→	
IPA	2.131 kg-CO_2e/kg	Simple LCA, JEMAI	→	
Electricity	0.426 kg-CO_2e/kWh	JLCA-LCA database 4th edition	0.561 kg-CO_2e/kWh	TC common data
Film lamination-PP	0.047 kg-CO_2e/m^2	Film manufacturer	→	
Hot-melt (EVA)	2.34 kg-CO_2e/kg	LCA-Pro, JEMAI	→	
2t-truck	0.209 kg-CO_2e/tkm	Simple LCA, JEMAI	NA	
1.5t-truck-50% loaded	NA		0.397 kg-CO_2e/tkm	TH database
4t-truck	0.143 kg-CO_2e/tkm	Simple LCA, JEMAI	NA	
7t-truck-50% loaded	NA		0.355 kg-CO_2e/tkm	TH database
10t-truck	0.121 kg-CO_2e/tkm	Simple LCA, JEMAI	NA	
11t-truck-50% loaded	NA		0.106 kg-CO_2e/tkm	TH database

In Japan, secondary data of paper assorted by items is well prepared by Japan Paper Association; those are Fine paper, Recycled fine paper, Coated paper, Recycled coated paper, Cardboard, Boxboard, Newspaper and so on. Major factor of environmental load is procurement of paper for Printing Service, but secondary data of it is under the process of revising and is substituted by European data in Thailand. It appears to be lower than Japanese fine paper which is used for text, but it is applied to calculation here.

Core materials except for paper are ink and printing plate, but there are no secondary data for both of those which are issued by manufacturers in Thailand. If those materials are manufactured in Japan, addition of the load from shipping from Japan to Thailand can solve problems, but unfortunately both are Thai made materials. When taking disorganized national database into consideration, it is perhaps difficult to expect Thai local manufacturers to prepare secondary data, so the ones which are publicized by Japanese manufactures are utilized as alternatives here.

On another front, secondary data for electricity and transportation are already verified and registered on the list of national database in Thailand. Electricity plays very important role for CO_2e calculation for the load by production facility, it is fortunate that precise calculation for production is possible based on the local data.

6.5.2.3 LCCO_2e comparison of Thai and Japanese methods for short run

The real production for textbook here is 500 copies which are categorized into “short run” in printing jobs. Preconditions are set for comparison from the view points of areal difference.

- Amount of paper usage and transportation distance from paper mill to the factory are the same for both Thailand and Japan. Emission factor of paper becomes altered for comparison purpose.
- Amount of conventional ink and transportation distance from ink manufacturer to the factory are the same for both Thailand and Japan.
- Number of printing plates and transportation distance from printing plate manufacturer to the factory are the same for both Thailand and Japan.
- Categories of printing machines for cover of book printing and text of book printing are the same for both Thailand and Japan. Emission factor of electricity becomes altered for comparison purpose.
- Categories of book binding machine and film laminating machine for cover are the same for both Thailand and Japan. Emission factors of electricity and film which is laminated on the cover of the book become altered for comparison purpose.
- Distance from the factory to designated place is the same for both Thailand and Japan. Emission factors of different size of trucks become altered for comparison purpose.
- Scenarios for disposal and recycle are based on the ones in Japan. Methods of collecting garbage in the town and recycled partly for pulp production in the big cities could be similar, but in the rural area could be quite different. The research of disposal and recycle is not conducted to model new scenario precisely here, so calculation scheme is simply followed by Japanese way.

Following Japanese way for disposal and recycle might diverge sharply from original comparison purpose, but it is judged that adopting Japanese way is better than utilizing newly created scenarios based on uncertain research.

Four different patterns are prepared after taking preconditions into account.

- JP1, it is assumed that the production is done in Japan, namely secondary data in Japan and CtP which is much more common in Japan but still rare in Thailand are utilized. This pattern is a sort of cornerstone when comparing different types of patterns for sensitivity analysis later.
- JP2, it is assumed that the production is done in Japan and secondary data in Japan is utilized, but old-fashioned CtF is utilized instead of CtP. It is expected to become apparent that the impact from the difference of CtP and CtF in Japan for total environmental load.
- TH1, it is assumed that secondary data of paper/film/logistics (truck) which are already organized by Thai institution and CtF which is still usual method in Thailand are utilized. Secondary data of electricity in Japan is utilized because of estimating the impact of changing emission factor of electricity.
- TH2, it almost fits actual production, secondary data of electricity/paper/film/truck and CtF are utilized. As explained above, some part of calculation is still based on Japanese scenario since there are some unknowns in Thailand.

Four different patterns for production of 500 copies are summarized in Figure 6.6.

Stage	Process	Method-JP1			Method-JP2			Method-TH1			Method-TH2		
		CtP, JP secondary data			CtF, JP secondary data			CtF, TH secondary data (Paper, Film, Truck)			CtF, TH secondary data (Electricity, Paper, Film, Truck)		
Procurement	Paper	266	25.6%	39.7%	266	24.8%	38.5%	233	22.4%	36.6%	233	19.1%	31.3%
	Ink	3	0.3%		3	0.3%		4	0.4%		4	0.3%	
	Water & additives	0	0.0%		0	0.0%		0	0.0%		0	0.0%	
	Plate(procurement)	144	13.9%		144	13.4%		144	13.8%		144	11.8%	
Production	Plate(production)	36	3.5%	53.6%	69	6.4%	55.0%	69	6.6%	56.8%	89	7.3%	63.1%
	Design & editing	123	11.8%		123	11.5%		123	11.8%		162	13.3%	
	Press	281	27.0%		281	26.2%		281	27.0%		370	30.4%	
	Postpress	117	11.3%		117	10.9%		119	11.4%		147	12.1%	
Delivery	Delivery	1	0.1%	0.1%	1	0.1%	0.1%	1	0.1%	0.1%	1	0.1%	0.1%
Waste&Recycle	Disposal	3	0.3%	6.5%	3	0.3%	6.3%	3	0.3%	6.5%	3	0.2%	5.6%
	Recycle-paper	33	3.2%		33	3.1%		33	3.2%		33	2.7%	
	Recycle-aluminum	32	3.1%		32	3.0%		32	3.1%		32	2.6%	
	Total(kg-CO_2e):	1,039			1,072			1,042			1,218		
	Per book(kg-CO_2e):	2.078			2.144			2.084			2.436		
	% change to JP1:	NA			103.2%			100.3%			117.2%		

*Grey cell are the load which is changed from JP1

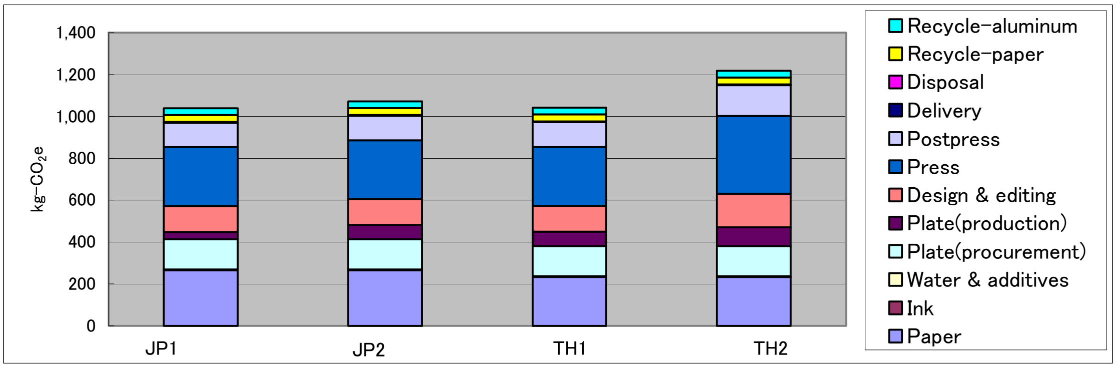


Figure 6.6 LCCO$_2$e comparisons (500 copies) of JP1/JP2/TH1/TH2

JP1 which is production by CtP in Japan is set as cornerstone, and then compared with JP2, TH1 and TH2 respectively.

Total CO_2e emission from JP2 will be 1,072kg-CO_2e (2.144kg-CO_2e/copy) when changed from JP1 (1,039kg-CO_2e, 2.078kg-CO_2e/copy), just 3.2% increase by changing printing plate output system from CtF to CtP. From the nature of Printing Service, occupancy level of printing plate output is relatively low, so does not influence so much in negative way.

When scenario is changed to TH1 which is based on the production based on CtF and part of secondary data (paper, film and truck) in Thailand, CO_2e emission is 1,042 kg-CO_2e (2.084kg-CO_2e/copy). It is almost the same as JP1 because emission factor of paper in Thailand is calculated by utilizing lower emission factor compared with the one in Japan, so the load from paper is 233 kg-CO_2e which is 33kg kg-CO_2e lower than JP1. Emission factor for paper in Thailand is drawn from European database based on cardboard for package production varying from normal paper for book production, therefore total CO_2e emission is almost the same because of cancel effect.

Comparison of JP1 and TH2 fits reality closely in the case study since Thai emission factor of electricity is utilized in TH2. Electricity consumption plays major role for short run job because the impact from production occupies more than half of environmental load. The load from production is 557 kg-CO_2e in JP1 and is 768 kg-CO_2e in TH2, so 37.9% increase when focusing only on production. Total CO_2e emission is 1,218kg-CO_2e (2.436kg-CO_2e/copy); it is 17.2% increase from JP1. In case that emission factor of paper in Thailand is the same as the one in Japan, total CO_2e emission could be 1,251kg-CO_2e (2.502kg-CO_2e/copy), so increased percentage would be 20.4% instead.

6.5.2.4 LCCO_2e comparison of Thai and Japanese methods for medium run

Production volume of 500 copies is usually categorized into short run job, so another case study for medium run is configured for 3,000 copies. The result is summarized in Figure 6.7.

Stage	Process	Method-JP1(3000 copies) CtP, JP secondary data			Method-TH2(3000 copies) CtF, TH secondary data (Electricity, Paper, Film, Truck)		
Procurement	Paper	1,101	51.5%	58.8%	1,060	44.7%	51.6%
	Ink	11	0.5%		17	0.7%	
	Water & additives	1	0.0%		1	0.0%	
	Plate(procurement)	144	6.7%		144	6.1%	
Production	Plate(production)	36	1.7%	35.3%	89	3.8%	43.0%
	Design & editing	123	5.8%		162	6.8%	
	Press	426	19.9%		561	23.7%	
	Postpress	169	7.9%		208	8.8%	
Delivery	Delivery	3	0.1%	0.1%	3	0.1%	0.1%
Waste&Recycle	Disposal	12	0.6%	5.8%	12	0.5%	5.3%
	Recycle-paper	81	3.8%		81	3.4%	
	Recycle-aluminum	32	1.5%		32	1.4%	
	Total(kg-CO_2e):	2,139			2,370		
	Per book(kg-CO_2e):	0.713			0.790		
	% change to Method-JP1:	NA			110.8%		

*Grey cell are the load which is changed from JP1

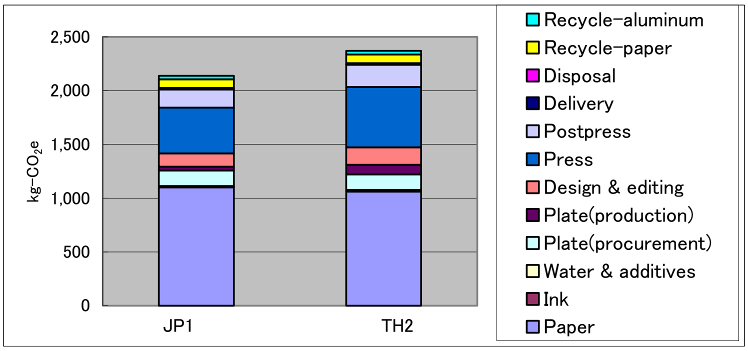


Figure 6.7 LCCO_2e comparison (3,000 copies) of JP1 and TH2

Only JP1 and TH2 are compared to know the difference between short run and medium run. Proportion of the load from paper and production is quite different when run length is changed to medium. The load from procurement is 39.7% in JP1 and 31.3% in TH2 for 500 copies, but it rises up to 58.8% in JP1 and 51.6% in TH2 for 3,000 copies. At the same time, the load from production (electricity) is 53.6% in JP1 and 63.1% in TH2 for 500 copies, but it moves downward to 35.3% and 43.0% for 3,000 copies. Total CO_2e emission from JP1 is 2,139kg-CO_2e (0.713kg-CO_2e/copy); it is almost one third of the load per book at the production of 500 copies. Total CO_2e emission from TH2 is 2,370kg-CO_2e (0.790kg-CO_2e/copy), it is less than one third of the load per book at the production of 500 copies and upward percentage is 10.8% from JP1. Increased percentage from JP1 to TH2 is much less when run length is changed to medium run.

From breakdown of case study for 500 copies and 3,000 copies, questions of enrooting Printing Service LCA in emerging country becomes evident through LCCO_2e calculation of target sample which is a textbook at CU.

6.6 ENVIRONMENTAL AWARENESS IN THAILAND

Thailand Greenhouse Management Organization (TGO) is currently driving Thai industrial sectors to Low-carbon society. Many industries expect that the utilization of CFP could increase competitiveness of Thai products. For CFP, TGO already launched 20 of pilot projects which started from 2009, but its activity does not come to be recognized sensuously.

Therefore, in order to know environmental awareness of Thai people, awareness survey for CFP and awareness survey for weighting impact categories are conducted to know contemporary condition concretely.

6.6.1 Awareness survey for CFP

6.6.1.1 Questionnaire survey and result

CFP questionnaire survey is carefully started with organizing framework of questionnaire. It is summarized in Table 6.6 and detailed questionnaire result is shown in Appendix A.

Table 6.6 Questionnaire for CFP at CU campus

Q1	Do you know CFP?	Yes 1	Not really 2	No 3
Q2	Have you ever seen CFP logo?	Yes 1	Not really 2	No 3
Q3	Are you willing to purchase CFP products?	Yes 1	Not really 2	No 3
Q4	Are you willing to purchase CFP products even though expensive?	Yes 1	if same price 2	No 3
Q5	Do you think CFP can promote our life move forward to low-carbon?	Yes 1	Not really 2	No 3

Thank you very much!

Interviewees consist of 50 males and 50 females, equally divided into two genders. All interviewees are not only students, 46 are university personnel on campus. Cross tabulation by gender and occupation is shown in Figure 6.8.

Item		Occupation: Student	Occupation: Worker	Total
Gender	Male	35	15	50
	Female	19	31	50
	Total:	54	46	100

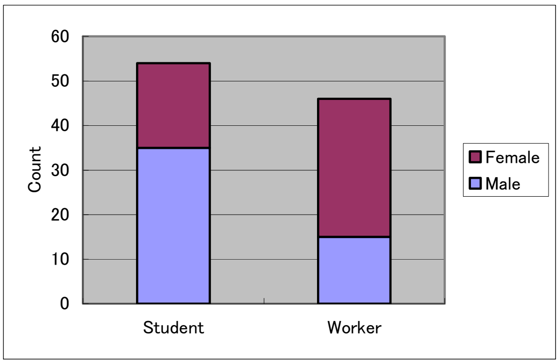


Figure 6.8 Cross tabulation by gender and occupation of interviewees

Number of students and workers are almost even, but the ratio of gender is different. Male is majority for students occupying 64.8% and female is majority for workers occupying

67.4%. Many of university personnel on campus are females recent days. Figure 6.9 shows breakdown of ages, undergraduate students whose age ranges from 19-year old to 22 -year old are 42, so almost half are students, not workers on campus.

Item		Age														Total
		19	20	21	22	23	24	25	26	27	28	29	30	31	34	
Gender	Male	4	6	8	7	7	6	4	4	1	1	2	0	0	0	50
	Female	2	4	7	4	6	7	3	4	1	3	5	1	1	2	50
	Total:	6	10	15	11	13	13	7	8	2	4	7	1	1	2	100

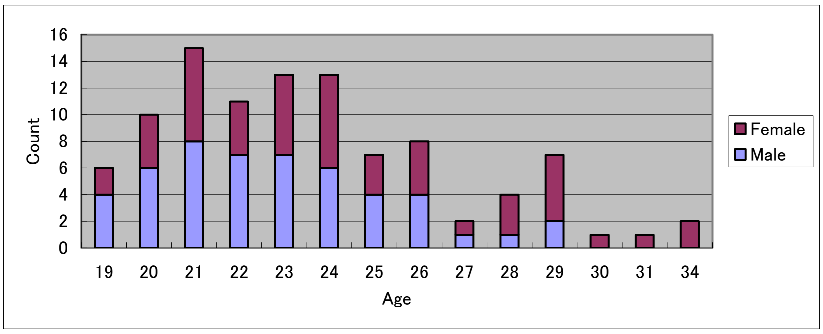


Figure 6.9 Cross tabulation by gender and age breakdown

There are five questions prepared for interviews to know name recognition of CFP on campus. It must be understood that the interviews are conducted on CU campus which is the best of the best university in Thailand, so collected information here could be different from Thai average information.

Firstly, question comes that “Do you know CFP?”, only 15% has rock-steady image of positive opinion. The answer of “Not really” and “No” totals 85, so most of people do not have clear understanding of CFP even on CU campus. More females tend not to know CFP when looking at the number of females’ “Not really” and “No”, so target of publicity activity is obviously female. It is summarized in Figure 6.10.

Item		Q1: Do you know CFP?			Total
		Yes	Not really	No	
Gender	Male	11	8	31	50
	Female	4	20	26	50
	Total:	15	28	57	100

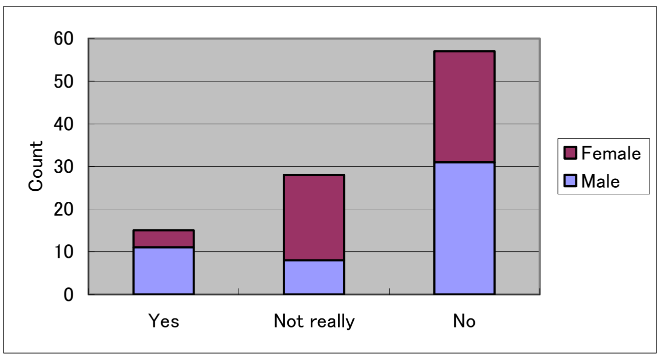


Figure 6.10 Cross tabulation by gender and Q1

Secondly, question comes that "Have you seen CFP logo?", only 11 see CFP logo, 89 see it less likely, the number of negative answers almost equals to the number of CFP recognition degree in Q1. In order to let people know about CFP, the concept and the logo should be all-in-one and promoted to be recognized. It is indicated in Figure 6.11.

Item		Q2:Have you ever seen CFP logo?			Total
		Yes	Not really	No	
Gender	Male	6	7	37	50
	Female	5	13	32	50
	Total:	11	20	69	100

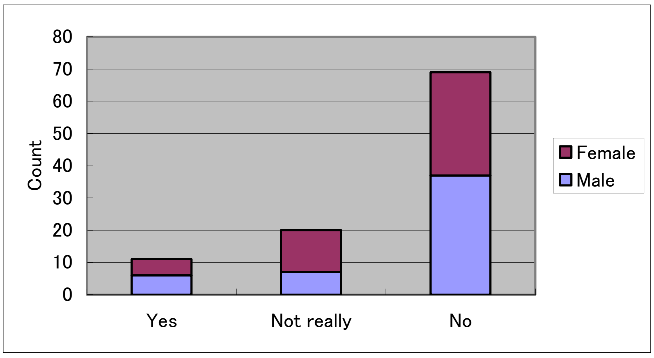


Figure 6.11 Cross tabulation by gender and Q2

Thirdly, question comes that "Are you willing to purchase CFP products?" after explaining the concept of CFP and some case studies in Thailand. After interviewees can understand CFP, they can understand very fast since this interviews are conducted on CU campus, evidence their approvals. Strong negative opinion which is absolute "No" for purchasing CFP product is only 7, 61 of them show strong buying motivations. It is shown in Figure 6.12.

Item		Q3: Are you willing to buy CFP products?			Total
		Yes	Not really	No	
Gender	Male	25	22	3	50
	Female	36	10	4	50
	Total:	61	32	7	100

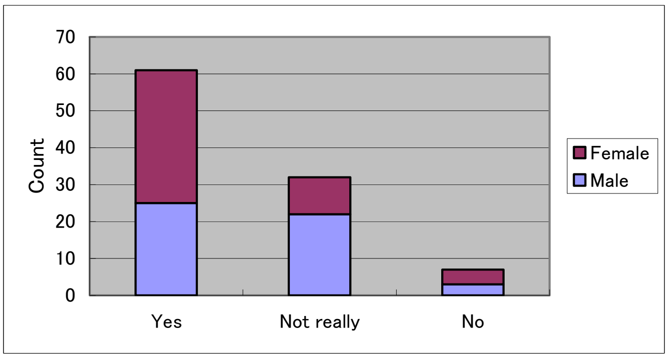


Figure 6.12 Cross tabulation by gender and Q3

Fourthly, question comes that "Are you willing to purchase CFP products even though expensive?"; it is the most important question in this questionnaire. Only one person accepts price increase for CFP products, but 99 make objections against price hike. Product suppliers should listen to negative opinions actively; most of people do not give permissions for CFP products which are environment-friendly to raise prices. It is indicated in Figure 6.13.

Item		Q4:Are you willing to buy even if expensive?			Total
		Yes	if same price	No	
Gender	Male	1	39	10	50
	Female	0	44	6	50
	Total:	1	83	16	100

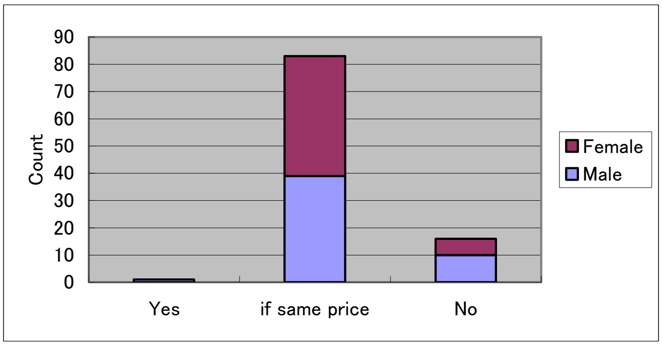


Figure 6.13　Cross tabulation by gender and Q4

Fifthly, question comes that "Do you think CFP can promote our life move forward to Low-carbon?", it is high-level question since CFP and structuring Low-carbon society can be linked to understand CO_2e reduction which is the same as global warming issue. Almost three fourth of people favor promotion of CFP and only one opposes it strongly. It is summarized in Figure 6.14.

Item		Q5: Do you think CFP can promote our life move forward to low-carbon?			Total
		Yes	Not really	No	
Gender	Male	33	16	1	50
	Female	38	12	0	50
	Total:	71	28	1	100

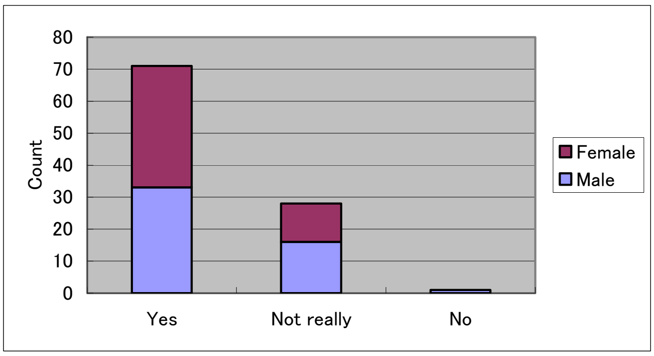


Figure 6.14　Cross tabulation by gender and Q4

CFP is not well known in Thailand yet, but after the explanation of CFP concept, many people show their strong support if the price is not raised. As a precondition to no price hike, there is possibility for CFP to be promoted in positive way. Many People in Thailand, not only on CU campus, can understand the positive loop of CFP and Low-carbon society, so CFP will be in widespread use in the future. Detailed result is shown in Appendix B.

6.6.1.2 Correlative relationship of variables in questionnaires

In order to find out correlative relationship between questions for CFP, correlation coefficient was assessed by two different methods, one is Kendall's correlation coefficient and the other is Spearman's correlation coefficient.

If the relationship between questions (variables) can be clarified, it is not difficult to forecast what could happen when one variable is known. Generally, it should be interpreted whether there is correlative relationship between variables after the investigation or not. First step is working on a test for statistical dependence between variables by Kendall's or Spearman's correlation coefficient to detect strong correlation, and then next step is conducting chi-square tests to evaluate comparisons for mutual independences. Kendall's and Spearman's correlation coefficients are tabulated in Table 6.7.

Table 6.7 Kendall's and Spearman's correlation coefficients

Item			Gender	Age	Occupation	Q1	Q2	Q3	Q4	Q5
Kendall	Gender	Correlation Coefficient	1.000	.186*	.321**	−0.023	−0.085	−.193*	−0.083	−0.115
		Significance Probability	.	0.031	0.001	0.810	0.381	0.049	0.409	0.251
		N	100	100	100	100	100	100	100	100
	Age	Correlation Coefficient	.186*	1.000	.546**	−0.076	−.192*	−0.077	0.025	−0.138
		Significance Probability	0.031	.	0.000	0.356	0.021	0.359	0.768	0.108
		N	100	100	100	100	100	100	100	100
	Occupation	Correlation Coefficient	.321**	.546**	1.000	0.024	−.210*	−0.022	0.107	−0.008
		Significance Probability	0.001	0.000	.	0.803	0.031	0.819	0.286	0.937
		N	100	100	100	100	100	100	100	100
	Q1	Correlation Coefficient	−0.023	−0.076	0.024	1.000	.542**	−0.029	−0.062	−0.163
		Significance Probability	0.810	0.356	0.803	.	0.000	0.755	0.516	0.090
		N	100	100	100	100	100	100	100	100
	Q2	Correlation Coefficient	−0.085	−.192*	−.210*	.542**	1.000	0.057	−0.068	−0.022
		Significance Probability	0.381	0.021	0.031	0.000	.	0.545	0.481	0.823
		N	100	100	100	100	100	100	100	100
	Q3	Correlation Coefficient	−.193*	−0.077	−0.022	−0.029	0.057	1.000	.398**	.454**
		Significance Probability	0.049	0.359	0.819	0.755	0.545	.	0.000	0.000
		N	100	100	100	100	100	100	100	100
	Q4	Correlation Coefficient	−0.083	0.025	0.107	−0.062	−0.068	.398**	1.000	.219*
		Significance Probability	0.409	0.768	0.286	0.516	0.481	0.000	.	0.028
		N	100	100	100	100	100	100	100	100
	Q5	Correlation Coefficient	−0.115	−0.138	−0.008	−0.163	−0.022	.454**	.219*	1.000
		Significance Probability	0.251	0.108	0.937	0.090	0.823	0.000	0.028	.
		N	100	100	100	100	100	100	100	100
			Gender	Age	Occupation	Q1	Q2	Q3	Q4	Q5
Spearman	Gender	Correlation Coefficient	1.000	.217*	.321**	−0.024	−0.088	−.198*	−0.083	−0.115
		Significance Probability	.	0.030	0.001	0.811	0.383	0.048	0.412	0.254
		N	100	100	100	100	100	100	100	100
	Age	Correlation Coefficient	.217*	1.000	.637**	−0.094	−.237*	−0.093	0.030	−0.163
		Significance Probability	0.030	.	0.000	0.352	0.018	0.356	0.770	0.105
		N	100	100	100	100	100	100	100	100
	Occupation	Correlation Coefficient	.321**	.637**	1.000	0.025	−.217*	−0.023	0.107	−0.008
		Significance Probability	0.001	0.000	.	0.805	0.030	0.820	0.288	0.937
		N	100	100	100	100	100	100	100	100
	Q1	Correlation Coefficient	−0.024	−0.094	0.025	1.000	.571**	−0.033	−0.066	−0.170
		Significance Probability	0.811	0.352	0.805	.	0.000	0.745	0.515	0.090
		N	100	100	100	100	100	100	100	100
	Q2	Correlation Coefficient	−0.088	−.237*	−.217*	.571**	1.000	0.062	−0.071	−0.022
		Significance Probability	0.383	0.018	0.030	0.000	.	0.542	0.484	0.826
		N	100	100	100	100	100	100	100	100
	Q3	Correlation Coefficient	−.198*	−0.093	−0.023	−0.033	0.062	1.000	.410**	.464**
		Significance Probability	0.048	0.356	0.820	0.745	0.542	.	0.000	0.000
		N	100	100	100	100	100	100	100	100
	Q4	Correlation Coefficient	−0.083	0.030	0.107	−0.066	−0.071	.410**	1.000	.221*
		Significance Probability	0.412	0.770	0.288	0.515	0.484	0.000	.	0.027
		N	100	100	100	100	100	100	100	100
	Q5	Correlation Coefficient	−0.115	−0.163	−0.008	−0.170	−0.022	.464**	.221*	1.000
		Significance Probability	0.254	0.105	0.937	0.090	0.826	0.000	0.027	.
		N	100	100	100	100	100	100	100	100

There are 10 strong correlations in both tables, but demographic data such as Gender/Age/Occupation are already reviewed in a previous clause, so only cross tabulations of demographic data and questions or questions each other are examined here. Highly important correlations are targeted to be interests after inessential correlations are eliminated; correlations between Gender/Q3, Occupation/Q2 and Q4/Q5 are selected respectively. For those correlations, chi-square test which is statistical procedure and its result is evaluated by reference to the chi-square distribution is conducted to assess in the next step.

First of chi-square tests, there are two variable, one is Gender (Male/Female) and the other is Q3 ("Are you willing to purchase CFP products?").

The null hypothesis (H_0) is that gender and willingness to purchase CFP products are not related, namely are independent. On the other hand, the alternative hypothesis (H_1) is that gender and willingness to purchase CFP products are related, namely are not independent. Chi-square result which is calculated by dividing square of the difference between the observed frequency and the expected frequency by the expected frequency is 6.626, then compared with the number of value at 5% of significant level is 4.30 and the one at 1% of significant level is 9.92 since the degree of freedom is 2.

Chi-square result of 6.626 is in the rejected area for 5% of significant level but not in the rejected area for 1% of significant level. It means that H_0 is rejected at 5% of significant level and not rejected at 1% of significant level. Conclusion is that gender is related (dependent) to willingness to purchase CFP products with 5% of error probability but is not related (independent) to willingness to purchase CFP products with 1% of error probability.

From the result, gender does not have strong influence on purchase motivation of CFP products, so spread enlightenment of CFP does not need to specify gender in a very strict sense which is 1% significance level. It is shown in Table 6.8.

Table 6.8 Chi-square test for Gender and Q3

<Chi-Square test>
・Variable-A Gender: Male/Female
・Variable-B Q3: Are you willing to purchase CFP products?
・H_0(Null Hypothesis): Two variables are independent=Two variables are not relate
・H_1(Alternative Hypothesis): Two variables are not independent=Two variables ar

Crosstabulation of Gender & Q3

Item		Q3			Total
		Yes	Not really	No	
Gender	Male	25	22	3	50
	Female	36	10	4	50
Total:		61	32	7	100

Chi-square test

Item	Chi-sqr.	D.F.	Asymptotic significance level (both side)
Pearson χ 2	6.626	2	0.036
plausibility	6.750	2	0.035
Linkage	2.549	1	0.110
Count	100		

Second of chi-square tests, there are two variable, one is Occupation (Student/Worker) and the other is Q2 (“Have you seen CFP logo?”).

The null hypothesis (H_0) is that occupation and recognition of CFP logo are not related, namely are independent. On the other hand, the alternative hypothesis (H_1) is that occupation and recognition of CFP logo are related, namely are not independent. Chi-square result is 8.695, then compared to the number of value at 5% of significant level is 4.30 and the one at 1% of significant level is 9.92 since the degree of freedom is 2.

Chi-square result of 8.695 is in the rejected area for 5% of significant level but not in the rejected area for 1% of significant level. It means that H_0 is rejected at 5% of significant level and not rejected at 1% of significant level. Conclusion is that occupation is related (dependent) to recognition of CFP logo with 5% of error probability, but is not related (independent) to recognition of CFP logo with 1% of error probability.

From the result, occupation does not have very strong influence on recognition of CFP logo, so spread enlightenment of CFP does not need to target students especially in a very strict sense which is 1% significance level. It is shown in Table 6.9.

Table 6.9 Chi-square test for Occupation and Q2

<Chi-Square test>
・Variable-A Occupation: Student/Worker
・Variable-B Q2: Have you ever seen CFP logo?
・H_0(Null Hypothesis): Two variables are independent=Two variables are not related
・H_1(Alternative Hypothesis): Two variables are not independent=Two variables are rel

Crosstabulation of Occupation & Q2

Item		Q2			Total
		Yes	Not really	No	
Occupation	Student	6	5	43	54
	Worker	5	15	26	46
	Total:	11	20	69	100

Chi-square test

Iem	Chi-sqr.	D.F.	Asymptotic significance level (both side)
Pearson χ 2	8.695	2	0.013
plausibility	8.915	2	0.012
Linkage	2.774	1	0.096
Count	100		

Third of chi-square tests, there are two variable, one is Q4 (“Are you willing to purchase CFP products even though expensive?”) and the other is Q5 (“Do you think CFP can promote our life move forward to low-carbon?”).

The null hypothesis (H_0) is that willingness to purchase CFP products at more than normal price and possibility for CFP products to promote Low-carbon life style are not related, namely are independent. On the other hand, the alternative hypothesis (H_1) is that willingness to purchase CFP products at more than normal price and possibility for CFP products to promote Low-carbon life style are related, namely are not independent. Chi-square result is 8.436, then compared to the number of value at 5% of significant level is 2.78 and the one at 1% of significant level is 4.60 since the degree of freedom is 4.

Chi-square result of 8.436 is in the rejected area for both 5% and 1% of significant level at the same time. It means that H_0 is rejected at both 5% and 1% of significant level. Conclusion is that willingness to purchase CFP products at more than normal price is related (dependent) to possibility for CFP products to promote Low-carbon life style with 1% of error probability.

From the result, people opposing strongly against price increase still believe that CFP products can help constructing low-carbon society. It is shown in Table 6.10.

Table 6.10 Chi-square test for Q4 and Q5

<Chi-Square test>
・Variable-A Q4: Are you willing to purchase CFP products even though expensive?
・Variable-B Q5: Do you think CFP can promote our life move forward to low-carbon?
・H_0(Null Hypothesis): Two variables are independent=Two variables are not related
・H_1(Alternative Hypothesis): Two variables are not independent=Two variables are rel

Crosstabulation of Q4 & Q5

Item		Q5: Yes	Not really	No	Total
Q4	Yes	1	0	0	1
	If same price	62	21	0	83
	No	8	7	1	16
Total:		71	28	1	100

Chi-square test

Item	Chi-sqr.	D.F.	Asymptotic significance level (both side)
Pearson χ 2	8.436	4	0.077
plausibility	7.028	4	0.134
Linkage	5.909	1	0.015
Count	100		

Overall conclusion for CFP awareness in Thailand is strongly positive when limited to academic related people there. In the next subclause, awareness survey for 9-impact category is conducted to know basic ideas of Thai people by impact categories.

6.6.2 Awareness survey for importances of 9-impact category

6.6.2.1 Survey by Analytic Hierarchy Process (AHP) for different groups

When trying to know environment conscious level by people in a specific group or in a specific region, AHP is conducted to show their importances of 9-impact category which is developed by Nagata Laboratory at Waseda University.

For this study, people inviting questionnaires in two groups besides CU students and personnel are defined. One is “Printers” belonging to Thai Printing Association and the other is “Housewives” having strong influence on buying behavior. Both are key groups to know importances of 9-impact category for further research.

Demographic background is summarized for three groups including CU students and personnel. It is indicated in Figure 6.15.

Age	CU_Male	CU_Female	Printers_Male	Printers_Female	Housewives_Female	Total
19-24	38	30	2	1	2	73
25-30	12	17	1	2	3	35
31-36	0	3	1	2	7	13
37-42	0	0	2	4	7	13
43-48	0	0	1	6	4	11
49-54	0	0	2	6	12	20
55-60	0	0	1	7	3	11
61-66	0	0	0	0	1	1
67-72	0	0	1	1	1	3
Total:	50	50	11	29	40	180

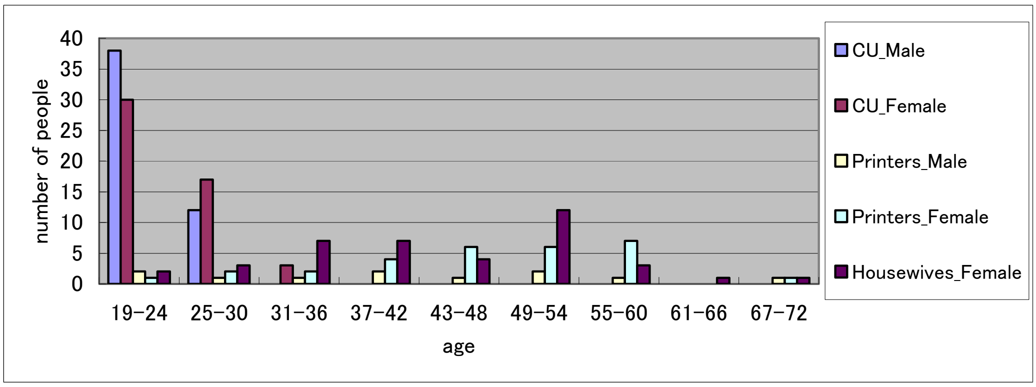


Figure 6.15 Demographics of three categories

It is not necessary to discuss about CU related data since interviewees are mostly students and junior staff on campus, but is necessary to know that interviewees in other two groups are scattered by the scale of age.

For Printers, total interviewees are 40 and number of male is 11 (27.5%) showing that full-time housewife is comparatively rare in Thailand. When looking at the age bracket, interviewees who are under 48 years old are 22 (55.0%), so midpoint is age bracket ranging from 43-year old to 48-year old.

For Housewives, total interviewees are 40 and surely all are female. When looking at the age bracket, interviewees who are under 42 years old are 19 (47.5%), so midpoint is age bracket ranging from 37-year old to 42-year old.

The interviewees across the board are mainly middle aged and female. It should be reminded whenever comparing various kinds of data analysis.

6.6.2.2 Comparison of AHP result in Thailand and Japan

Latest AHP from three groups in Thailand are summarized and compared with the ones from two groups which are “Printers” and “Scientists” in Japan. It is shown in Figure 6.16.

For CU students and personnel, “Resource consumption” is ranked first, “Ecosystem effect” stands second and “Global warming” sits third. Their focus is mainly on scarcity of resources, global warming issue is not paid attention as number one issue.

For Housewives and Printers in Thailand, “Global warming” is ranked first, “Energy drain” stands second and “Air pollution” sits third, two groups shows same tendency. Definitive reasons for the results are not known, but it could be considered that global warming issue also gets a lot of media attentions in Thailand.

For Printers in Japan, they are 30 members from Japan Waterless Printing Association and operators of CO_2e calculator for printing. Namely, they are at the edge of printing industry from the viewpoint of environment conscious, so the result could be the most ideal among imaginable ones. They view “Global warming” as first priority and “Energy drain” as second priority, their way of viewing is all the same as Housewives and Printers in Thailand. Even though their bases of daily activities are different, importances of first and second impact categories they pay attention are all the same. It is summarized in Figure 6.16.

Impact Categories	Chula Univ. Thailand	Housewives Thailand	Printers Thailand	Printers Japan	Scientists*1 Japan
1.Energy drain	0.098	0.142	0.152	0.142	**0.154**
2.Global warming	0.134	**0.168**	**0.156**	**0.161**	0.106
3.Ozone depletion	0.129	0.109	0.117	0.114	0.101
4.Acid precipitate	0.084	0.083	0.096	0.079	0.076
5.Resource consumption	**0.168**	0.089	0.087	0.098	0.112
6.Air pollution	0.100	0.112	0.130	0.106	0.103
7.Ocean & water pollution	0.082	0.110	0.103	0.118	0.100
8.Problem of waste disposal	0.067	0.089	0.071	0.059	0.097
9.Ecosystem effect	0.138	0.098	0.088	0.122	0.151

Reference: Nagata Lab. at Waseda Univ.

*1: Survey was conducted around 10-year ago, so not updated data.

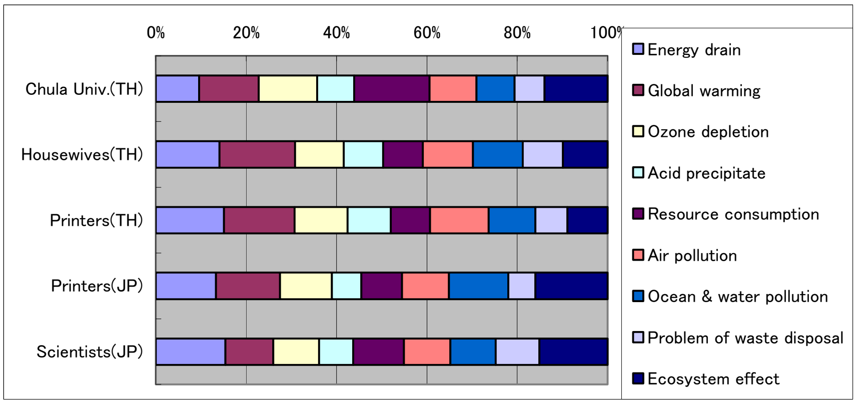


Figure 6.16 AHP result in Thailand and Japan

As a result of AHP in Thailand and Japan, it is clear that people who are deeply involved in printing related and buying activities, that is to say that suppliers and consumers are very conscious about “Global warming” and “Energy drain”, but contrastingly do not care almost nothing for “Problem of waste disposal”.

On the other hand, people in academic field in both countries are trying to look straight the real environmental problem. They consider “Resource consumption” as top priority in Thailand and “Energy drain” as high-priority issue in Japan, it means that drawdown of mineral resources in the near future is worried in both categories.

So on that point, in order to speed up people to shift their mood to environment conscious, “Global warming” is definitely critical factor, but people in academic field should keep thinking the best balance of environment conscious.

6.7 ESTABLISHING ELP METHOD IN EMERGING COUNTRIES

6.7.1 Limitation of data collection for emission factor for ELP in Thailand

In order to set emission factor (ELF: Environmental Loaf Factor) for Environmental Load Point (ELP), annual consumption for specific items in the country are necessary ones for calculating annual load for each impact category. But, in most of emerging countries, it is difficult to collect all of 66 items for 9-impact category which are required to calculate ELF as emission factor of ELP.

Therefore, verification should be done to leave no doubt about this issue. The verification approach is comparing ELP result with full set of annual consumption data and the one with limited set of annual consumption data shown in Table 6.11.

Table 6.11 Limited items to calculate annual load for ELF in Japan

Impact category	Item	Weighting coefficient C	Consumtion or Emission TQ	Annual load A=C×TQ	Year	Reference
Energy drain	oil	1.00E+00	1.99E+11	1.99E+11	2006	*1 Energy Statistics Yearbook 2006, United Nations
	coal	1.10E-01	1.79E+11	1.97E+10	2006	*1 Energy Statistics Yearbook 2006, United Nations
	natural gas	7.70E-01	7.22E+10	5.56E+10	2007	*2 BP Statistics 2008, BP
	uranium ore	1.48E+01	1.09E+07	1.61E+08	2010	*3 Uranium2003:Resources/Production/Demand, OECD Nuclear Energy Agency
	wood	5.00E-02	6.87E+10	3.43E+09	2005	*4 Wood Consumption & Self-sufficient Ratio, Forestry Agency
			Sub total:	2.78E+11		
Global warming	CO_2	1.00E+00	1.21E+12	1.21E+12	2008	*5 GHG Emission Data, Greenhouse Gas Inventory Office of Japan
	N_2O	3.20E+02	2.25E+10	7.19E+12	2008	*5 GHG Emission Data, Greenhouse Gas Inventory Office of Japan
	CH_4	2.45E+01	2.13E+10	5.21E+11	2008	*5 GHG Emission Data, Greenhouse Gas Inventory Office of Japan
			Sub total:	8.92E+12		
Ozone depletion	CFC-11	1.00E+00	0.00E+00	0.00E+00	1999	*6 CFC Emission in Japan, Ministry of Environment
			Sub total:	0.00E+00		
Acid precipitate	NOx(NO_2)	7.00E-01	8.90E+08	6.23E+08	2005	*7 Air Pollutant Emission, Ministry of Environment
	SOx(SO_2)	1.00E+00	5.67E+08	5.67E+08	2005	*7 Air Pollutant Emission, Ministry of Environment
			Sub total:	1.19E+09		
Resource consumption	iron ore	1.00E+00	1.39E+11	1.39E+11	2007	*9 Imported Iron ore, World Steel Asociation
			Sub total:	1.39E+11		
Air pollution	NOx(NO_2)	1.40E+00	8.90E+08	1.25E+09	2005	*7 Air Pollutant Emission, Ministry of Environment
	SOx(SO_2)	1.00E+00	5.67E+08	5.67E+08	2005	*7 Air Pollutant Emission, Ministry of Environment
			Sub total:	1.81E+09		
Ocean & water pollution	BOD	1.00E+00	0.00E+00	0.00E+00	1988	*B Columbium & Tantalum Minerals Yearbook, US Geological Survey
			Sub total:	0.00E+00		
Waste disposal	Solid Waste	1.00E+00	4.81E+10	4.81E+10	2008	*22 Emission & Processing of Disposal in 2008, Ministry of Environment
			Sub total:	4.81E+10		
Ecosystem influence	Dioxin	1.40E+03	0.00E+00	0.00E+00	2004	*21 Emission Inventory of Dioxin, Ministry of Environment
			Sub total:	0.00E+00		

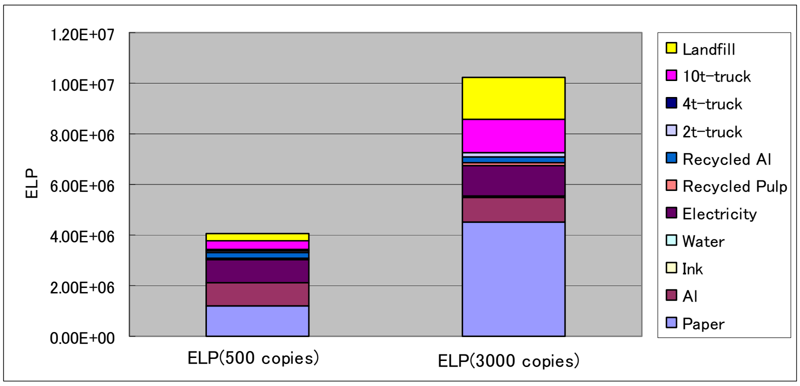
Some of 66 items, such as NOx and SOx are reutilized for calculating more than one impact category, are narrowed down to 14 items which are main inventory data from the software named “Simple LCA” and utilized for ELP calculation in previous chapters. Only one item which is emission of particles cannot be collected even though it is listed as inventory data.

The most difficult part of data collection in emerging countries is data capture for annual consumption of mineral resources. Only annual load from 14 items are considered for ELF calculation, namely influence from other items are completely eliminated.

Case study of Thai text book at CU is taken up here again to evaluate if limited data of annual consumption can act on the result extensively or not. It is summarized in Figure 6.17 with full set of data and in Figure 6.18 with limited set of data.

Process	Input(500)	Input(3000)	ELF	ELP(500)		ELP(3000)	
1.Paper	276.210 kg	1,058.750 kg	4.27E+03	1.18E+06	29.1%	4.52E+06	44.2%
2.Al	10.000 kg	10.000 kg	9.41E+04	9.41E+05	23.2%	9.41E+05	9.2%
3.Ink(Polyurethane)	1.033 kg	4.276 kg	1.37E+04	1.41E+04	0.3%	5.85E+04	0.6%
4.Water	2.583 kg	10.691 kg	1.78E−01	4.60E−01	0.0%	1.90E+00	0.0%
5.Electricity	1,243.908 kWh	1,655.352 kWh	7.42E+02	9.22E+05	22.8%	1.23E+06	12.0%
6.Recycled Pulp	149.351 kg	374.659 kg	2.73E+02	4.08E+04	1.0%	1.02E+05	1.0%
7.Recycled Al	10.000 kg	10.000 kg	2.33E+04	2.33E+05	5.8%	2.33E+05	2.3%
8.2t−truck	41.208 tkm	114.936 tkm	1.64E+03	6.77E+04	1.7%	1.89E+05	1.8%
9.4t−truck	2.843 tkm	2.843 tkm	1.45E+03	4.12E+03	0.1%	4.12E+03	0.0%
10.10t−truck	278.549 tkm	1,069.382 tkm	1.23E+03	3.42E+05	8.4%	1.31E+06	12.8%
11.Landfill	15.477 kg*1	83.459 kg*1	1.97E+04	3.04E+05	7.5%	1.64E+06	16.0%
			Total ELP:	4.05E+06		1.02E+07	
			ELP per copy:	8.10E+03		3.41E+03	

Reference: Nagata Laboratory at Waseda University

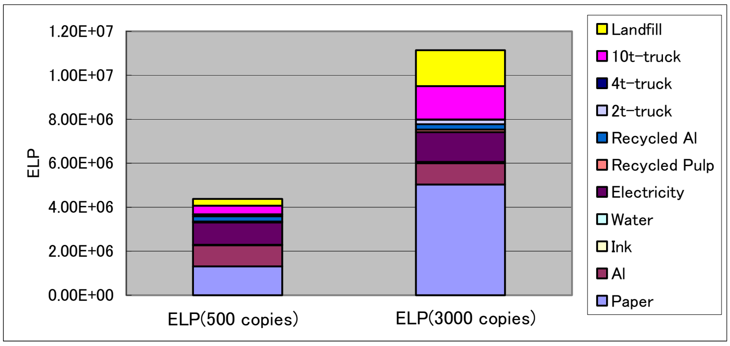


*1: Weight of products × Landfill ratio(12.2%)

Figure 6.17 ELP summaries for 500 copies and 3000 copies of textbook with full set of data

Process	Input(500)	Input(3000)	ELF	ELP(500)		ELP(3000)	
1.Paper	276.210 kg	1,058.750 kg	4.75E+03	1.31E+06	30.0%	5.03E+06	45.2%
2.Al	10.000 kg	10.000 kg	9.62E+04	9.62E+05	22.0%	9.62E+05	8.6%
3.Ink(Polyurethane)	1.033 kg	4.276 kg	1.49E+04	1.54E+04	0.4%	6.36E+04	0.6%
4.Water	2.583 kg	10.691 kg	1.93E-01	4.97E-01	0.0%	2.06E+00	0.0%
5.Electricity	1,243.908 kWh	1,655.352 kWh	8.21E+02	1.02E+06	23.3%	1.36E+06	12.2%
6.Recycled Pulp	149.351 kg	374.659 kg	3.02E+02	4.51E+04	1.0%	1.13E+05	1.0%
7.Recycled Al	10.000 kg	10.000 kg	2.36E+04	2.36E+05	5.4%	2.36E+05	2.1%
8.2t-truck	41.208 tkm	114.936 tkm	1.86E+03	7.68E+04	1.8%	2.14E+05	1.9%
9.4t-truck	2.843 tkm	2.843 tkm	1.68E+03	4.77E+03	0.1%	4.77E+03	0.0%
10.10t-truck	278.549 tkm	1,069.382 tkm	1.42E+03	3.95E+05	9.0%	1.52E+06	13.6%
11.Landfill	15.477 kg[*1]	83.459 kg[*1]	1.96E+04	3.04E+05	6.9%	1.64E+06	14.7%
			Total ELP:	4.37E+06		1.11E+07	
			ELP per copy:	8.75E+03		3.71E+03	

Reference: Nagata Laboratory at Waseda University



*1: Weight of products × Landfill ratio(12.2%)

Figure 6.18 ELP summaries for 500 copies and 3000 copies of textbook with limited set of data

As a result of comparison of textbook production in Japan, ELP which is based on AHP result from Japanese Printer is increased at 7.9% for 500 copies and 8.8% for 3,000 copies respectively when 66 items for calculating ELF is limited to 14 items. This margin of error is acceptable and deserve considering to be utilized for further analysis in emerging countries.

6.7.2 Comparison of ELP in Thailand and Japan

After AHP is researched in a specific country, next thing to be done for ELP calculation is data collection of annual consumption for limited impact categories. Data collection result and the comparison with the ones in Japan are summarized in Table 6.12

Table 6.12 Annual consumptions for 14 items for limited impact categories in Thailand

Impact category	Item	Consumption or Emission (TH)	Year	Reference	Consumption or Emission (JP)	TH/JP
Energy drain	oil	4.91E+10	2009	US Energy Information Administration	1.99E+11	24.6%
	coal	3.23E+10	2009	US Energy Information Administration	1.79E+11	18.0%
	natural gas	3.13E+10	2009	US Energy Information Administration	7.22E+10	43.4%
	uranium ore	6.50E+06	2002	Ministry of Natural Resources and Environmnet, Thailand	1.09E+07	59.9%
	wood	1.29E+07	2006	Ministry of Agriculture and Cooperatives, Thailand	6.87E+10	0.0%
Global warming	CO2	2.78E+11	2007	National Statistics Office, Thailand	1.21E+12	22.9%
	N2O	2.80E+07	2005	International Energy Agency, Thailand	2.25E+10	0.1%
	CH4	6.40E+07	2009	National Statistics Office, Thailand	2.13E+10	0.3%
Acid precipitate	NOx(NO2)	8.90E+08	2006	National Statistics Office, Thailand	8.90E+08	100.0%
	SOx(SO2)	4.62E+08	2006	National Statistics Office, Thailand	5.67E+08	81.5%
Resource consumption	iron ore	1.55E+09	2007	Ministry of Natural Resources and Environmnet, Thailand	1.39E+11	1.1%
Air pollution	NOx(NO2)	8.90E+08	2006	National Statistics Office, Thailand	8.90E+08	100.0%
	SOx(SO2)	4.62E+08	2006	National Statistics Office, Thailand	5.67E+08	81.5%
Waste disposal	Solid Waste	1.53E+10	2008	JGSEE King Monkut's University of Technology Thonburi	4.81E+10	31.8%

Collection of data for items in impact categories except for particles which cannot be collected for this study is typical data even for emerging countries for environment related issues. Table 6.12 shows comparisons with the consumption of each item in Japan, they could be good indicators to have ideas about the size of economy issues and the level of environmental problems in Thailand.

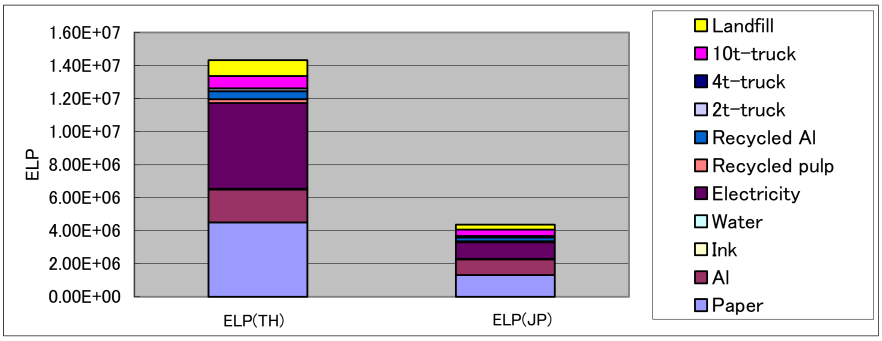
Key indicators from the comparisons are;

- Oil consumption is nearly one forth and coal consumption is one fifth of the ones in Japan. Natural gas consumption is over 40% of Japan, so Thailand depends on natural gas for energy generation.
- Greenhouse gas which is mainly from CO_2 emission is around one fifth and is not considered small amount when considering the difference of economy size such as Gross Domestic Product.
- Main influential factors such as NOx and SOx for Acid precipitate and Air pollution emit in the air are almost the same amount of the ones in Japan. It is also not considered small impact by the same reason above.

After data collection is done in Thailand, ELP comparison of Thailand and Japan is validated. It is shown in Figure 6.19

Process	ELF(TH)	ELP in Thailand			ELF(JP)	ELP in Japan			⊿	%
		Input	ELP			Input	ELP			
1. Paper	1.63E+04	276.210 kg	4.51E+06	31.5%	4.75E+03	276.210 kg	1.31E+06	30.0%	-3.19E+06	-70.9%
2. Al	1.98E+05	10.000 kg	1.98E+06	13.8%	9.62E+04	10.000 kg	9.62E+05	22.0%	-1.02E+06	-51.4%
3. Ink(Polyurethane)	5.61E+04	1.033 kg	5.79E+04	0.4%	1.49E+04	1.033 kg	1.54E+04	0.4%	-4.25E+04	-73.4%
4. Water	9.76E-01	2.580 kg	2.52E+00	0.0%	1.93E-01	2.580 kg	4.98E-01	0.0%	-2.02E+00	-80.2%
5. Electricity	4.17E+03	1,243.908 kWh	5.18E+06	36.2%	8.21E+02	1,243.908 kWh	1.02E+06	23.4%	-4.16E+06	-80.3%
6. Recycled pulp	1.54E+03	149.351 kg	2.30E+05	1.6%	3.02E+02	149.351 kg	4.51E+04	1.0%	-1.85E+05	-80.4%
7. Recycled Al	4.95E+04	10.000 kg	4.95E+05	3.5%	2.36E+04	10.000 kg	2.36E+05	5.4%	-2.59E+05	-52.4%
8. 2t truck	3.98E+03	41.208 tkm	1.64E+05	1.1%	1.86E+03	41.208 tkm	7.66E+04	1.8%	-8.74E+04	-53.3%
9. 4t-truck	3.16E+03	2.843 tkm	8.97E+03	0.1%	1.68E+03	2.843 tkm	4.78E+03	0.1%	-4.19E+03	-46.8%
10. 10t-truck	2.67E+03	278.549 tkm	7.43E+05	5.2%	1.42E+03	278.549 tkm	3.96E+05	9.0%	-3.48E+05	-46.8%
11. Landfill	6.17E+04	15.477 kg*1	9.55E+05	6.7%	1.96E+04	15.477 kg*1	3.03E+05	6.9%	-6.52E+05	-68.2%
		Total ELP:	1.43E+07				4.37E+06		-9.95E+06	-69.5%

Reference: Nagata Laboratory at Waseda University



*1: Weight of products*Landfill ratio(12.2%)

Figure 6.19 ELP comparison of textbook (500 copies) produced in Thailand and Japan

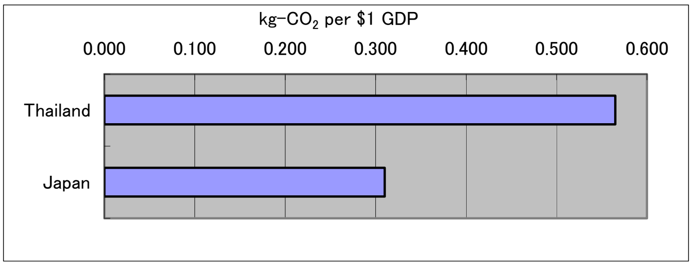
For the comparison shown above, AHP result from Thai/Japanese Printers and limited 14 items to calculate annual load are utilized for both countries to define same basic condition.

Inventory data for each item is supposed to be the same in Thailand.

The Bottom line is ELP result in Japan is almost 30% of the one in Thailand when printing 500 copies of textbook. The reason is that major factors to push up ELP are Paper and Electricity; ELFs for two of those are increased at more than one-digit level in Thailand. Aluminum which consists of printing plate can be added to major influential factors above since it is third biggest impact on ELP result for this case study here.

This result might be under suspicion because the result differs greatly when comparing. Figure 6.20 could show comprehensive ideas and backup the difference of ELP results.

Year	2007
Scale	kg-CO_2 per $1 GDP
Thailand	0.565
Japan	0.310
JP/TH	54.9%



Reference: United Nations Statistics Division

Figure 6.20 Comparison of CO_2 emission per $1 GDP in Thailand and Japan

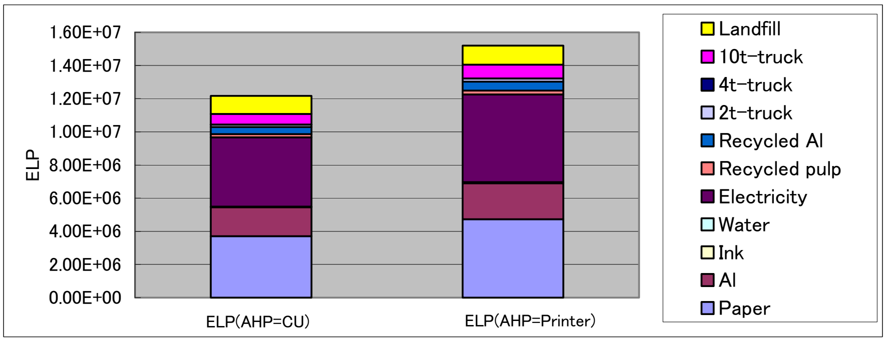
This data shows that CO_2 emission to generate $1 of GDP, the number in Japan is nearly half of the one in Thailand. It means that efficiency of production and service is down to the half level in Thailand. If focusing only on manufacturing except for service related activities, this difference is easily imagined that efficiency in Thailand can be worse than current figure.

6.7.3 Comparison of ELP based on different AHP result in Thailand

Questionnaires to know importances of impact categories by AHP is conducted for CU, Housewives and Printers in Thailand, so ELP based on different importances of impact categories is verified. Figure 6.21 indicates the difference of ELP by two different importances of impact categories.

Process	ELF(TH)	ELP(AHP=CU)			ELF(TH)	ELP(AHP=Printer)			⊿	%
		Input	ELP			Input	ELP			
1. Paper	1.34E+04	276.210 kg	3.70E+06	30.4%	1.71E+04	276.210 kg	4.72E+06	31.1%	1.02E+06	27.5%
2. Al	1.74E+05	10.000 kg	1.74E+06	14.3%	2.18E+05	10.000 kg	2.18E+06	14.3%	4.37E+05	25.1%
3. Ink(Polyurethane)	4.38E+04	1.033 kg	4.52E+04	0.4%	5.88E+04	1.033 kg	6.07E+04	0.4%	1.55E+04	34.4%
4. Water	7.93E−01	2.580 kg	2.04E+00	0.0%	9.95E−01	2.580 kg	2.57E+00	0.0%	5.22E−01	25.5%
5. Electricity	3.36E+03	1,243.908 kWh	4.18E+06	34.3%	4.25E+03	1,243.908 kWh	5.29E+06	34.8%	1.11E+06	26.5%
6. Recycled pulp	1.24E+03	149.351 kg	1.85E+05	1.5%	1.57E+03	149.351 kg	2.34E+05	1.5%	4.91E+04	26.5%
7. Recycled Al	4.34E+04	10.000 kg	4.34E+05	3.6%	5.44E+04	10.000 kg	5.44E+05	3.6%	1.10E+05	25.3%
8. 2t truck	3.39E+03	41.208 tkm	1.40E+05	1.1%	4.38E+03	41.208 tkm	1.80E+05	1.2%	4.09E+04	29.3%
9. 4t−truck	2.74E+03	2.843 tkm	7.80E+03	0.1%	3.52E+03	2.843 tkm	1.00E+04	0.1%	2.21E+03	28.3%
10. 10t−truck	2.32E+03	278.549 tkm	6.46E+05	5.3%	2.98E+03	278.549 tkm	8.30E+05	5.5%	1.84E+05	28.4%
11. Landfill	7.01E+04	15.477 kg*1	1.08E+06	8.9%	7.42E+04	15.477 kg*1	1.15E+06	7.6%	6.41E+04	5.9%
		Total ELP:	1.22E+07				1.52E+07		3.03E+06	24.9%

Reference: Nagata Laboratory at Waseda University



*1: Weight of products*Landfill ratio(12.2%)

Figure 6.21 ELP comparison of textbook (500 copies) by CU and Printers in Thailand

CU and Printers are selected to be compared at first. CU prioritizes Resource consumption, Ecosystem effect and Global warming in series. On the other hand, Printers care Global warming primarily, then Energy drain and Air pollution follows consecutively.

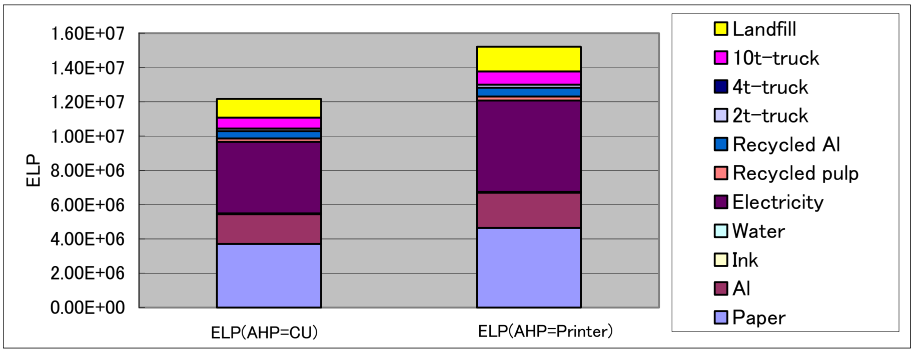
As seen in Figure 6.21, importances of impact categories drawn from AHP results can have significant impact on the difference of ELP when looking at almost 25% increase from CU based impact category to Printers based impact category.

And when getting an in-depth look at detailed impact on each breakdown, the proportion of the load on each is almost the same. ELP undergoes a change with the same proportions for all breakdowns.

ELP based on CU is compared with the one based on Housewives to know the difference between previous comparison and current comparison. It is shown in Figure 6.22.

Process	ELF(TH)	ELP(AHP=CU)			ELF(TH)	ELP(AHP=Housewives)			⊿	%
		Input	ELP			Input	ELP			
1. Paper	1.34E+04	276.210 kg	3.70E+06	30.4%	1.68E+04	276.210 kg	4.64E+06	30.5%	9.37E+05	25.3%
2. Al	1.74E+05	10.000 kg	1.74E+06	14.3%	2.05E+05	10.000 kg	2.05E+06	13.5%	3.07E+05	17.6%
3. Ink(Polyurethane)	4.38E+04	1.033 kg	4.52E+04	0.4%	5.72E+04	1.033 kg	5.91E+04	0.4%	1.39E+04	30.7%
4. Water	7.93E-01	2.580 kg	2.04E+00	0.0%	1.01E+00	2.580 kg	2.61E+00	0.0%	5.61E-01	27.4%
5. Electricity	3.36E+03	1,243.908 kWh	4.18E+06	34.3%	4.28E+03	1,243.908 kWh	5.32E+06	35.0%	1.15E+06	27.4%
6. Recycled pulp	1.24E+03	149.351 kg	1.85E+05	1.5%	1.58E+03	149.351 kg	2.36E+05	1.6%	5.06E+04	27.3%
7. Recycled Al	4.34E+04	10.000 kg	4.34E+05	3.6%	5.14E+04	10.000 kg	5.14E+05	3.4%	7.99E+04	18.4%
8. 2t truck	3.39E+03	41.208 tkm	1.40E+05	1.1%	4.11E+03	41.208 tkm	1.69E+05	1.1%	2.98E+04	21.4%
9. 4t-truck	2.74E+03	2.843 tkm	7.80E+03	0.1%	3.27E+03	2.843 tkm	9.30E+03	0.1%	1.50E+03	19.2%
10. 10t-truck	2.32E+03	278.549 tkm	6.46E+05	5.3%	2.76E+03	278.549 tkm	7.69E+05	5.1%	1.22E+05	18.9%
11. Landfill	7.01E+04	15.477 kg[*1]	1.08E+06	8.9%	9.31E+04	15.477 kg[*1]	1.44E+06	9.5%	3.57E+05	32.9%
		Total ELP:	1.22E+07				1.52E+07		3.04E+06	25.0%

Reference: Nagata Laboratory at Waseda University



*1: Weight of products*Landfill ratio(12.2%)

Figure 6.22 ELP comparison of textbook (500 copies) by CU and Housewives in Thailand

The amount of reduction from ELP based on CU to ELP based on Housewives is promptly 25%, it is just the same as the result of the comparison of ELP based on CU and the one based on Printers. Importances of impact categories from the top to the third for Printers and Housewives look all the same, so it could be a reason why the result of ELP is exactly the same for both comparisons.

6.7.4 Establishment of ELP in Malaysia

As a result of successful establishment of ELP in Thailand, same trial is conducted in Malaysia for wide-range of environment impact assessment.

In Malaysia, there is no academic institution which has printing related departments with certain level in terms of size, so trial to develop ELP was collaborated with The Nets Group of Companies (NGOC) which is a private printing company.

Establishing ELP is followed by the procedure starting from determining category importances for nine impact categories for Malaysian printers. Interviewees are selected from NGOC only, so just 13 people took part in interviews. Interviewees for ELP Thai version was 40 people at printing companies and for ELP Japanese version was 30 people at JWPA, so 13 people for ELP Malaysia version looks a bit inferior compared with the ones for two countries. Category importances for printers from three countries are summarized in Figure 6.23.

Impact Categories	Printers Thailand	Printers Japan	Printers Malaysia
1.Energy drain	0.152	0.142	0.096
2.Global warming	0.156	0.161	0.191
3.Ozone depletion	0.117	0.114	0.122
4.Acid precipitate	0.096	0.079	0.081
5.Resource consumption	0.087	0.098	0.081
6.Air pollution	0.130	0.106	0.106
7.Ocean & water pollution	0.103	0.118	0.109
8.Problem of waste disposal	0.071	0.059	0.070
9.Ecosystem effect	0.088	0.122	0.144

Reference: Nagata Lab. at Waseda Univ.

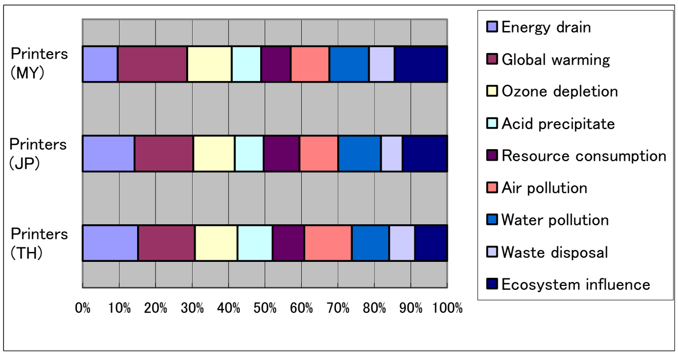


Figure 6.23 Category importances for nine impact categories in TH/JP/MY

Global warming is also ranked first in Malaysia and it is particularly worth noting that Global warming is sticking out and is far away from Ecosystem effect ranked 2nd place. Printers' conscious in Thailand and Japan are quite similar since 1st and 2nd highly weighted impact categories are the same, but the one in Malaysia is slightly different.

Second step of ELP is investigating annual consumption or emission and calculating annual load of items in impact categories. It is summarized in Table 6.13.

Table 6.13 Annual consumption or emission to calculate annual load for items in impact categories

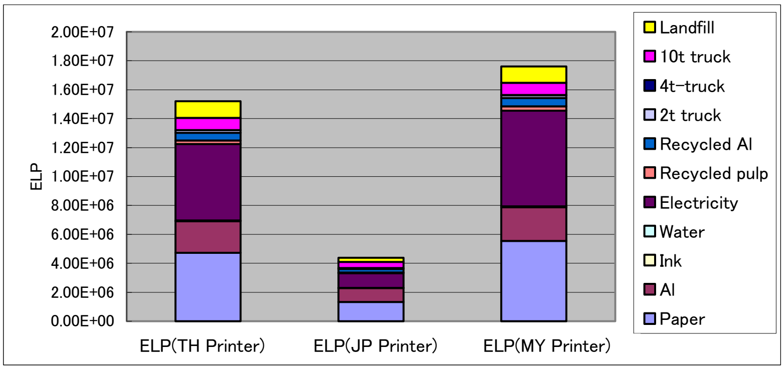
Impact category	Item	Weighting coefficient C	Consumption or Emission TQ	Annual load A=C×TQ	Year	Reference
Energy drain	oil	1.00E+00	2.89E+10	2.89E+10	2009	US Energy Information Administration
	coal	1.10E-01	6.66E+09	7.32E+08	2009	US Energy Information Administration
	natural gas	7.70E-01	2.33E+10	1.79E+10	2009	US Energy Information Administration
	uranium ore	1.48E+01	0.00E+00	0.00E+00		
	wood	5.00E-02	0.00E+00	0.00E+00		
Global warming	CO_2	1.00E+00	1.94E+11	1.94E+11	2007	United Nations Statistics Division
	N_2O	3.20E+02	4.36E+05	1.40E+08	2007	United Nations Statistics Division
	CH_4	2.45E+01	1.87E+09	4.59E+10	2007	United Nations Statistics Division
Ozone depletion	Data is not utilized for ELP calculation for Printing Service					
Acid precipitate	$NOx(NO_2)$	7.00E-01	8.90E+08	7.56E+08	2009	Compendium of Environmental Statistics Malaysia 2010
	$SOx(SO_2)$	1.00E+00	4.62E+08	1.80E+08	2009	Compendium of Environmental Statistics Malaysia 2010
Resource consumption	Iron ore	1.00E+00	1.55E+09	0.00E+00	2007	
Air pollution	$NOx(NO_2)$	1.40E+00	8.90E+08	1.25E+09	2006	Compendium of Environmental Statistics Malaysia 2010
	$SOx(SO_2)$	1.00E+00	4.62E+08	4.62E+08	2006	Compendium of Environmental Statistics Malaysia 2010
Ocean & water pollution	Data is utilized for ELP calculation for Printing Service, but its ifluence is beneath notice					
Waste disposal	Solid Waste	1.00E+00	1.53E+10	8.40E+09	2008	Global Environmental Centre, Malaysia
Ecosystem influence	Data is not utilized for ELP calculation for Printing Service					

When creating ELP Thai version, items in impact categories were narrowed down since data of some items could not be collected. In Malaysia, same problem is encountered and three more items such as uranium ore, wood and iron ore are eliminated. There are still three items for ELP Thai version and ELP Japanese version, so those are modified to eliminate three items only when compared with ELP Malaysia version for disinterested comparison.

ELP for three different countries are summarized based on textbook production for CU student, shown in Figure 6.24.

Process	Input	Printer (TH)		Printer (JP)		Printer (MY)	
		ELF-1	ELP	ELF-2	ELP	ELF-3	ELP
1. Paper	276.210 kg	1.71E+04	4.72E+06	4.77E+03	1.32E+06	2.01E+04	5.55E+06
2. Al	10.000 kg	2.18E+05	2.18E+06	9.63E+04	9.63E+05	2.32E+05	2.32E+06
3. Ink(Polyurethane)	1.033 kg	5.88E+04	6.07E+04	1.50E+04	1.55E+04	6.74E+04	6.96E+04
4. Water	2.580 kg	9.95E-01	2.57E+00	1.93E-01	4.98E-01	1.25E+00	3.23E+00
5. Electricity	1,243.908 kWh	4.25E+03	5.29E+06	8.25E+02	1.03E+06	5.32E+03	6.62E+06
6. Recycled pulp	149.351 kg	1.57E+03	2.34E+05	3.04E+02	4.54E+04	1.97E+03	2.94E+05
7. Recycled Al	10.000 kg	5.44E+04	5.44E+05	2.36E+04	2.36E+05	5.80E+04	5.80E+05
8. 2t truck	41.208 tkm	4.38E+03	1.80E+05	1.87E+03	7.71E+04	4.59E+03	1.89E+05
9. 4t-truck	2.843 tkm	3.52E+03	1.00E+04	1.68E+03	4.78E+03	3.58E+03	1.02E+04
10. 10t-truck	278.549 tkm	2.98E+03	8.30E+05	1.42E+03	3.96E+05	3.02E+03	8.41E+05
11. Landfill	15.477 kg*1	7.42E+04	1.15E+06	1.96E+04	3.03E+05	7.32E+04	1.13E+06
	Total ELP:		1.52E+07		4.38E+06		1.76E+07

Reference: Nagata Laboratory at Waseda University



*1: Weight of products*Landfill ratio(12.2%)

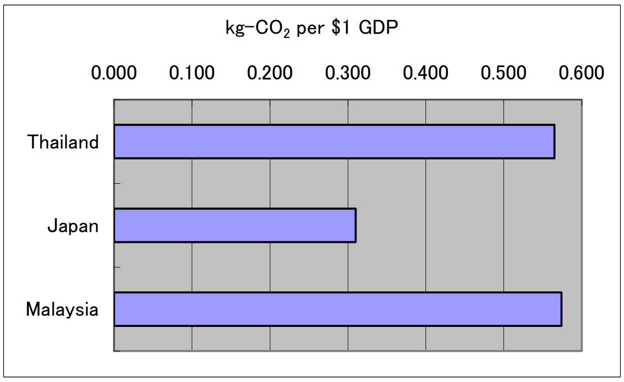
Figure 6.24 ELP by nine impact categories in TH/JP/MY

ELP results from three different countries based on category importances of "Printer" are compared. ELP in Japan is one fourth of the one in Malaysia and one third of Thailand. When ELP in Thailand is compared with the one in Malaysia, the load in Thailand is around 15% less than the one in Malaysia. Annual consumption and emission are totally different for two countries, but the result looks quite similar, not like comparison with Japan.

Missing three items never influencs the result because ELP with three items and ELP without three items are compared each other and no significant difference is confirmed.

In order to make sure that degree of ELP difference is acceptable or not, carbon dioxide emission per $1 GDP is compared, it is done for Japan and Thailand in previous sub clause. It is modified and indicated in Figure 6.25.

Year	2007
Scale	kg-CO_2 per $1 GDP
Thailand	0.565
Japan	0.310
Malaysia	0.574
JP/TH	54.9%
MY/TH	101.6%
JP/MY	54.0%



Reference: United Nations Statistics Division

Figure 6.25 Comparison of CO_2 emissions per $1 GDP in TH/JP/MY

This data shows that CO_2 emission to generate $1 of GDP, the number in Japan is nearly half of the ones in Thailand and Malaysia. It indicates that inefficiency of production and service in Thailand and Malaysia; efficiency levels of two countries are roughly half of Japan. When comparing Thailand and Malaysia, the figures are almost the same. ELP results for both countries also show the vicinity level, so this data can backup that ELP can perform effectively by minimum effort when comparing environmental loads of different countries.

For the future, Malaysia can work on $LCCO_2$ and Integrated LCA together, it is a really leapflogging instance in private sector in Southeast Asia. These achievements promise concrete accomplishments to shift to Eco-design for Printing Service by utilizing quantitative method aggressively.

6.8 CONCLUSION

Printing Service LCA ranging from primary data collection at production site to secondary data collection by bibliographical survey is established in emerging countries without any serious obstacles. Though there is limited condition such as utilization of secondary data from advanced countries, the comparison of environmental load by LCA methods such as $LCCO_2e$ and ELP can be performed from now on to know the difference between emerging countries and advanced countries.

In Thailand, by conducting questionnaire survey for CU students and personnel, low visibility of CFP becomes apparent. From this result in academic field, low level of general recognition for CFP can be easily forecasted. Nonetheless quite low recognition rate of CFP, many people at CU believe that it will support to build Low-carbon society in the future after appropriate explanation is done. Even though statistical tests could not find out the relationships between variables which are demographic data and various kinds of questions to pinpoint the target group to convey messages, but the government related institutions should promote CFP omnidirectionally to give opportunities for the people to think about reducing environmental load by daily behaviors. Awareness campaign for CFP which is well developed can encourage all types of people to direct their attentions to environment conscious products. This movement will connect to newly developed Integrated LCA index in the near future. People are very positive to take actions, so passing up this opportunity would be waste.

Carbon centered evaluation method is viewed with skepticism in advanced countries since many believe that other environmental influences should be considered in some way, it also happens in emerging countries. Surveys for different groups of people mostly show that global warming is top priority among importances of impact categories, but it does not stick out and other impact category such as energy drain is also considered to be important as well. Therefore, the demand for Integrated LCA such as ELP will be stronger and stronger from now; its method should be schematized and utilized in emerging countries even though it has minor limited condition.

Taking all of these results above into account, Printing Service LCA not only about CFP calculation but also about Integrated LCA approach can be established even in Thailand and Malaysia with certain level of effort.

These are case studies of transferring and localizing of Printing Service LCA in Thailand and Malaysia, but are not regarded as success example for specific countries. All of procedures and actions described above can be adopted for other emerging countries. Printing Service LCA will soon be transferred and localized in Thailand and Malaysia.

Primary data collection is not so difficult since printing related facilities which are utilized all over the world are all the same though mixture of old and new should be considered. But, secondary data collection sometimes meets obstacles because of pending arrangement in national database which is supposed to be organized by government institutions in emerging countries. For the case study here, secondary data of paper occupying majority of the load is not prepared in the country and is misappropriated to Japanese secondary data. Data for paper is the most important factor for Printing Service LCA, so two different kinds of paper which are coated paper and coated cardboard should be well prepared at least to compare CFP at certain level.

Many people especially in academic fields in both advanced and emerging countries feel that CFP cannot show real environmental load and try to develop comprehensive Integrated LCA approach, but it is not successful yet. When most of people in town cannot understand CFP perfectly, it is presumed that comprehension of the result of Integrated LCA must be much more obscurity. The time might not be ripe for go on to the next step right now. Unless it is straightforward for Integrated LCA to utilize for Business to Consumer basis, it might be much easier for Business to Business basis to start utilizing Integrated LCA as consolidated indicator in the streamline of supply chain.

Finding out the solution to the problem of getting the concept of Integrated LCA across is a great challenge in the near future.

CHAPTER 7

EUROPEAN CORPORATE ACTIVITY BASED LCA APPROACH FOR PRINTING SERVICE

ABSTRACT

European Printing Service LCA by allocation method is based on Corporate activity based LCA following the idea of The Greenhouse Gas Protocol Initiative. Main purposes are reducing organizational environmental load and promoting environment conscious products by figuring out CO_2e emission mostly for any size of business enterprises. So on that point, the case study is performed by a real mid-sized packaging printer for different quantities of jobs for different allocation methods. Firstly, overall corporate environmental loads of Carbon Footprint (CO_2e emission) and Integrated LCA (ELP) are calculated to grasp the loads per annual sales and per capita. Secondary, though only product-focused LCA method is applied for Printing Service LCA in Japan so far, Corporate activity based LCA is utilized for producing long run (100,000 copies), medium run (10,000 copies) and short run (1,000 copies). Allocation method which is based on paper usage is adopted, and then compares it with general cumulative method. Thirdly, allocation basis is changed from paper usage to electricity especially for medium run and short run jobs. As a result of comparing allocation method with cumulative method for long/medium/short run jobs, Corporate activity based LCA could perform in effective way because it can avoid lack of input and double counting problem. But, it should be reminded that it works only under limited conditions since allocation basis could change real figure of result sometimes.

7.1 INTRODUCTION

Printing Service LCA methods covering wide range of environmental aspects created concreted achievements in the stream of establishing CFP calculation scheme in Japan. Additionally, in Thailand, the ones in Japan was transferred and customized to be appropriate for the nation under limited conditions. This successful trial from joint research project with Chulalongkorn University sets a course for other emerging countries for future implementations of Printing Service LCA.

When turning eyes to European countries developing several different kinds of Integrated LCA methods in the past, currently there are methods focusing not only on production for specific products, but also on corporate activities including whole environmental loads from back-office divisions which are non-productive divisions. This Corporate activity based LCA approach in Europe tries to improve both corporate energy efficiency and environmental product performance especially for small and medium sized companies.

On the basis of the concept of “The Greenhouse Gas Protocol Initiative” which is well known international accounting tool to manage greenhouse gas emission, a couple of countries develop Corporate activity based LCA in different forms in Europe already.

7.2 PURPOSE OF THE STUDY

The European countries having a lot of experiences accept the concept of The Greenhouse Gas Protocol Initiative and are developing Corporate activity based LCA to pursuit organizational energy-efficiency and Eco-design for Printing Services.

The real medium-sized printing company handling Packaging Printing Service becomes a subject for an experiment here to verify whether Corporate activity based LCA is considered of value or not to promote overall reduction of the environmental load. The advantages of European approach are verified by the comparative analyses of Corporate activity based LCA and Product focused LCA through real packaging jobs ranging from short run to long run.

7.3 BACKGROUND OF THE STUDY

7.3.1 The Greenhouse Gas Protocol Initiative

7.3.1.1 Organizational background

The Greenhouse Gas Protocol Initiative (GHG Protocol) presented itself when the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) necessitated the international standard for quantification and reporting of corporate greenhouse gas to fight against climate change.

Both WRI and WBCSD agreed to work together to set standardized methods for greenhouse gas accounting, and then formed task force consisting of environmental groups and business enterprises. The first edition of GHG Protocol for corporate standard was established after four years of discussions and then published in 2001. It soon became absolute standard for project accounting.

In both advanced and emerging countries, GHG Protocol was chosen as partners of governments, businesses and non-government organizations by wide-spreading all over the world. Figure 7.1 shows many countries in the world are utilizing the program now.

Reference: The Greenhouse Gas Protocol Initiative

Figure 7.1 National and regional programs using GHG Protocol

In the next stage, GHG protocol was credited by International Organization for Standardization (ISO) and became core part of ISO related documents calculating greenhouse gas emission and removals. Currently, many of corporate, non-corporate organizations are working closely with GHG protocol; list of organizations is shown in Appendix C.

GHG Protocol has grown up as well-known global accounting tool to calculate and assist reducing greenhouse gas emissions to fight against climate change for more than a decade working with WRI and WBCSD. It shows quantification scheme for many of different types of organization.

7.3.1.2 Multiple purposes by GHG emission control

Business enterprises should manage GHG inventory to carry out the will of multiple purposes. GHG protocol is meant to offer different kinds of information to different kinds of people surrounding the organization. It is summarized as business goals in Table 7.1.

Table 7.1 Business goals served by GHG inventories

Managing GHG risks and identifying reduction opportunities
* Identifying risks associated with GHG constraints in the future
* Identifying cost effective reduction opportunities
* Setting GHG targets, measuring and reporting progress
Public reporting and participation in voluntary GHG programs
* Voluntary stakeholder reporting of GHG emissions and progress towards GHG targets
* Reporting to government and NGO reporting programs, including GHG registries
* Eco-labelling and GHG certification
Participating in mandatory reporting programs
* Participating in government reporting programs at the national, regional, or local level
Participating in GHG markets
* Supporting internal GHG trading programs
* Participating in external cap and trade allowance trading programs
* Calculating carbon/GHG taxes
Recognition for early voluntary action
* Providing information to support "baseline protection" and/or credit for early action

Reference: "A Corporate Accounting and Reporting Standard", The Greenhouse Gas Protocol

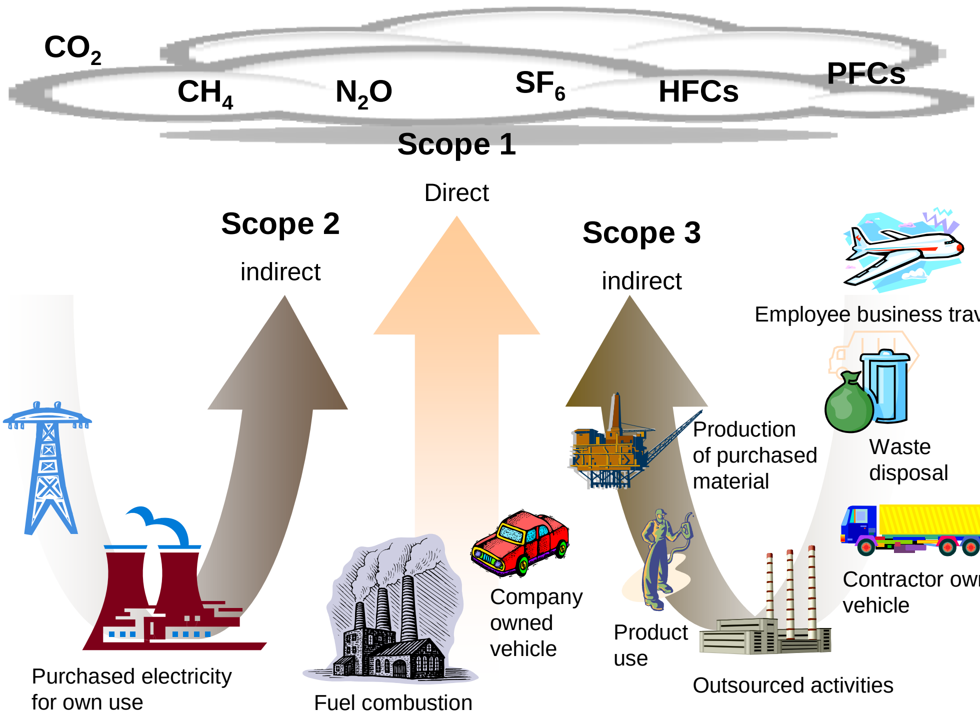
7.3.1.3 Definition of direct and indirect GHG emission

Establishing operational boundaries in consideration of direct and indirect GHG emissions can assist in achieving multiple purposes of business enterprises and its supply chain.

It is quite important for business enterprises to enrich their deep understanding about GHG emissions which are accumulating from inventory data and tackle earnestly about reduction of GHG emissions.

Direct GHG emissions are the ones from controllable activities by business enterprises; on the other hand, indirect emissions are the ones from uncontrollable continuum activities by supply chain of business enterprises.

In order to explain the difference of direct and indirect GHG emissions, three types of “scope” are categorized as scope-1, scope-2 and scope-3 respectively. Especially scope-1 and scope-2 should be carefully partitioned to guarantee that a couple of business enterprises never calculate GHG emissions redundantly without becoming aware of double accounting in the stream of supply chain. Scopes are illustrated in Figure 7.2.



Reference: “A Corporate Accounting and Reporting Standard”, The Greenhouse Gas Protocol

Figure 7.2　Categorization of GHG emissions in scope-1/scope-2/scope-3

Direct GHG emissions from the main stream are scope-1 and are thought to be controlled by the business enterprise. Basically, GHG emissions which are included in Kyoto Protocol are in scope-1, but other greenhouse gases could be stated separately from the main report. Prevailing activities from scope-1 are;

- Generation of electricity, heat or steam by boilers, furnaces and turbines
- Manufacturing or processing of chemicals and materials
- Transportation of materials, products, waste and employees
- Temporary emissions from intentional or unintentional releases

When the business enterprise generates electricity in-house and sell it to the others, emissions from it cannot be deducted from scope-1 by any reason.

Scope-2 is calculated as GHG emissions when the business enterprise purchases electricity which is utilized for its own use; it is counted when the electricity is generated at the power plant. Purchasing of electricity usually occupies large portion of the environmental load in the organization, so is appropriate target for reduction of GHG emissions from electricity by;

- Modification on current facility to promote energy efficiency
- Constructing new energy efficient facilities
- Changing to renewable energy source which are provided by green power markets

Calculating greenhouse gas emissions from scope-2, namely counting up the environmental load from purchased electricity generation is predominant factor for many organizations, so reduction related opportunities for scope-2 are extremely significant.

Scope-3 is selective factor among three scopes and is a controversial one since supply chain is not controllable by the business enterprises in most of the cases. Informative lists of categories which are neither in scope-1 nor scope-2 are;

- Extraction and production of purchased materials and fuels
- Transport-related activities
- Electricity related activities not included in scope-2
- Leased assets, franchises and outsourced activities
- Use of sold products and services
- Waste disposal

Calculating greenhouse gas emissions from scope-3 can cover wide range of life cycle analysis of products. In other words, without scope-3, overall environmental load cannot be evaluated as a product. This scope is still under discussion about the covered area, but some of essential parts here should be included to complete full range of LCA for a product.

7.3.2 INTERGRAF Recommendations

7.3.2.1 Organizational background

INTERGRAF, International confederation for printing and allied industries was re-organized in 1984 by 23 national printing federations from 20 countries in Europe. Back in 1930, it was originally started as the International Bureau of the Federations of Master Printers in Berlin, and then unionized as an organization in Brussels in 1976.

It leads European printing industry consisting of 132,000 printing companies employing around 853,000 people in 27 European countries and defends their vested interests by lobbying, informing and networking in a positive manner.

In order to face newly emerging problems in the global market, INTERGRAF was metamorphosed to aim to unite EU printing industries as one. As a result of organizational transformation in almost a century, INTERGRAF and local federations in member countries are cooperating closely and bring synergy effectiveness for action assignments in a constructive manner.

Current main issues of INTERGRAF are indicated in Table 7.2.

Table 7.2 Latest main issues of INTERGRAF

<COMPETITIVENESS> **Delocalisation to low-cost countries** The imports of printed products from low-cost countries have increased drastically, which is putting additional pressure on the industry in Europe. **Innovation, R&D** Supporting the industry in creating growth through innovation and value-added services. **Quality Standards** Promoting the use of ISO standards in print production, which ensures high quality of the product and predictability for the client.
<ECONOMICS & STATISTICS> **Eurostat** Ensuring comprehensive and updated classifications of activities and products from the European and worldwide printing industry. **Annual Statistical Report** Publication of a comprehensive collection of data on companies and products in the European Printing Industry.
<IMAGE> **Print Power and Two Sides** Large scale project to promote the use of print in communication and its environmental friendliness to print buyers in Europe.
<ENVIRONMENT> **Air emissions** Monitoring of developments in legislation at European and national level. (Revision of IPPC, NEC National Emissons Ceilings, Best Available Techniques as resulting from IPPC) **Sustainability in the paper chain** Increasing the amount of paper recycled in the EU through voluntary industry agreements. **Carbon footprint** Finding a methodology to calculate the carbon emissions coming from the print supply chain. **EU Ecolabel** An ecolabel for printed products was suggested by the European Commission in 2003.
<HEALTH & SAFETY> **REACH** Providing guidelines to companies about the impact of REACH particularly with regard to obligations for downstream users. **Elimination of harmful substances** Monitoring the exclusion of potentially harmful substances in solvents, according to scientific criteria.
<SOCIAL POLICY, TRAINING & EDUCATION> **Project on Socially responsible restructuring for printing companies** A one-year project to identify and tackle the challenges of the printing sector, and to identify best practices in socially responsible restructuring. **Developments in labour conditions** Monitoring developments in national labour relations, creating an overview of outcomes of negotiations. **Young Leaders in Print** Providing an opportunity for young print managers to network and get training.

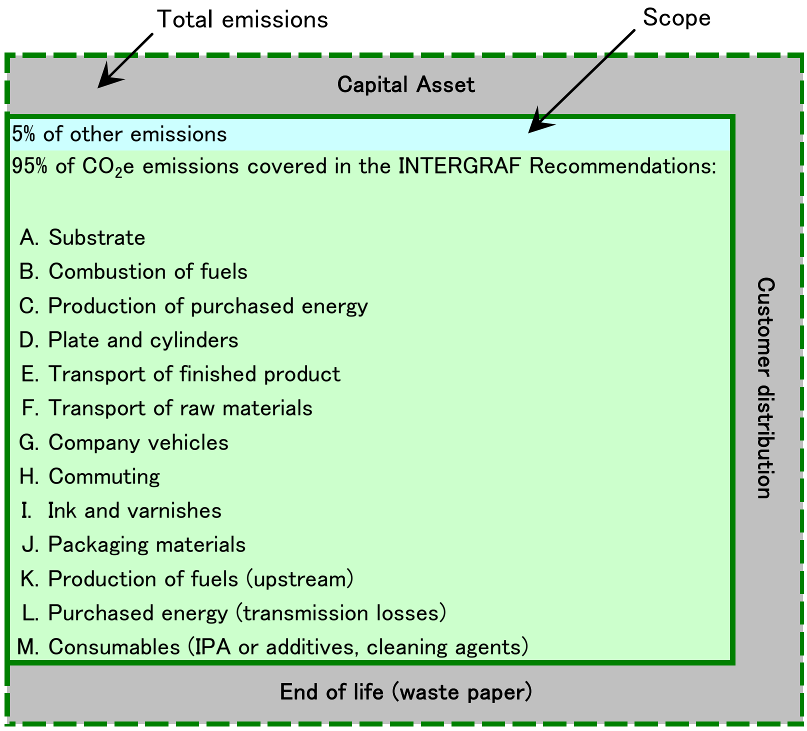
Reference: Main issues, INTERGRAF

7.3.2.2 Recommended parameters for calculating CO_2e emission

Especially in Europe, the market is regulated by strict environmental restrictions, so printers and print buyers are under the pressure from public administrations and consumers. Public opinions about climate change are more sensational in every nation in Europe.

INTERGRAF learned that CFP for Printing Services is one of the demands from the market all over the world, so started assisting printers and print buyers to calculate the environmental load from their activities to make their production eco-friendly and also improve cost performance at the same time.

There are different kinds of CO_2e calculators showing logical calculation scheme. Those schemes explaining reasons behind the figures were developed by federation members in Europe through the work with INTERGRAF. The deliverables from their enthusiastic works are summarized as INTERGRAF Recommendations, and illustrated in Figure 7.3.



Reference: 13 parameters of INTERGRAF Recommendation

Figure 7.3 13 parameters of INTERGRAF Recommendations

Main purpose of INTERGRF Recommendations is providing opportunities for any size of printing companies to model CO_2e calculation schemes in their organization to apply to the international market where many global companies participate actively.

7.3.2.3 Categorizing recommended parameters in detail

When one complies with 13 parameters of INTERGRAF Recommendations, it is possible to state that 95% of CO_2e emissions are calculated within the scope based on different types of case studies by federation members.

All parameter are categorized as “Site related” and “Product related” to understand that which parameters should be calculated by allocation method for “Site related” and by specific figures of usage amount for “Product related”. Additionally, scopes of GHG protocol are defined to know which parameters can be influenced by own activities or by outside activities. Figure 7.4 shows Site/Product related categories, scopes of GHG protocol, and also average portion of each parameter from a single printing company on a yearly basis.

	Parameters	Site/Product relevant	GHG scope
A:	Production of substrate	Product	scope-3
C:	Production of purchased energy	Site	scope-2
B:	On-site combustion of fuels	Site	scope-1
F:	Transport of raw materials	Product	scope-3
I:	Production of inks and varnishes	Product	scope-3
L:	Purchased energy (upstream and transmission losses)	Site	scope-3
E:	Transport of finished product	Product	scope-3
K:	Production of fuels	Site	scope-3
M:	Production of IPA and cleaning agents	Site	scope-3
H:	Employees commuting	Site	scope-3
D:	Production of aluminum plates	Site	scope-3
J:	Production of packaging materials	Product	scope-3
G:	Company owned or leased vehicle	Site	scope-1

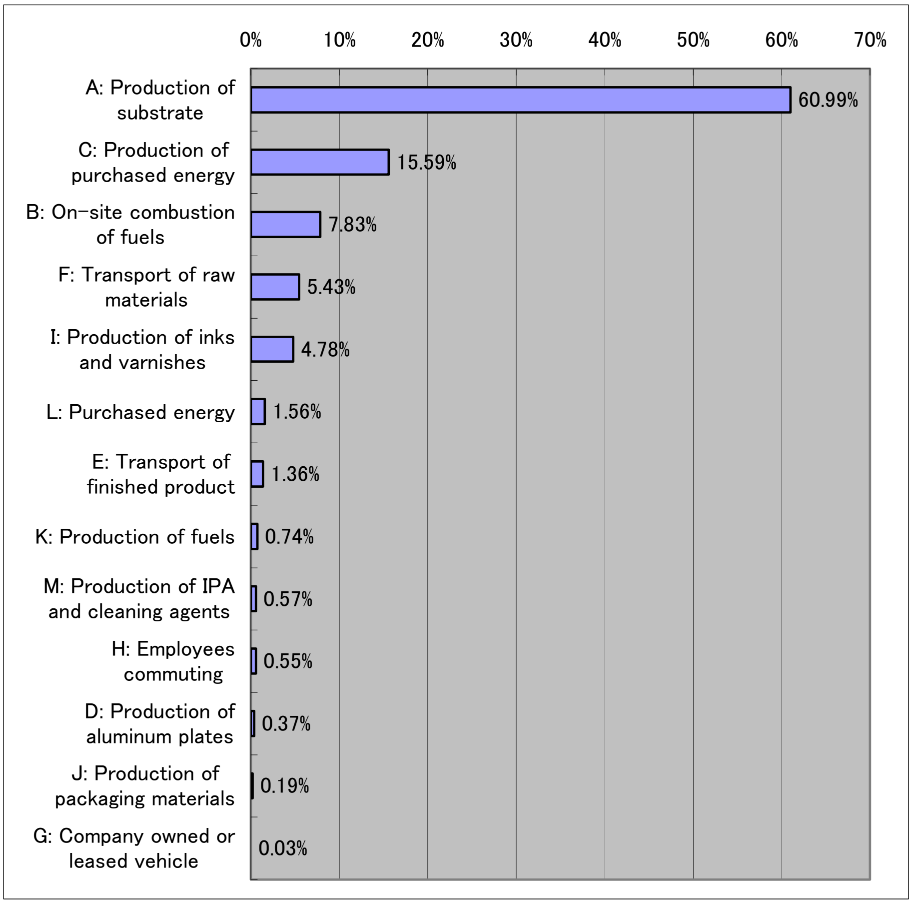


Figure 7.4 Average portion of each parameter from a single printing company

INTERGRAF Recommendations remind us of what should be calculated and also what can be excluded from calculation. Most of parameters which are excluded are;

- Production of other materials (e.g. plate developing agents, fountain solution and so on)
- Transport of other raw materials than the substrates
- Transport, treatment of production waste and waste water
- Business travel by employees and visitors

- Emissions from VOCs

Some of parameters are excluded by current studies, but will be included after trustful future studies will be done to support the idea to expand the operating boundaries. This is a case of a packaging printer, so exceptional instances should be taken into account.

7.4 CASE STUDY OF CORPORATE ACTIVITY BASED LCA

7.4.1 Precondition of the study

A printing company dealing mainly with packaging business for this case study is defined in Table 7.3.

Table 7.3 Corporate information of a packaging printer for the case study

Category	Item	Unit	Annual figures
Basic information	Turnover	€	8,500,000
	Total asset	€	10,000,000
	Employees	−	35
Utility	Electricity	kWh	1,200,000
	Water	litre	850,000
	Gas	m^3	0
Input	Paper	kg	1,800,000
	Ink	kg	5,000
	Varnish	kg	10,000
	Plate (Al)	kg	7,500
	Van	tkm	26,500
	2t-truck	tkm	43,525
	4t-truck	tkm	233,888
	10t-truck	tkm	1,530,000
Output	Wasted paper	kg	360,000

This company is typical medium-sized one with annual sales of 8.5 million euro (11.5 million USD) from packaging focus business by the efforts of 35 employees. Total amount of utility, input and output are summarized above.

Total inputs of transportation for materials and products are divided into three different sizes of trucks by the scale of ton-km (tkm) method. For transportation by 10-ton truck, cardboard which is biggest item among materials is calculated based on 850 km averaged distance. It occupies over 80% of total load and has definitely major impact.

For transportation by 4-ton and 2-ton trucks, materials/recycled items/two-time (am and pm) delivery of products are calculated based on certain averaged distances which are investigated individually.

For vans, it is calculated for both sales related activity and employee commuting. This company consists of 35 employees (eight salespersons out of 35 employees). For sales activities, each salesperson travels 45km a day. For employees' commuting, 35 employees travel 20 km of roundtrip, so total tkm a year are calculated by multiplication of;

- Sales: 45km*8 salespersons*250 business days*0.1t/van=9,000tkm

- Employees: 20km*35 employees*250 business days*0.1t/van=17,500tkm

Computational logics for all items are shown in Figure 7.5.

Item	Annual amount (kg, 250-day)	Daily amount (kg, 1-day)	Truck	Avg. distance (km)	Total (tkm)	%
Cardboard	1,800,000	7,200	10t truck	850	1,530,000	83.4%
Al	7,500	30	4t truck	285	2,138	12.8%
Recycled Pulp	360,000	1,440	4t truck	240	86,400	
Recycled Al	7,500	30	4t truck	180	1,350	
Delivery(products)-AM	720,000	2,880	4t truck	100	72,000	
Delivery(products)-PM	720,000	2,880	4t truck	100	72,000	
Ink	5,000	20	2t truck	65	325	2.4%
Disposal(products)	1,440,000	5,760	2t truck	30	43,200	
Sales activity	–	100	Van	360	9,000	1.4%
Employees commuting	–	100	Van	20	17,500	
					1,833,913	

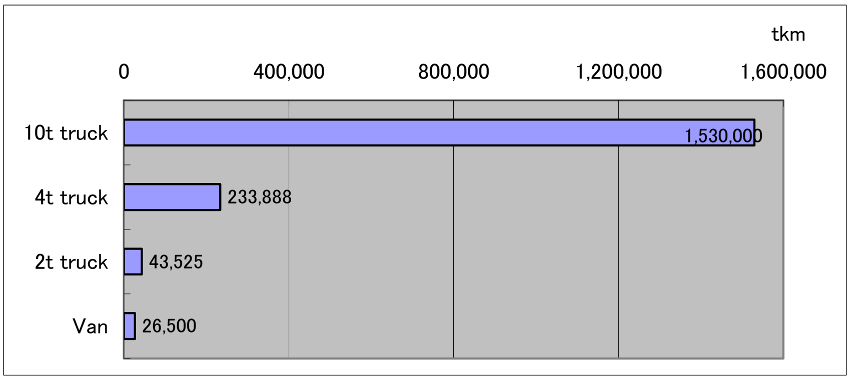


Figure 7.5 Total tkm from 10t/4t/2t-truck and van

7.4.2 Corporate LCCO$_2$e and ELP

Based on corporate basic information of a packaging printer, total CO$_2$e emission and ELP which is developed as Integrated LCA method are calculated by different views.

Compared to INTERGRAF recommendations, items which are not included here in the case study are;

- Packaging materials
- Production of fuels
- Consumables such as cleaning agents and Isopropyl alcohol(IPA)

These items are thought to be very small impacts from our past study and also INTERGRAF study (total of three items are just 1.5%) which is shown in Figure 7.4, so are recognized as out of system boundary by cut-off rule here.

On the contrary, items which are not in the list of INTERGRAF Recommendations are;

- Water
- Van for salesperson
- Recycled Pulp
- Recycled Al
- Landfill

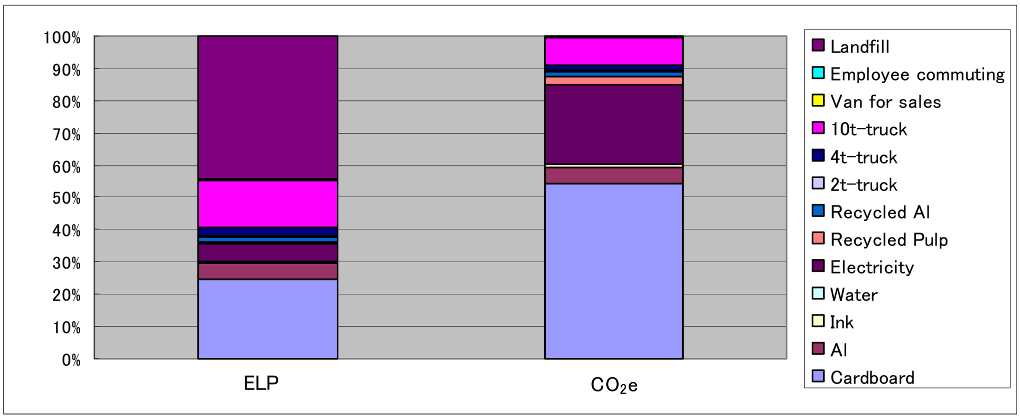
The reason why end-of-life related items are included here is that it is surely unavoidable part of LCA study. They are somehow outstep in other product's system boundary, but are daringly included in calculation to ensure consistency with the previous studies.

Another kind of item is Water; it is included even though it has such small impact. The reason being that it is absolutely hot issue since Water Footprinting comes under the review for international standardization now. Collecting primary data of water will be certainly recognized as useful one in the future.

Summary of corporate CO_2e emission and ELP is summarized in Figure 7.6.

Process	Input	ELF	CO_2e emission coefficient	ELP		CO_2e		⊿
1.Cardboard	1,800,000 kg	1.92E+03	6.37E-01	3.46E+09	24.5%	1.15E+06	54.4%	29.9%
2.Al	7,500 kg	9.86E+04	1.43E+01	7.40E+08	5.2%	1.07E+05	5.1%	-0.1%
3.Ink(Polyurethane)	5,000 kg	1.15E+04	4.53E+00	5.76E+07	0.4%	2.27E+04	1.1%	0.7%
4.Water	850,000 kg	1.59E-01	1.97E-04	1.35E+05	0.0%	1.67E+02	0.0%	0.0%
5.Electricity	1,200,000 kWh	6.49E+02	4.26E-01	7.79E+08	5.5%	5.11E+05	24.2%	18.7%
6.Recycled Pulp	360,000 kg	2.39E+02	1.67E-01	8.60E+07	0.6%	6.01E+04	2.9%	2.2%
7.Recycled Al	7,500 kg	2.43E+04	3.16E+00	1.82E+08	1.3%	2.37E+04	1.1%	-0.2%
8.2t-truck	43,525 tkm	1.77E+03	2.09E-01	7.72E+07	0.5%	9.10E+03	0.4%	-0.1%
9.4t-truck	233,888 tkm	1.61E+03	1.43E-01	3.76E+08	2.7%	3.34E+04	1.6%	-1.1%
10.10t-truck	1,530,000 tkm	1.36E+03	1.21E-01	2.08E+09	14.7%	1.85E+05	8.8%	-5.9%
11.Van for sales	9,000 tkm	1.66E+03	3.19E-01	1.49E+07	0.1%	2.87E+03	0.1%	0.0%
12.Van for commuting	17,500 tkm	1.66E+03	3.19E-01	2.90E+07	0.2%	5.58E+03	0.3%	0.1%
13.Landfill	175,680 kg*1	3.56E+04	3.49E-03	6.26E+09	44.2%	6.13E+02	0.0%	-44.2%
			Total ELP/CO_2e:	1.41E+10		2.11E+06		

Reference(ELP): Nagata Laboratory at Waseda University
Reference(CO_2e): JEMAI "SimpleLCA"



*1: Weight of products × Landfill ratio(12.2%)

Figure 7.6 Annual corporate LCCO_2e and ELP of a packaging printer

Environmental loads of CO_2e and ELP are easily comprehensive when they are shown as indicators by calculation utilized by total turnover and number of employees.

In order to raise up the sales for a packaging printer in one year, 248kg-CO_2e per 1,000 Euros (1,353 USD) is emitted to achieve annual sales volume. It is further fact that 60,200 kg-CO_2e per employee is discharged (241kg-CO_2e per day) in a year. To understand the environmental impact easily, Table 7.4 indicates annual CO_2e emission and ELP per turnover and employee.

Table 7.4 CO_2e emission and ELP per turnover and employee

Process	ELP		CO_2e		ELP per turnover (thousand Euros)	CO_2e per turnover (thousand Euros)	ELP per employees	CO_2e per employees
1.Cardboard	3.46E+09	24.5%	1.15E+06	54.4%	4.07E+05	1.35E+02	9.89E+07	3.28E+04
2.Al	7.40E+08	5.2%	1.07E+05	5.1%	8.70E+04	1.26E+01	2.11E+07	3.06E+03
3.Ink(Polyurethane)	5.76E+07	0.4%	2.27E+04	1.1%	6.78E+03	2.66E+00	1.65E+06	6.47E+02
4.Water	1.35E+05	0.0%	1.67E+02	0.0%	1.59E+01	1.97E-02	3.87E+03	4.78E+00
5.Electricity	7.79E+08	5.5%	5.11E+05	24.2%	9.16E+04	6.01E+01	2.23E+07	1.46E+04
6.Recycled Pulp	8.60E+07	0.6%	6.01E+04	2.9%	1.01E+04	7.07E+00	2.46E+06	1.72E+03
7.Recycled Al	1.82E+08	1.3%	2.37E+04	1.1%	2.14E+04	2.79E+00	5.20E+06	6.77E+02
8.2t-truck	7.72E+07	0.5%	9.10E+03	0.4%	9.09E+03	1.07E+00	2.21E+06	2.60E+02
9.4t-truck	3.76E+08	2.7%	3.34E+04	1.6%	4.43E+04	3.93E+00	1.08E+07	9.56E+02
10.10t-truck	2.08E+09	14.7%	1.85E+05	8.8%	2.45E+05	2.18E+01	5.95E+07	5.29E+03
11.Van for sales	1.49E+07	0.1%	2.87E+03	0.1%	1.76E+03	3.38E-01	4.27E+05	8.20E+01
12.Van for commuting	2.90E+07	0.2%	5.58E+03	0.3%	3.42E+03	6.57E-01	8.30E+05	1.60E+02
13.Landfill	6.26E+09	44.2%	6.13E+02	0.0%	7.36E+05	7.21E-02	1.79E+08	1.75E+01
Total:	1.41E+10		2.11E+06		1.66E+06	2.48E+02	4.04E+08	6.02E+04

Reference(ELP): Nagata Laboratory at Waseda University
Reference(CO_2e): JEMAI "SimpleLCA"

7.4.3 Comparison of allocation and cumulative method for long run

In order to know the difference of figures comparing allocation method which is Corporate activity based LCA and cumulative method which is Product focused LCA, a packaging job of 100,000 of paper package which is calculated in previous chapter is an issue of concern.

For allocation method, usage amount for each item is keyed and then is allocated based on usage amount of paper for a specific job. The reason why paper is set as cornerstone for allocation method is that it is the most influential factor from the viewpoint of CO_2e emission.

Here in this case study, usage amount of paper is 2,071kg and it occupies 0.115% of total amount of paper usage in one year. Each load from other items is calculated based on the allocation ratio of paper usage.

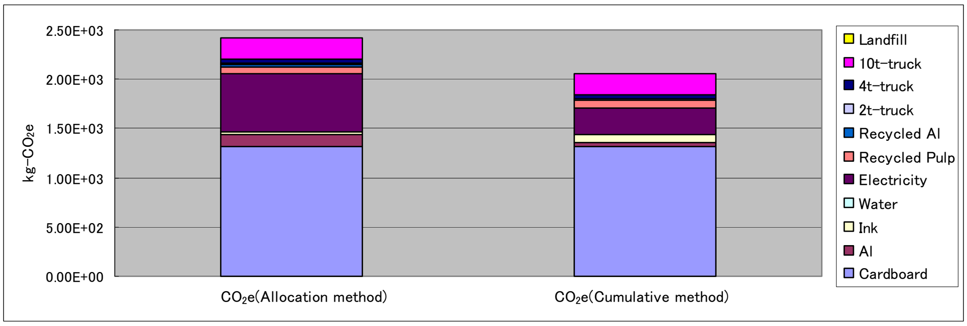
For CO_2e emission, the figure from allocation method is 2,430kg-CO_2e for 100,000 copies (24g-CO_2e/copy), so it is 344 kg-CO_2e (16.5%) higher than cumulative method. It mainly comes from the difference of electricity since it is 325 kg-CO_2e higher than cumulative method. This figure occupies almost 95% of total difference, so it is definitely major cause. When looking at other CO_2e emission, Al (printing plate) is overestimated. On the other hand, though it is nothing special, paper related items such as transportation for delivery and landfill is almost same as cumulative method since allocation is based on paper.

For ELP, overall rate of increase is much smaller than CO_2e emission. And, the fact showing allocation method is higher than cumulative method is the same as CO_2e emission, but the content of the difference is quite different. Electricity is one of the major causes, but it is only around 40% of total difference.

The comparison of allocation method and cumulative method in terms of CO_2e emission and ELP are summarized in Figure 7.7 and Figure 7.8.

Process	CO_2e	Input(corporate)	Allocated percentage	CO_2e (Allocation)		Input(products)	CO_2e (Cumulative)		⊿	%
1.Cardboard	6.37E-01	1,800,000 kg	0.115%	1.32E+03	54.4%	2,071 kg	1.32E+03	63.4%	0.00E+00	100.0%
2.Al	1.43E+01	7,500 kg	0.115%	1.23E+02	5.1%	3 kg	4.29E+01	2.1%	8.05E+01	287.6%
3.Ink(Polyurethane)	4.53E+00	5,000 kg	0.115%	2.61E+01	1.1%	17 kg	7.70E+01	3.7%	-5.09E+01	33.8%
4.Water	1.97E-04	850,000 kg	0.115%	1.93E-01	0.0%	43 kg	8.47E-03	0.0%	1.84E-01	2274.4%
5.Electricity	4.26E-01	1,200,000 kWh	0.115%	5.88E+02	24.2%	618 kWh	2.63E+02	12.6%	3.25E+02	223.4%
6.Recycled Pulp	1.67E-01	360,000 kg	0.115%	6.92E+01	2.9%	473 kg	7.90E+01	3.8%	-9.82E+00	87.6%
7.Recycled Al	3.16E+00	7,500 kg	0.115%	2.73E+01	1.1%	3 kg	9.48E+00	0.5%	1.78E+01	287.6%
8.2t-truck	2.09E-01	43,525 tkm	0.115%	1.05E+01	0.4%	49 tkm	1.02E+01	0.5%	2.25E-01	102.2%
9.4t-truck	1.43E-01	233,888 tkm	0.115%	3.85E+01	1.6%	312 tkm	4.46E+01	2.1%	-6.13E+00	86.3%
10.10t-truck	1.21E-01	1,530,000 tkm	0.115%	2.13E+02	8.8%	1,717 tkm	2.08E+02	10.0%	5.25E+00	102.5%
11.Van for sales	3.19E-01	9,000 tkm	0.115%	3.30E+00	0.1%	45 tkm	1.44E+01	0.7%	-1.11E+01	23.0%
12.Employee commuting	3.19E-01	17,500 tkm	0.115%	6.42E+00	0.3%	42 tkm	1.34E+01	0.6%	-6.98E+00	47.9%
11.Landfill	3.49E-03	175,680 kg*1	0.115%	7.05E-01	0.0%	195 kg*1	6.81E-01	0.0%	2.49E-02	103.7%
			Total CO_2e:	2.43E+03		Total CO_2e:	2.08E+03		3.44E+02	116.5%

Reference(CO_2e): JEMAI "Simple LCA"

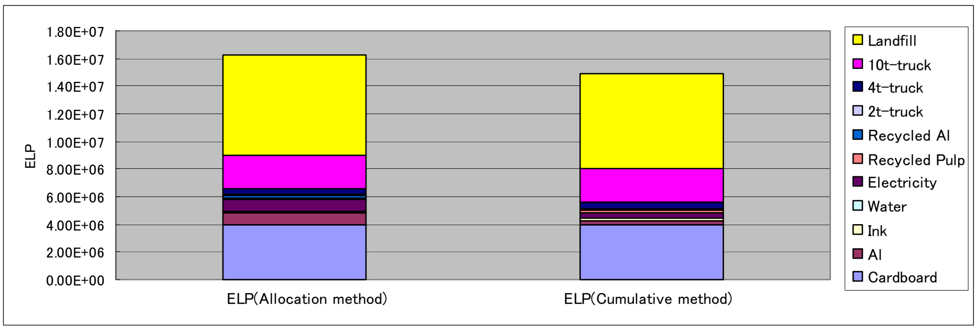


*1: Weight of products × Landfill ratio(12.2%)

Figure 7.7 Comparison of allocation and cumulative method in CO_2e emission (100,000 copies)

Process	ELF	Input(corporate)	Allocated percentage	ELP (Allocation)		Input(products)	ELP (Cumulative)		⊿	%
1.Cardboard	1.92E+03	1,800,000 kg	0.115%	3.98E+06	24.5%	2,071 kg	3.98E+06	26.4%	0.00E+00	100.0%
2.Al	9.86E+04	7,500 kg	0.115%	8.51E+05	5.2%	3 kg	2.96E+05	2.0%	5.55E+05	287.6%
3.Ink(Polyurethane)	1.15E+04	5,000 kg	0.115%	6.63E+04	0.4%	17 kg	1.96E+05	1.3%	-1.30E+05	33.8%
4.Water	1.59E-01	850,000 kg	0.115%	1.56E+02	0.0%	43 kg	6.85E+00	0.0%	1.49E+02	2274.4%
5.Electricity	6.49E+02	1,200,000 kWh	0.115%	8.96E+05	5.5%	618 kWh	4.01E+05	2.7%	4.95E+05	223.4%
6.Recycled Pulp	2.39E+02	360,000 kg	0.115%	9.89E+04	0.6%	473 kg	1.13E+05	0.7%	-1.40E+04	87.6%
7.Recycled Al	2.43E+04	7,500 kg	0.115%	2.09E+05	1.3%	3 kg	7.28E+04	0.5%	1.37E+05	287.6%
8.2t-truck	1.77E+03	43,525 tkm	0.115%	8.89E+04	0.5%	49 tkm	8.70E+04	0.6%	1.91E+03	102.2%
9.4t-truck	1.61E+03	233,888 tkm	0.115%	4.33E+05	2.7%	312 tkm	5.02E+05	3.3%	-6.91E+04	86.3%
10.10t-truck	1.36E+03	1,530,000 tkm	0.115%	2.40E+06	14.7%	1,717 tkm	2.34E+06	15.5%	5.90E+04	102.5%
11.Van for sales	1.66E+03	9,000 tkm	0.115%	1.72E+04	0.1%	45 tkm	7.47E+04	0.5%	-5.75E+04	23.0%
12.Employee commuting	1.66E+03	17,500 tkm	0.115%	3.34E+04	0.2%	42 tkm	6.97E+04	0.5%	-3.63E+04	47.9%
11.Landfill	3.56E+04	175,680 kg*1	0.115%	7.20E+06	44.2%	195 kg*1	6.95E+06	46.1%	2.54E+05	103.7%
			Total ELP:	1.63E+07		Total ELP:	1.51E+07		1.20E+06	107.9%

Reference(ELP): Nagata Laboratory at Waseda University



*1: Weight of products × Landfill ratio(12.2%)

Figure 7.8 Comparison of allocation and cumulative method in ELP (100,000 copies)

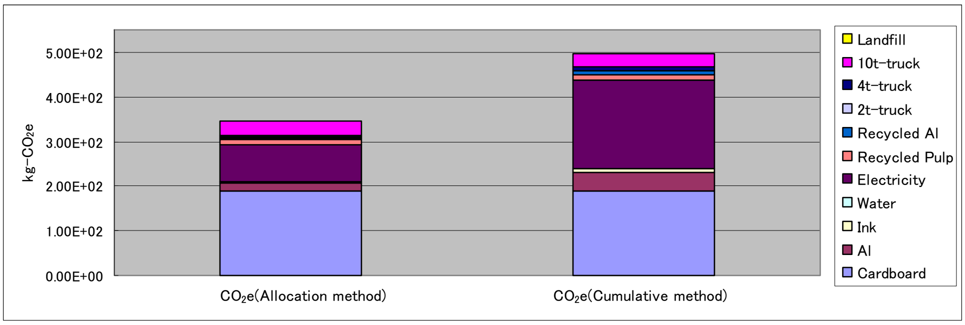
This difference is thought to come from electricity usage of back-office divisions and intrinsic error of allocation method. When allocation method is adopted, certain amount of intrinsic error should be pardonable since the entire load is as sure as allocated on a specific job in varying degree.

7.4.4 Comparison of allocation and cumulative method for medium run

Accepting an order of 100,000 copies is quite big order for medium-sized company, so unsurprising average order is set as 10,000 copies. The comparison of different number of order, namely the one of medium run is calculated. It is shown in Figure 7.9.

Process	CO_2e	Input(corporate)	Allocated percentage	CO_2e (Allocation)		Input(products)	CO_2e (Cumulative)		⊿	%
1.Cardboard	6.37E-01	1,800,000 kg	0.016%	1.89E+02	54.4%	296 kg	1.89E+02	37.6%	0.00E+00	100.0%
2.Al	1.43E+01	7,500 kg	0.016%	1.76E+01	5.1%	3 kg	4.29E+01	8.6%	-2.53E+01	41.1%
3.Ink(Polyurethane)	4.53E+00	5,000 kg	0.016%	3.72E+00	1.1%	2 kg	9.06E+00	1.8%	-5.34E+00	41.1%
4.Water	1.97E-04	850,000 kg	0.016%	2.75E-02	0.0%	6 kg	1.18E-03	0.0%	2.64E-02	2329.6%
5.Electricity	4.26E-01	1,200,000 kWh	0.016%	8.41E+01	24.2%	461 kWh	1.96E+02	39.2%	-1.12E+02	42.8%
6.Recycled Pulp	1.67E-01	360,000 kg	0.016%	9.89E+00	2.9%	68 kg	1.14E+01	2.3%	-1.47E+00	87.1%
7.Recycled Al	3.16E+00	7,500 kg	0.016%	3.90E+00	1.1%	3 kg	9.48E+00	1.9%	-5.58E+00	41.1%
8.2t-truck	2.09E-01	43,525 tkm	0.016%	1.50E+00	0.4%	7 tkm	1.46E+00	0.3%	3.29E-02	102.2%
9.4t-truck	1.43E-01	233,888 tkm	0.016%	5.50E+00	1.6%	46 tkm	6.58E+00	1.3%	-1.08E+00	83.6%
10.10t-truck	1.21E-01	1,530,000 tkm	0.016%	3.04E+01	8.8%	245 tkm	2.96E+01	5.9%	7.99E-01	102.7%
11.Van for sales	3.19E-01	9,000 tkm	0.016%	4.72E-01	0.1%	9 tkm	2.87E+00	0.6%	-2.40E+00	16.4%
12.Employee commuting	3.19E-01	17,500 tkm	0.016%	9.18E-01	0.3%	8 tkm	2.55E+00	0.5%	-1.63E+00	36.0%
11.Landfill	3.49E-03	175,680 kg*1	0.016%	1.01E-01	0.0%	28 kg*1	9.77E-02	0.0%	3.10E-03	103.2%
			Total CO_2e:	3.47E+02		Total CO_2e:	5.01E+02		-1.54E+02	69.2%

Reference(CO_2e): JEMAI "Simple LCA"



*1: Weight of products × Landfill ratio(12.2%)

Figure 7.9 Comparison of allocation and cumulative method in CO_2e emission (10,000 copies)

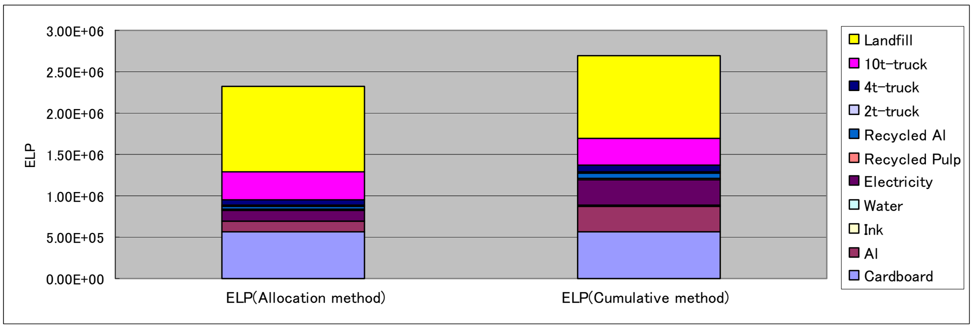
By changing number of copies from 100,000 to 10,000, the relationship balance between allocation method and cumulative method is completely changed. The figure by allocation method is higher than cumulative method when producing 100,000 copies, but it is not when producing 10,000 copies.

For medium run production by the scale of CO_2e emission, allocation method is around two thirds compare to cumulative method; it is totally opposite result of long run production. It is expected that allocation method is higher since it should include the load from back-office division which is additional factor to production. Electricity is a major factor and has impact over 70% of total difference, but not as much as long run production.

For ELP comparison, the result is more or less the same as CO_2e emission, but the ratio of increase from allocation method to cumulative method is around 15%, it is exact half of CO_2e emission. It is indicated in Figure 7.10.

Process	ELF	Input(corporate)	Allocated percentage	ELP (Allocation)		Input(products)	ELP (Cumulative)		⊿	%
1.Cardboard	1.92E+03	1,800,000 kg	0.016%	5.70E+05	24.5%	296 kg	5.70E+05	20.9%	0.00E+00	100.0%
2.Al	9.86E+04	7,500 kg	0.016%	1.22E+05	5.2%	3 kg	2.96E+05	10.9%	−1.74E+05	41.1%
3.Ink(Polyurethane)	1.15E+04	5,000 kg	0.016%	9.47E+03	0.4%	2 kg	2.30E+04	0.8%	−1.36E+04	41.1%
4.Water	1.59E−01	850,000 kg	0.016%	2.23E+01	0.0%	6 kg	9.56E−01	0.0%	2.13E+01	2329.6%
5.Electricity	6.49E+02	1,200,000 kWh	0.016%	1.28E+05	5.5%	461 kWh	2.99E+05	11.0%	−1.71E+05	42.8%
6.Recycled Pulp	2.39E+02	360,000 kg	0.016%	1.41E+04	0.6%	68 kg	1.62E+04	0.6%	−2.10E+03	87.1%
7.Recycled Al	2.43E+04	7,500 kg	0.016%	2.99E+04	1.3%	3 kg	7.28E+04	2.7%	−4.28E+04	41.1%
8.2t−truck	1.77E+03	43,525 tkm	0.016%	1.27E+04	0.5%	7 tkm	1.24E+04	0.5%	2.79E+02	102.2%
9.4t−truck	1.61E+03	233,888 tkm	0.016%	6.19E+04	2.7%	46 tkm	7.40E+04	2.7%	−1.21E+04	83.6%
10.10t−truck	1.36E+03	1,530,000 tkm	0.016%	3.43E+05	14.7%	245 tkm	3.34E+05	12.3%	8.99E+03	102.7%
11.Van for sales	1.66E+03	9,000 tkm	0.016%	2.46E+03	0.1%	9 tkm	1.49E+04	0.5%	−1.25E+04	16.4%
12.Employee commuting	1.66E+03	17,500 tkm	0.016%	4.78E+03	0.2%	8 tkm	1.33E+04	0.5%	−8.50E+03	36.0%
11.Landfill	3.56E+04	175,680 kg*1	0.016%	1.03E+06	44.2%	28 kg*1	9.98E+05	36.6%	3.17E+04	103.2%
			Total ELP:	2.33E+06		Total ELP:	2.72E+06		−3.96E+05	85.5%

Reference(ELP): Nagata Laboratory at Waseda University



*1: Weight of products × Landfill ratio(12.2%)

Figure 7.10 Comparison of allocation and cumulative method in ELP (10,000 copies)

7.4.5 Comparison of allocation and cumulative method for short run

For order placement of normal job, 1,000 copies job is minimum one when considering cost performance of normal offset printing. It is defined as short run job for this case study.

When producing 1,000 packages, CO_2e emission by allocation method is around one third of cumulative method. It shows exact the same trend as medium run job, namely over 70% of the difference of increase comes from electricity.

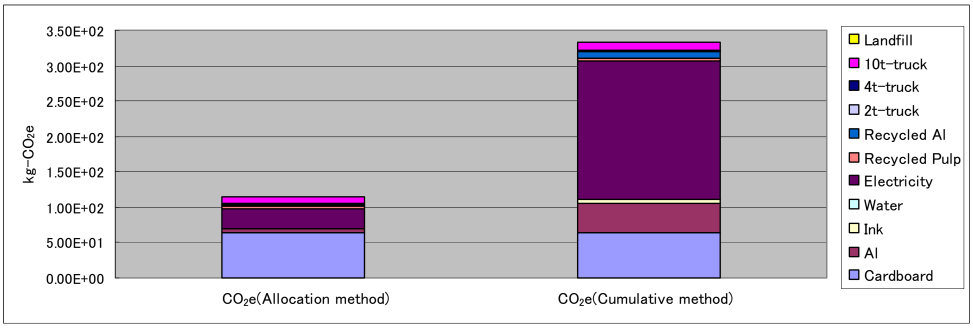
For long run job, when producing 100,000 copies, the ratio of the load from paper is over 60%, but dropped to less than 20% here for short run job. It is not major factor to influence overall load, so allocated by usage amount of paper is not appropriate for short run job. For this specific job, the load from electricity occupies almost 60% of total load; therefore linchpin of allocation should be electricity instead of paper.

For ELP comparison, the trend of final result is the same as CO_2e emission, but the ratio of the difference is much less, it is about 40% of the total. Electricity and Al are two major factors to lower the result from cumulative method and have even influence on the result.

Both comparisons of CO_2e emission and ELP for short run job are summarized in Figure 7.11 and 7.12 respectively.

Process	CO_2e	Input(corporate)	Allocated percentage	CO_2e (Allocation)		Input(products)	CO_2e (Cumulative)		⊿	%
1.Cardboard	6.37E-01	1,800,000 kg	0.006%	6.31E+01	54.4%	99 kg	6.31E+01	18.9%	0.00E+00	100.0%
2.Al	1.43E+01	7,500 kg	0.006%	5.90E+00	5.1%	3 kg	4.29E+01	12.8%	-3.70E+01	13.8%
3.Ink(Polyurethane)	4.53E+00	5,000 kg	0.006%	1.25E+00	1.1%	1 kg	4.53E+00	1.4%	-3.28E+00	27.5%
4.Water	1.97E-04	850,000 kg	0.006%	9.21E-03	0.0%	2 kg	3.94E-04	0.0%	8.82E-03	2337.5%
5.Electricity	4.26E-01	1,200,000 kWh	0.006%	2.81E+01	24.2%	460 kWh	1.96E+02	58.6%	-1.68E+02	14.3%
6.Recycled Pulp	1.67E-01	360,000 kg	0.006%	3.31E+00	2.9%	23 kg	3.84E+00	1.1%	-5.34E-01	86.1%
7.Recycled Al	3.16E+00	7,500 kg	0.006%	1.30E+00	1.1%	3 kg	9.48E+00	2.8%	-8.18E+00	13.8%
8.2t-truck	2.09E-01	43,525 tkm	0.006%	5.00E-01	0.4%	2 tkm	4.18E-01	0.1%	8.23E-02	119.7%
9.4t-truck	1.43E-01	233,888 tkm	0.006%	1.84E+00	1.6%	16 tkm	2.29E+00	0.7%	-4.48E-01	80.4%
10.10t-truck	1.21E-01	1,530,000 tkm	0.006%	1.02E+01	8.8%	82 tkm	9.92E+00	3.0%	2.60E-01	102.6%
11.Van for sales	3.19E-01	9,000 tkm	0.006%	1.58E-01	0.1%	2 tkm	6.38E-01	0.2%	-4.80E-01	24.8%
12.Employee commuting	3.19E-01	17,500 tkm	0.006%	3.07E-01	0.3%	4 tkm	1.28E+00	0.4%	-9.69E-01	24.1%
11.Landfill	3.49E-03	175,680 kg*1	0.006%	3.37E-02	0.0%	9 kg*1	3.14E-02	0.0%	2.31E-03	107.4%
			Total CO_2e:	1.16E+02		Total CO_2e:	3.34E+02		-2.18E+02	34.7%

Reference(CO_2e): JEMAI "Simple LCA"

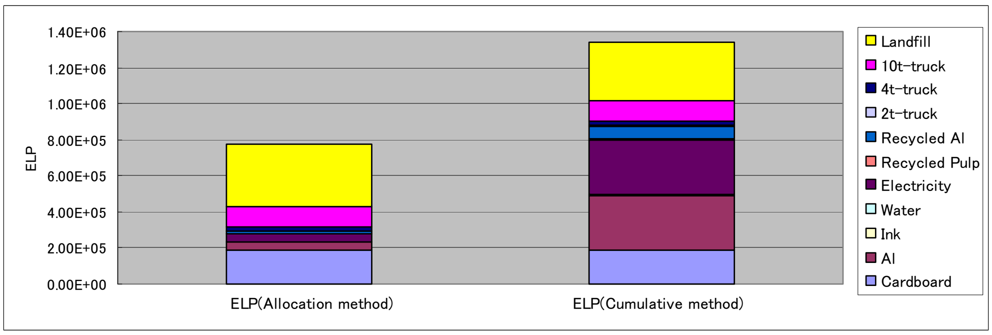


*1: Weight of products × Landfill ratio(12.2%)

Figure 7.11 Comparison of allocation and cumulative method in CO_2e emission (1,000 copies)

Process	ELF	Input(corporate)	Allocated percentage	ELP (Allocation)		Input(products)	ELP (Cumulative)		⊿	%
1.Cardboard	1.92E+03	1,800,000 kg	0.006%	1.90E+05	24.5%	99 kg	1.90E+05	14.1%	0.00E+00	100.0%
2.Al	9.86E+04	7,500 kg	0.006%	4.07E+04	5.2%	3 kg	2.96E+05	22.0%	-2.55E+05	13.8%
3.Ink(Polyurethane)	1.15E+04	5,000 kg	0.006%	3.17E+03	0.4%	1 kg	1.15E+04	0.9%	-8.35E+03	27.5%
4.Water	1.59E-01	850,000 kg	0.006%	7.45E+00	0.0%	2 kg	3.19E-01	0.0%	7.13E+00	2337.5%
5.Electricity	6.49E+02	1,200,000 kWh	0.006%	4.28E+04	5.5%	460 kWh	2.99E+05	22.2%	-2.56E+05	14.3%
6.Recycled Pulp	2.39E+02	360,000 kg	0.006%	4.73E+03	0.6%	23 kg	5.49E+03	0.4%	-7.64E+02	86.1%
7.Recycled Al	2.43E+04	7,500 kg	0.006%	1.00E+04	1.3%	3 kg	7.28E+04	5.4%	-6.28E+04	13.8%
8.2t-truck	1.77E+03	43,525 tkm	0.006%	4.25E+03	0.5%	2 tkm	3.55E+03	0.3%	6.99E+02	119.7%
9.4t-truck	1.61E+03	233,888 tkm	0.006%	2.07E+04	2.7%	16 tkm	2.58E+04	1.9%	-5.05E+03	80.4%
10.10t-truck	1.36E+03	1,530,000 tkm	0.006%	1.15E+05	14.7%	82 tkm	1.12E+05	8.3%	2.93E+03	102.6%
11.Van for sales	1.66E+03	9,000 tkm	0.006%	8.22E+02	0.1%	2 tkm	3.32E+03	0.2%	-2.50E+03	24.8%
12.Employee commuting	1.66E+03	17,500 tkm	0.006%	1.60E+03	0.2%	4 tkm	6.64E+03	0.5%	-5.04E+03	24.1%
11.Landfill	3.56E+04	175,680 kg*1	0.006%	3.44E+05	44.2%	9 kg*1	3.21E+05	23.8%	2.36E+04	107.4%
			Total ELP:	7.78E+05		Total ELP:	1.35E+06		-5.68E+05	57.8%

Reference(ELP): Nagata Laboratory at Waseda University



*1: Weight of products × Landfill ratio(12.2%)

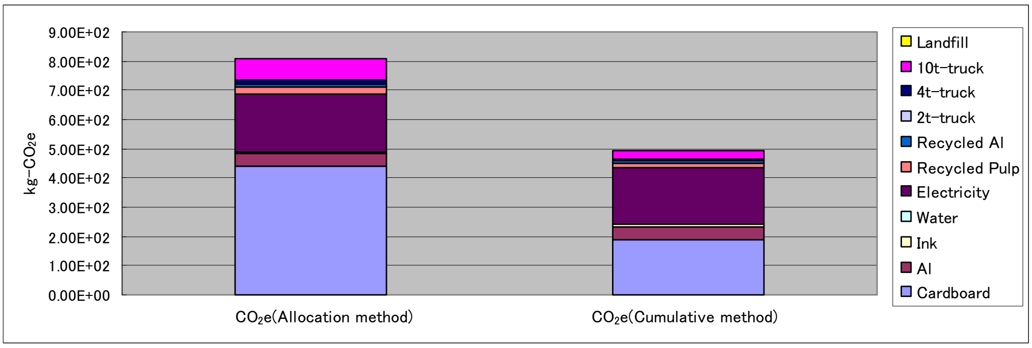
Figure 7.12 Comparison of allocation and cumulative method in ELP (1,000 copies)

7.4.6 Changing of allocation method from paper basis to electricity basis

All calculations for CO_2e emission and ELP are based on usage amount of paper, so change it to be based on usage amount of electricity. New calculation result for medium run for CO_2e emission is shown in Figure 7.13.

Process	CO_2e	Input(corporate)	Allocated percentage	CO_2e (Allocation)		Input(products)	CO_2e (Cumulative)		⊿	%
1.Cardboard	6.37E−01	1,800,000 kg	0.038%	4.40E+02	54.4%	296 kg	1.89E+02	37.6%	2.52E+02	233.6%
2.Al	1.43E+01	7,500 kg	0.038%	4.12E+01	5.1%	3 kg	4.29E+01	8.6%	−1.70E+00	96.0%
3.Ink(Polyurethane)	4.53E+00	5,000 kg	0.038%	8.70E+00	1.1%	2 kg	9.06E+00	1.8%	−3.59E−01	96.0%
4.Water	1.97E−04	850,000 kg	0.038%	6.43E−02	0.0%	6 kg	1.18E−03	0.0%	6.31E−02	5442.4%
5.Electricity	4.26E−01	1,200,000 kWh	0.038%	1.96E+02	24.2%	461 kWh	1.96E+02	39.2%	0.00E+00	100.0%
6.Recycled Pulp	1.67E−01	360,000 kg	0.038%	2.31E+01	2.9%	68 kg	1.14E+01	2.3%	1.17E+01	203.4%
7.Recycled Al	3.16E+00	7,500 kg	0.038%	9.10E+00	1.1%	3 kg	9.48E+00	1.9%	−3.75E−01	96.0%
8.2t−truck	2.09E−01	43,525 tkm	0.038%	3.49E+00	0.4%	7 tkm	1.46E+00	0.3%	2.03E+00	238.9%
9.4t−truck	1.43E−01	233,888 tkm	0.038%	1.28E+01	1.6%	46 tkm	6.58E+00	1.3%	6.27E+00	195.3%
10.10t−truck	1.21E−01	1,530,000 tkm	0.038%	7.11E+01	8.8%	245 tkm	2.96E+01	5.9%	4.15E+01	239.9%
11.Van for sales	3.19E−01	9,000 tkm	0.038%	1.10E+00	0.1%	9 tkm	2.87E+00	0.6%	−1.77E+00	38.4%
12.Employee commuting	3.19E−01	17,500 tkm	0.038%	2.14E+00	0.3%	8 tkm	2.55E+00	0.5%	−4.07E−01	84.0%
11.Landfill	3.49E−03	175,680 kg*1	0.038%	2.36E−01	0.0%	28 kg*1	9.77E−02	0.0%	1.38E−01	241.0%
			Total CO_2e:	8.10E+02		Total CO_2e:	5.01E+02		3.09E+02	161.7%

Reference(CO_2e): JEMAI "Simple LCA"



*1: Weight of products × Landfill ratio(12.2%)

Figure 7.13 Comparison of two methods based on electricity in CO_2e emission (10,000 copies)

In contrast with paper based allocation method, the figure by electricity based allocation method is higher than cumulative method and is the same as the result from long run job.

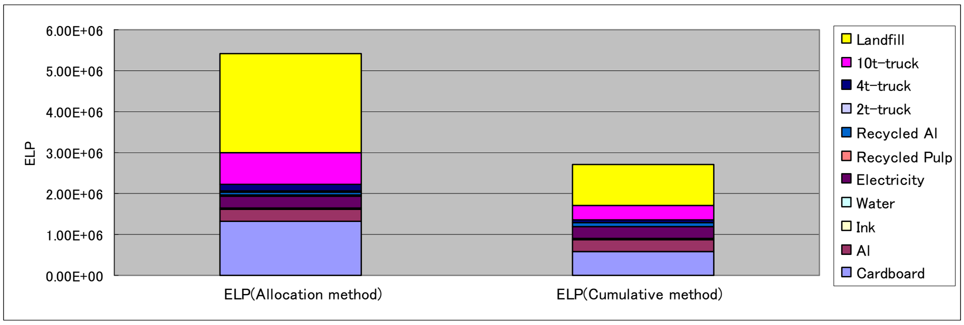
Allocated percentage based on paper is 0.016% compared to annual usage, but jumped up to 0.038% when basis is changed to electricity from paper. The result of CO_2e emission by cumulative method from 10,000 packages production is 501kg-CO_2e, and on the one hand, 810 kg-CO_2e by allocation method. Increased percentage is much higher than long run job of 100,000 packages production.

This is not based on usage amount of paper, so CO_2e emission of paper by allocation method is more than double of cumulative method. Among all materials utilized in printing production, usage amount of paper is the most sharply-defined item since calculation never be complicated not in the same way of ink, water and electricity.

For ELP comparison, the final result is almost exactly double from cumulative method to allocation method and is summarized in Figure 7.14.

Process	ELF	Input(corporate)	Allocated percentage	ELP (Allocation)		Input(products)	ELP (Cumulative)		⊿	%
1.Cardboard	1.92E+03	1,800,000 kg	0.038%	1.33E+06	24.5%	296 kg	5.70E+05	20.9%	7.61E+05	233.6%
2.Al	9.86E+04	7,500 kg	0.038%	2.84E+05	5.2%	3 kg	2.96E+05	10.9%	−1.17E+04	96.0%
3.Ink(Polyurethane)	1.15E+04	5,000 kg	0.038%	2.21E+04	0.4%	2 kg	2.30E+04	0.8%	−9.12E+02	96.0%
4.Water	1.59E−01	850,000 kg	0.038%	5.20E+01	0.0%	6 kg	9.56E−01	0.0%	5.11E+01	5442.4%
5.Electricity	6.49E+02	1,200,000 kWh	0.038%	2.99E+05	5.5%	461 kWh	2.99E+05	11.0%	0.00E+00	100.0%
6.Recycled Pulp	2.39E+02	360,000 kg	0.038%	3.30E+04	0.6%	68 kg	1.62E+04	0.6%	1.68E+04	203.4%
7.Recycled Al	2.43E+04	7,500 kg	0.038%	6.99E+04	1.3%	3 kg	7.28E+04	2.7%	−2.88E+03	96.0%
8.2t-truck	1.77E+03	43,525 tkm	0.038%	2.97E+04	0.5%	7 tkm	1.24E+04	0.5%	1.73E+04	238.9%
9.4t-truck	1.61E+03	233,888 tkm	0.038%	1.45E+05	2.7%	46 tkm	7.40E+04	2.7%	7.06E+04	195.3%
10.10t-truck	1.36E+03	1,530,000 tkm	0.038%	8.00E+05	14.7%	245 tkm	3.34E+05	12.3%	4.67E+05	239.9%
11.Van for sales	1.66E+03	9,000 tkm	0.038%	5.74E+03	0.1%	9 tkm	1.49E+04	0.5%	−9.20E+03	38.4%
12.Employee commuting	1.66E+03	17,500 tkm	0.038%	1.12E+04	0.2%	8 tkm	1.33E+04	0.5%	−2.12E+03	84.0%
11.Landfill	3.56E+04	175,680 kg*1	0.038%	2.40E+06	44.2%	28 kg*1	9.98E+05	36.6%	1.41E+06	241.0%
			Total ELP:	5.44E+06		Total ELP:	2.72E+06		2.71E+06	199.6%

Reference(ELP): Nagata Laboratory at Waseda University



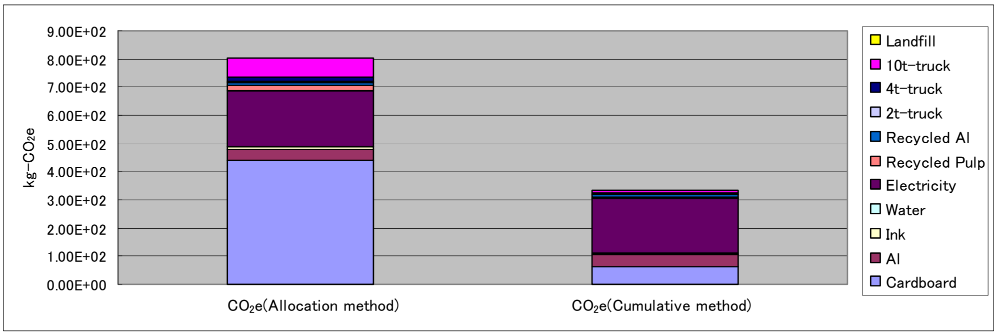
*1: Weight of products × Landfill ratio(12.2%)

Figure 7.14 Comparison of two methods based on electricity in ELP (10,000 copies)

For the results of both CO_2e emission and ELP for Short run jobs are indicated in Figure 7.15 and 7.16, the results are more or less the same as medium run.

Process	CO_2e	Input(corporate)	Allocated percentage	CO_2e (Allocation)		Input(products)	CO_2e (Cumulative)		⊿	%
1.Cardboard	6.37E−01	1,800,000 kg	0.038%	4.40E+02	54.4%	99 kg	6.31E+01	18.9%	3.76E+02	697.0%
2.Al	1.43E+01	7,500 kg	0.038%	4.11E+01	5.1%	3 kg	4.29E+01	12.8%	−1.79E+00	95.8%
3.Ink(Polyurethane)	4.53E+00	5,000 kg	0.038%	8.68E+00	1.1%	1 kg	4.53E+00	1.4%	4.15E+00	191.7%
4.Water	1.97E−04	850,000 kg	0.038%	6.42E−02	0.0%	2 kg	3.94E−04	0.0%	6.38E−02	16291.7%
5.Electricity	4.26E−01	1,200,000 kWh	0.038%	1.96E+02	24.2%	460 kWh	1.96E+02	58.6%	0.00E+00	100.0%
6.Recycled Pulp	1.67E−01	360,000 kg	0.038%	2.30E+01	2.9%	23 kg	3.84E+00	1.1%	1.92E+01	600.0%
7.Recycled Al	3.16E+00	7,500 kg	0.038%	9.09E+00	1.1%	3 kg	9.48E+00	2.8%	−3.95E−01	95.8%
8.2t-truck	2.09E−01	43,525 tkm	0.038%	3.49E+00	0.4%	2 tkm	4.18E−01	0.1%	3.07E+00	834.2%
9.4t-truck	1.43E−01	233,888 tkm	0.038%	1.28E+01	1.6%	16 tkm	2.29E+00	0.7%	1.05E+01	560.4%
10.10t-truck	1.21E−01	1,530,000 tkm	0.038%	7.10E+01	8.8%	82 tkm	9.92E+00	3.0%	6.10E+01	715.2%
11.Van for sales	3.19E−01	9,000 tkm	0.038%	1.10E+00	0.1%	2 tkm	6.38E−01	0.2%	4.63E−01	172.5%
12.Employee commuting	3.19E−01	17,500 tkm	0.038%	2.14E+00	0.3%	4 tkm	1.28E+00	0.4%	8.64E−01	167.7%
11.Landfill	3.49E−03	175,680 kg*1	0.038%	2.35E−01	0.0%	9 kg*1	3.14E−02	0.0%	2.04E−01	748.3%
			Total CO_2e:	8.08E+02		Total CO_2e:	3.34E+02		4.74E+02	241.7%

Reference(CO_2e): JEMAI "Simple LCA"

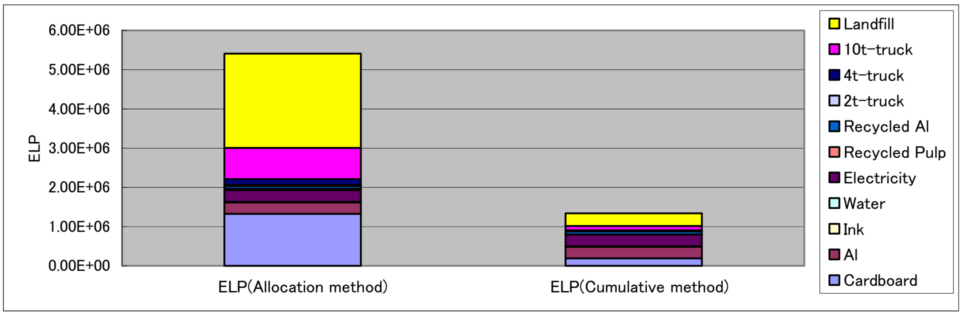


*1: Weight of products × Landfill ratio(12.2%)

Figure 7.15 Comparison of two methods based on electricity in CO_2e emission (1,000 copies)

Process	ELF	Input(corporate)	Allocated percentage	ELP (Allocation)		Input(products)	ELP (Cumulative)		⊿	%
1.Cardboard	1.92E+03	1,800,000 kg	0.038%	1.33E+06	24.5%	99 kg	1.90E+05	14.1%	1.14E+06	697.0%
2.Al	9.86E+04	7,500 kg	0.038%	2.84E+05	5.2%	3 kg	2.96E+05	22.0%	−1.23E+04	95.8%
3.Ink(Polyurethane)	1.15E+04	5,000 kg	0.038%	2.21E+04	0.4%	1 kg	1.15E+04	0.9%	1.06E+04	191.7%
4.Water	1.59E−01	850,000 kg	0.038%	5.19E+01	0.0%	2 kg	3.19E−01	0.0%	5.16E+01	16291.7%
5.Electricity	6.49E+02	1,200,000 kWh	0.038%	2.99E+05	5.5%	460 kWh	2.99E+05	22.2%	0.00E+00	100.0%
6.Recycled Pulp	2.39E+02	360,000 kg	0.038%	3.30E+04	0.6%	23 kg	5.49E+03	0.4%	2.75E+04	600.0%
7.Recycled Al	2.43E+04	7,500 kg	0.038%	6.97E+04	1.3%	3 kg	7.28E+04	5.4%	−3.03E+03	95.8%
8.2t−truck	1.77E+03	43,525 tkm	0.038%	2.96E+04	0.5%	2 tkm	3.55E+03	0.3%	2.61E+04	834.2%
9.4t−truck	1.61E+03	233,888 tkm	0.038%	1.44E+05	2.7%	16 tkm	2.58E+04	1.9%	1.19E+05	560.4%
10.10t−truck	1.36E+03	1,530,000 tkm	0.038%	7.99E+05	14.7%	82 tkm	1.12E+05	8.3%	6.87E+05	715.2%
11.Van for sales	1.66E+03	9,000 tkm	0.038%	5.73E+03	0.1%	2 tkm	3.32E+03	0.2%	2.41E+03	172.5%
12.Employee commuting	1.66E+03	17,500 tkm	0.038%	1.11E+04	0.2%	4 tkm	6.64E+03	0.5%	4.50E+03	167.7%
11.Landfill	3.56E+04	175,680 kg*1	0.038%	2.40E+06	44.2%	9 kg*1	3.21E+05	23.8%	2.08E+06	748.3%
			Total ELP:	5.42E+06		Total ELP:	1.35E+06		4.08E+06	402.8%

Reference(ELP): Nagata Laboratory at Waseda University



*1: Weight of products × Landfill ratio(12.2%)

Figure 7.16 Comparison of two methods based on electricity in ELP (1,000 copies)

Allocation method simply based on electricity results inappropriate figures which are not balanced because of wrong amount of usage of paper compared to actual input.

In order to know dividing point for allocation and cumulative method, CO_2e emission from same case study is indicated by stepwise manner in Figure 7.17.

Copies	Allocation method	Cumulative method	Allocation/ Cumulative
100,000	2,430	2,080	116.8%
80,000	1,960	1,740	112.6%
60,000	1,500	1,390	107.9%
40,000	1,040	973	106.9%
30,000	808	793	101.9%
20,000	577	609	94.7%
10,000	347	430	80.7%

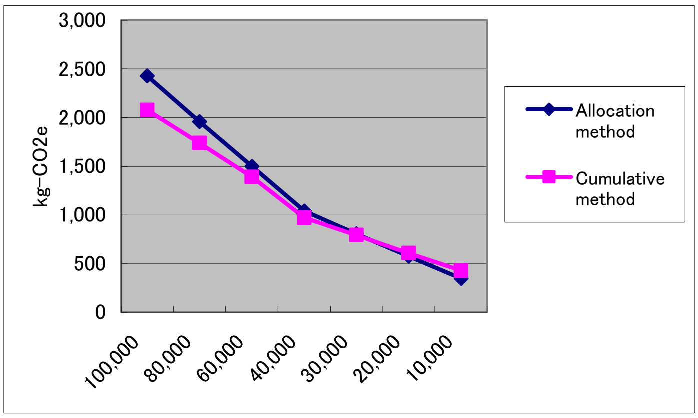


Figure 7.17 Dividing point for allocation method and cumulative method

As described above, CO_2e emissions from allocation method are supposed to be higher than cumulative method, but show inversion phenomenon when producing 30,000 copies of paper packages. No printing companies print same amount of orders constantly, so this analysis concludes that allocation method is not free from defect.

7.5 CONCLUSION

Corporate activity based LCA which is based on allocation method is quite easy to calculate environmental load by inputting some annual key factors such as paper, aluminum, ink, water and transportation. It is thought to help medium-sized printer having a problem about shortage of human resource to calculate environmental load since amount of time required for calculation is much shorter than Product focused LCA which is cumulative method.

Blind side of Corporate activity based LCA is unbalanced looking figure when it is compared with Product focused LCA which is cumulative method for medium run job or short run job though all environmental loads are allocated to every single job at any rate.

Corporate activity based LCA can show organization-focused environmental load and also is supposed to show product focused environmental load based on allocation method by minimum effort of manpower. It has functional role for medium-sized printers to know its overall environmental load in short period of time and by downmanned. But, the case study can come to the conclusion that Corporate activity based LCA could not function effectively for variety kinds of order quantity.

Basing point of allocation method, namely which item should be basis of allocating for entire calculation is a key factor to determine environmental load. For long run job, it is proved that calculation based on amount of paper usage is appropriate, but for short run job, calculation based on electricity usage can represent actual condition. It is obvious that biggest portion of the environmental load should be a basing point, so the ratios of log run jobs and short run jobs are carefully examined to decide which item should be a basing point when considering all jobs by annual organizational activities. It is significant to take the measure to find out a basing point for allocation method by considering proportional ratio for ordering amount which is difficult to be averaged.

When utilizing allocation method, it is reminded that there is a constrained condition to be counted. Allocation basis is normally calculated by the ratio of paper usage amount, but it cannot correctly adopt for short-run job as shown in this chapter. Then, another allocation basis such as electricity usage is used as basis for short-run job and incorrect figure of paper usage amount is calculated. Usually, paper usage amount is the easiest item to calculate correct amount, so this method does not work for short-run jobs in conclusion. It can work for organization which constantly handle same amount of orders which are nearly long-run jobs.

For taking steps to improve Corporate activity based LCA, the environmental loads from corporate activity and product production should be separated to improve energy efficiency for back-office division and production division individually. Even though persisting in allocation method, still calculating two different aspects separately is important since execution programs to improve energy efficiency in back-office division and modify product design from the view point of environment conscious are totally different ones.

Printing Service LCA is expected to be hassle-free by utilizing allocation method for corporate and product improvements, but it seems that it has its limits and utilization at any level of printing companies might be extremely difficult only when focusing on Product LCA. But, the bottom line is that organization itself should reduce environmental load by accumulating individual product improvement, so ideal approach for an organization may consist of allocation and cumulative methods. For this is what multilateral approach to heighten environment-conscious for an organization by utilizing different methods from the different point of views.

CHAPTER 8

CONCLUSION AND ACHIEVEMENTS

8.1 CONCLUSION OF THE STUDY

This study establishes quantitative assessment method such as $LCCO_2e$ and Integrated LCA for printing related production and develops Printing Service LCA for the first time in Japan. It assumes that Printing Service LCA should take practical utilization into consideration all the time to upgrade daily operational management which can reduce environmental load from multisided points of views.

All of knowledges which are found through tabletop simulations by theoretical concepts, bibliographical survey by patient effort and actual field study at production sites in the study are summarized below.

1. In order to position environmental issue as striking evaluation axis next to price and quality, transition from current qualitative assessment to newly developed quantitative assessment is ardently expected, so Printing Service LCA is desired to be schematized in hurried manner. Carbon emission quantification connecting directly to global warming problem is not only focused, but also Integrated LCA is demanded to be organized to concern about wide range of impact categories. This constructive movement is not limited domestically, is influenced by advanced methods overseas and is tried to be spread out all over Southeast Asia. The bottom line is that Printing Service LCA can boost up Eco-design supported by real numerical numbers, not by sensuous method.
2. Printing Services in advanced countries are losing traction because of radical media shift from analog to digital. On another front, the ones in emerging countries such as China and Brazil are showing dynamic growth. Emerging countries will trace the tracks of advanced countries without questions, so they should develop their own strategies to move away from current business models to value-added business models emphasizing environment conscious in analog printing field. In Japanese printing market, most of printers are relatively small compared with other manufacturing sectors, so they have to rethink their strategies and tactics not from the viewpoint of hardware side but from software side since they are not heavily funded. Environment conscious strategy and tactics should be mapped out especially in Printing Service requiring paper usage.
3. Qualitative assessment which is sensuous assessment method without tangible proof is utilized as main scale for eco-friendly printing. But, many of print buyers are not satisfied because they cannot see environmental improvement by actual figures. Currently, Printing Service LCA is schematized, so can show environmental improvement by showing calculated environmental load by real figures. Visualization of environmental load of purchased materials, production processes and disposal/recycle can make modifications on environmental problems for better.
4. Establishment of Printing Service LCA can act upon reduction of environmental load

directly by visualization of the load and change materials/processes based on Eco-design concept. It also can work for CFP leading people to low-carbon life style and Carbon Offsetting compensating carbon emissions, which are indirect methods to reduce the load.

5. Printing Service LCA can take notice of environmental factor only, but paying attention to economical factor which is influenced by Life cycle costing can propose cost cut approach from the standpoint of environmental load reduction. It is not plain price discount, but multiple recommendations which can accomplish cut of the price and environmental load at the same time.
6. Environmental load reduction scaled by carbon emission always propose paper usage reduction, but it is impossible when aforementioned printed matters cannot be shifted to digital media, namely can work out only by paper usage. Various kinds of Integrated LCA methods are compared in terms of their strength and limitation to be selected for Printing Service, and finally ELP is selected to be the best choice because it can cover broad area of impact categories in a balanced manner and can focus on NOx and SOx which are influential factors for Printing Service.
7. Printing Service LCA should be verified in practical use to know whether it can provide benefit or not. There are two cases to be studied; one is upgrading recycle rate by easy dismantled structural design for Package Printing Service, the other one is complete media change by shifting to electronic book from physical book for Information Printing Service. ELP can show that Eco-design based on easy dismantled structure can make packages easier to be recycled and is expected to reduce overall environmental load substantially. $LCCO_2e$ can show that comparing physical book with electronic book is not simple issue because there are many estimations and unknowns in calculation, contrary to all expectations which assumes the load for E-book is much less. Especially, allocated calculation for electronic device is not simple since how much of time is consumed for book reading only. It cannot be estimated correctly without extensive survey. For both of Packaging Printing Service and Information Printing Service, detailed cost performance comparison is conducted to elicit cost cut possibility when environmental load is successfully reduced at satisfactory level. Analysis for environmental factor and the one for economical factor should be conducted as one set of analysis.
8. Printing Service LCA can be transitioned and localized in emerging countries in Southeast Asia without any obstacles. Printing process is slightly different when comparing advanced country with emerging countries, but collection of primary data in production site and substitution of secondary data helped by database in advanced country are transformed to apply local manners without problems. It is not difficult for Printing Service LCA to be localized though secondary data is not well organized in the specific countries.
9. It is quite general for emerging country to work on Printing Service LCA because of

urgent respond to CFP by request from print buyers. In order to know recognition degree of CFP, small group survey is conducted to find out the way to understand relation nature between demographic data and questionnaires. Tangible result cannot be found unfortunately, but practical method can be proposed as statistical approach.

10. Integrated LCA is considered as important approach because focusing only on carbon emission is skeptical even in emerging countries. ELP can be organized based on category importance by local people and local consumption/emission data, so fixed as localized version without spending long time survey when local consumption/emission data is limited to necessary data for item’s inventory data. ELP can be mainly utilized for comparisons by different interest groups in different countries. From now on, comprehensive explanations about calculation processes and results of ELP are very challenging issues to be spread out.
11. Printing Service LCA is generally based on Product LCA relying on cumulative method domestically, but it is mainly based on Corporate activity based LCA influenced by The GHG Protocol Initiative in Europe. Corporate activity based LCA, namely allocation method is thought to have number of advantages, such as quick calculation by allocating all of annual input/output based on paper weight allocated percentage and unnecessary employment of excess personnel for extra calculation task. Additionally, it is thought to allocate the load in correct manner without slipping over or double accounting. But, it looks inferior compared with cumulative method since it has fatal condition which shows the limitation of order quantity. It means that calculated results from allocation method by different quantities sometimes show illogical figures. For example, when order is more than 40,000 of paper packages, the result looks logical, but it does not when order is less than that amount for packaging production. Allocation method should show higher environmental load since it includes the loads from entire organization, but it does not when order quantity is less than certain amount.
12. The basis for allocation method is thought to be carefully examined since highest proportion of material purchase or production process should be selected as allocated percentage standard to fit reality. But, when the basis is changed from paper to other items, then paper usage amount will be totally different numbers from real input. Generally, paper usage amount is the item to be grasped easily and the most important figure to be evaluated among all materials since it has biggest impact for entire environmental impact for Printing Service. So on that point, allocation method cannot be calculation standard for any size of printing companies because no printing companies produce only same amount of orders.

Printing Service LCA supported by two pillars which are LCCO_2e and Integrated LCA can encourage Eco-design to reduce environmental load and production cost at the same time through tabletop exercise and practical product rollout. Additionally, it has great possibility to assist Carbon Footprinting and Carbon Offsetting which are considered as marketing tools.

Printing Service LCA which has multilateral viewpoints can perform to improve product performance for internal purpose and boost up sales volume for external purpose.

8.2 ACTUAL ACHIEVEMENT AT OUR ORGANIZATION

Eco-design concept was established to eliminate dissociation between manufacturing and environment conservation at the beginning of the twentieth century. Rapid economical growth speeds up ecological destruction in the latter half of a century, and then many tried to schematize Eco-design concept for research and development of various kinds of products.

Natural resource saving, energy saving, recycled material usage, product recycle and longer operating life are necessary items to be considered when working on Eco-design in a general way, but focused points differ by product types.

It is impossible for Printing Service to be shifted to digital media completely, so abatement effort should be made to reduce environmental load for paper-based printed matters. In order to carry out the will of environmental load reduction, Eco-design should be promoted to set out environment-friendly printed matters by the support of Printing Service LCA.

As long as printing production requires raw material acquisition, material production, printing production, transportation of material/product, and disposal/recycle, environmental load never be zero in whatever we do. Therefore, Printing Service LCA must be utilized to reduce the load much more than the one used to be.

Eco-design concept is summarized in three steps in Figure 8.1.

Figure 8.1 Eco-design concept for Printing Service

This conceptual diagram shows two steps of incremental progress for Eco-design in Printing Service.

First step shows that Material, Method and Machine (3Ms) improvements by qualitative assessment method. For Material, ink has variety kinds of environment conscious inks such as VOC free, vegetable oil based ink, rise ink and so on. Recycled paper has been supported by many print buyers, but the one certified by FSC is newcomer. For Method, waterless printing method is quite popular because of no water usage during printing process, but it has minor impact in terms of environmental load. UV printing is now under the process of being replaced by light-emitting diode (LED), but is still major method covering wide range of substrates to be printed. For Machines, long press which has many printing units and the press with perfecting unit which can print both sides of paper at one time can shorten production time drastically, so electricity usage is expected to be reduced extensively.

All improvements on Material, Method and Machine are based on qualitative assessment which cannot compare current choice with newly selected choice by actual figures. For example, vegetable oil based ink is usually produced by small-quantity production, so the load from production is supposed to be higher than normal ink by large-quantity production. So on that point, prevailing concept believed by people’s feeling is sometimes neither accurate nor dependable. For this reason, quantitative assessment method is thought to be required inevitably.

Second step indicates that four ways of quantification methods are necessary based on life cycle concept. For $LCCO_2e$, it is recognized as vastly familiarized method since it does not take time to evaluate environmental load by the assist of well organized CO_2e emission factors by many different industries. It means that materials and processes which need to be changed or improved are easily found to be fixed by $LCCO_2e$ evaluation. For Integrated LCA, it is quite important to support continual improvements when $LCCO_2e$ cannot provide any proposal by only one viewpoint. It works as supplementary evaluation method to provide different types of ideas for improvements and changeovers. This study shows that Packaging Printing Service cannot have complete confidence in $LCCO_2e$ because it always concludes paper reduction is priority though paper media cannot be replaced by digital media for packaging production. On the other hand, ELP representing Integrated LCA through this study can propose changing structural design to promote easy-dismantled package design for recycling and reducing final disposal. ELP can fill the gap between $LCCO_2e$ evaluation and possible improvements in practice by multilateral viewpoints. For Life cycle costing, it is only one thing which does not relate to environmental issues in direct way. It is essential truth that most of print buyers heavily focus on cost performance, so focusing not only on environmental factors but also on economical factor is unavoidable reality aspect. Cost driving factor is usually linked with high environmental load, so reducing the load usually results certain amount of cost cut at the same time.

Future approach can point that showcasing actual figures of environmental load to outside should be conducted because utilizing LCA results which was calculated by many people's efforts should be fully utilized not only for internal use such as material changeover and process improvement for final product. For Carbon Footprinting, it has now a couple of different types of labels. Labels used to show only actual figure for product, but it could be changed to showing only reduction percentage from previous product or just logo itself. Some print buyers are reluctant to show actual figures on alert against competitor's advantageous movements. It is originally designed to reduce environmental load by motivating consumers to pay attention to CO_2e emission. This is experimental trial in real market to know if it works to lead consumers to low-carbon product choice or not. In order to know a result from the market, causal connection between Carbon Footprinting and consumer's choices should be validated in statistical way in the future. For Carbon Offsetting, it is different from Carbon Footprinting in the viewpoints of actual condition. Carbon Offsetting also allows products to show actual figures of environmental load same as Carbon Footprinting, but the load is compensated by funding CO_2e reduction projects approved mostly by United Nation's guidelines. It can contribute CO_2e reduction in tangible way and might be able to change consumer's choices to purchase low-carbon products in intangible way. It is higher in rank compared with Carbon Footprinting and costs to compensate CO_2e emission to get emission credit.

For other eco-labels, Integrated LCA should be translated for consumers in comprehensive way. Many people know that CO_2e emission is not only concerned matter, other environmental influences should be equally evaluated in some way. But, it is very difficult to describe about many different kinds of environmental influences at first. Integrated figure calculated by ELP is not comprehensive because of its unfamiliarity and complexity. Showing Integrated LCA indicators are not comprehensive, but showing them by comparing two different numerical numbers, such as before-and-after case studies, can send understandable messages directly to consumers. Explanation of Integrated LCA in an easily understood manner is expected for many people to grasp the essentials of wide range of environmental load by taking one look at eco labels.

Eco-design can be promoted to improve current printed matters and develop newly created printed matters for overall Printing Service in a stepwise fashion.

8.3 ACTUAL ACHIEVEMENT IN PRINTING INDUSTRY

Printing Service LCA started as LCCO_2e analysis at first in Japan since many people including consumers can understand about greenhouse gas emission which is linked with global warming problem receiving a high degree of media coverage. Shimizu Printing developed CO_2e calculator named “Printing Goes Green (PGG)” and launched for some of printing jobs combined with Carbon Offsetting services.

PGG is now open to members of Japan Waterless Printing Association (JWPA) with free of charge for spread enlightenment to validate the effectiveness of Printing Service LCA as demonstration experiment. JWPA organizes coursework consisting of four-time lectures regarding basic knowledge of LCA and actual operation of PGG. After completing the coursework, each printer is qualified to utilize PGG by themselves. Now, almost 50 printers are core members to use PGG.

PGG core members of JWPA also provide Carbon Offsetting service for their clients after calculating CO_2e emission by PGG. Its scheme is visualized in Figure 8.2.

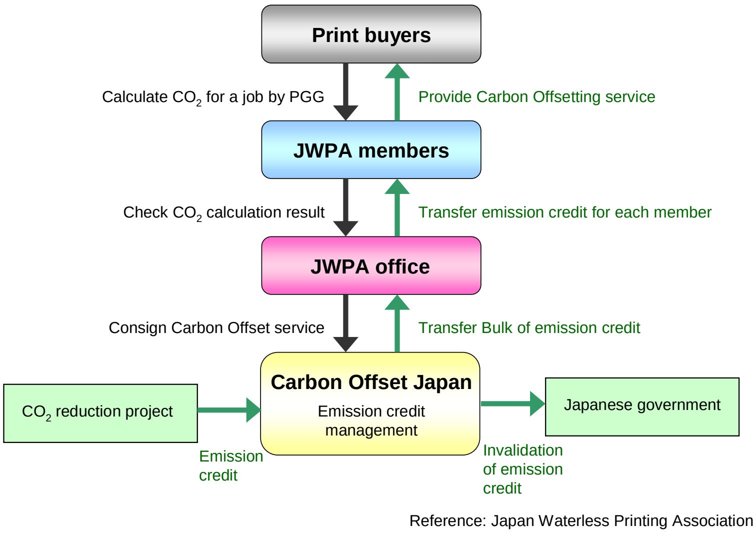


Figure 8.2 Carbon offsetting scheme by JWPA and Carbon Offset Japan (COJ)

JWPA office purchases emission credits in bulk to transfer those to members working on CO_2e emission calculation and Carbon Offsetting service. This scheme already compensates over 1,200 tones of emission credits in 32-months by PGG users at JWPA.

PGG has been utilized for almost two years, so need modification on calculation logic as the time advances. It is upgraded in the third quarter of 2011 as cloud computing software named “PGG CLOUD” to offer better service. Its advantages are summarized in Figure 8.3.

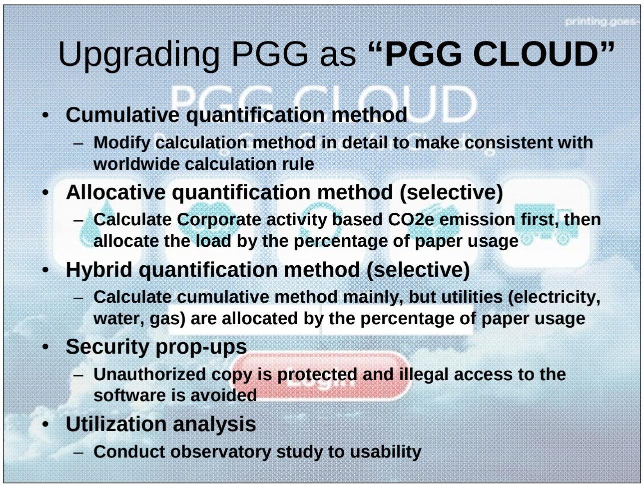


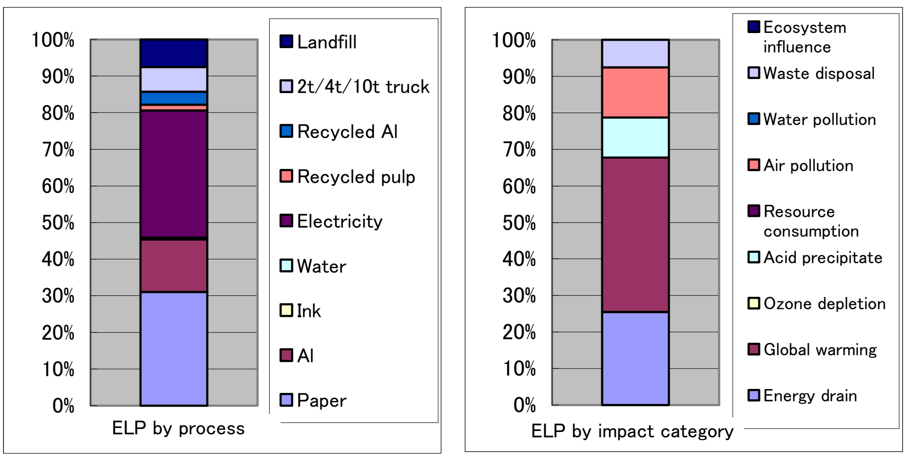
Figure 8.3 Advantages of PGG CLOUD

PGG CLOUD will be utilized by JWPA core members continuously with Carbon Offsetting service ongoingly and fast-forward printers in Thailand and Malaysia who also try to get better performance out of newly developed software.

Many printers in Japan and Southeast Asia are trying to make the fullest possible use of $LCCO_2e$ calculation already. On the other hand, it is a lot more difficult for printers to step up to Integrated LCA method, so different way of presenting data is suggested to be utilized more than actual state. It is proposed by Figure 8.4.

Calc.−1_ELP by Process (TH)			Calc.−2_ELP by impact category (TH)		
Process	ELP(AHP=Printer)		Impact category	ELP(AHP=Printer)	
1. Paper	4.73E+06	31.1%	1. Energy drain	3.88E+06	25.5%
2. Al	2.18E+06	14.3%	2. Global warming	6.43E+06	42.2%
3. Ink(Polyurethane)	6.07E+04	0.4%	3. Ozone depletion	0.00E+00	0.0%
4. Water	2.06E+03	0.0%	4. Acid precipitate	1.67E+06	11.0%
5. Electricity	5.29E+06	34.8%	5. Resource consumption	0.00E+00	0.0%
6. Recycled pulp	2.35E+05	1.5%	6. Air pollution	2.09E+06	13.7%
7. Recycled Al	5.44E+05	3.6%	7. Ocean & water pollution	0.00E+00	0.0%
8. 2t/4t/10t truck	1.02E+06	6.7%	8. Waste disposal	1.15E+06	7.6%
9. Landfill	1.15E+06	7.6%	9. Ecosystem influence	0.00E+00	0.0%
Total ELP:	1.52E+07			1.52E+07	

Reference: Nagata Laboratory at Waseda University



*1: Weight of products*Landfill ratio(12.2%)

Figure 8.4 ELP breakout by processes (left) and impact categories (right)

ELP calculation above is based on category importance by Thai printers and textbook production (500 copies) at CU cited in Chapter 6.

ELP by different processes is usually indicated to pinpoint which process has highest environmental load and should be improved to reduce the load in previous chapter, but ELP by different impact categories are shown here to be compared.

For instance, Electricity and Energy drain are mutually related closely since fossil fuels are used to generate electricity. So, it is highly important to work on improvements which can reduce electricity usage, namely squeeze operating hours of production facilities to reduce the load for Energy drain. It is easily pictured when looking at inventory data of a process.

Two different scales assist an estimator to have different points of views to comprehend essential points of ELP analysis. As a result of new way of evaluation, targets are modified and altered to be refined.

In the days ahead, $LCCO_2e$ will be able to spread out with Carbon Offsetting service, but not with Carbon Footprinting because of its complex nature of calculation scheme and bothersome application procedure here in Japan. ELP might be reshaped to be easily understandable scheme to explain the meaning of evaluation by processes or by impact categories. Only LCA professional can understand Integrated LCA method, but it should come with the twist for many of common consumers to have ideas what it means and how it is utilized to improve current environmental load.

8.4 ACTUAL ACHIEVEMENT IN EMERGING COUNTRIES

There are so many application forms for CFP in Thailand right now, so limited number of examiners cannot handle all of them in short time. Chulalongkorn University (CU) makes no effort to hide its gloom when knowing this situation, so decided to launch go-it-alone Carbon Footprinting logo which is only for Printing Service and called “Eco-Print logo”. Government related institution which is a certification body approves and supports CU’s idea. CU will prepare validation scheme and operation for Eco-Print logo to boost Carbon Footprinting in Thai printing industry. Their first trial of Eco-Print logo is shown in Figure 8.5.

Newsletter from Chulalongkorn Univ. “Eco-Print Logo ” created by Chulalongkorn Univ.

Figure 8.5 Eco-Print Logo created by CU

Some of big printers in Thailand focus mainly on exporting of printed matters ordered by European or American print buyers. They become acutely aware of requests to work on carbon calculations from foreign print buyers, so try to prepare themselves well in advance.

CU has PGG in their hand already and some of students learned about LCA basic concept and actual operation of PGG within a short time. CU is now ready to spread the use of Printing Service LCA across Thai printing industry aiming to go on to a next phase, namely grow out of price-oriented printing production from now on.

In Malaysia, the Nets Group of Companies (NGOC) which consists of creative company/printing company/printing related service company embodies one-stop center for environment conscious printing there. NGOC is definitely at the edge of Malaysian printing industry in terms of environment related printing technology. It has been an ardent supporter of environment-friendly printing methods such as usage of vegetable oil based ink, recycled paper, Forest Stewardship Council (FSC) certified paper, establishing ISO 14001 for whole organizations and so forth.

NGOC has been acting for an environment conscious printer for a decade, but their appeal points were always based on qualitative assessment. Therefore, it started utilizing PGG for their operation in spring of 2011 under one-on-one guidance of Shimizu Printing; it established Printing Service LCA for a short interval of time.

NGOC carried out the planning of open house event to launch “Nets Eco” project and invited a Hon. Minister of Energy, Green Technology and Water to make strong impression externally. During an event, a Hon. Minister’s name card was printed and calculation certificate was handed to Hon. Minister from chairman of NGOC. Photo and calculation sheets are shown in Figure 8.6.

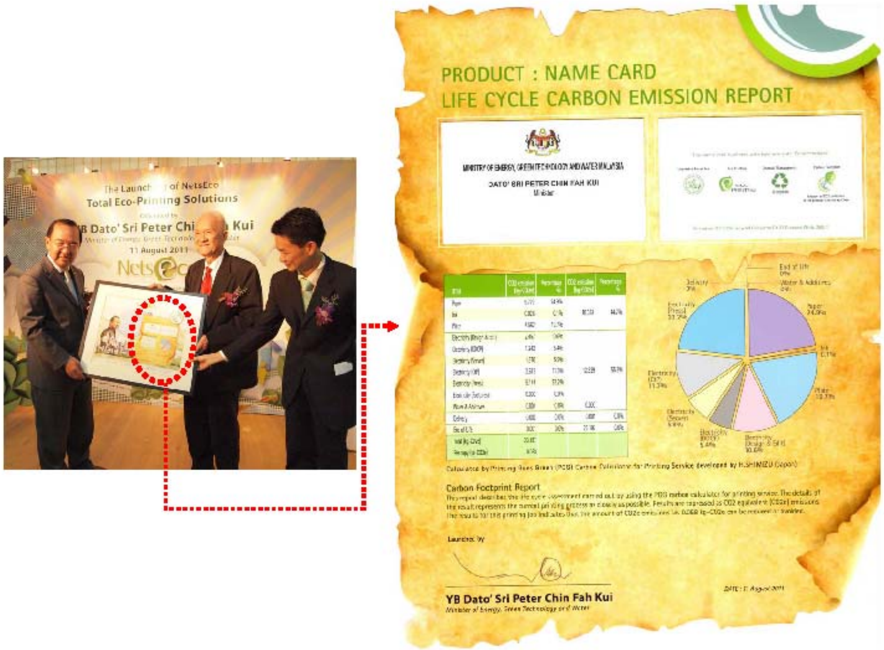


Figure 8.6　CFP of minister’s name card at NGOC executives

NGOC is dissatisfied with Carbon Footprinting only, so grapple with Integrated LCA at the same time. ELP which is already modified for Printing Services in Japan and Thailand is already upgraded for Malaysian printers. Detailed explanation of their trial to localize Printing Service LCA was described in previous chapter. New-wave for Malaysian printing industry can be recognized now.

Appendix A

Questionnaire result from CFP of CU, Printer, Housewife in Thailand

ID# Please do not write here
Your gender: Male/Female Your department:

		Yes	Not really	No
Q1	Do you know CFP?	1	2	3

		Yes	Not really	No
Q2	Have you ever seen CFP logo?	1	2	3

		Yes	Not really	No
Q3	Are you willing to purchase CFP products?	1	2	3

		Yes	if same price	No
Q4	Are you willing to purchase CFP products even though expensive?	1	2	3

		Yes	Not really	No
Q5	Do you think CFP can promote our life move forward to low-carbon?	1	2	3

Thank you very much!

ID	Gender	Age	Ocptn.	Q1	Q2	Q3	Q4	Q5
1	1	24	1	1	1	1	2	1
2	1	29	2	3	3	2	2	1
3	2	29	2	3	3	1	2	1
4	1	24	2	3	3	1	2	1
5	2	24	2	2	3	1	2	1
6	2	25	2	2	2	1	2	2
7	2	28	2	2	3	1	2	1
8	2	24	2	3	3	1	2	1
9	2	22	2	3	2	1	2	2
10	2	20	1	1	3	1	2	1
11	2	21	1	2	1	1	2	1
12	1	25	2	3	2	2	3	1
13	1	23	2	1	1	1	2	2
14	2	20	1	2	3	1	2	1
15	1	20	1	1	2	3	2	1
16	2	30	2	2	2	1	2	1
17	2	21	1	2	3	1	3	1
18	1	20	1	3	3	2	3	1
19	2	21	1	1	1	1	2	2
20	2	24	1	1	1	3	3	2
21	1	25	1	2	3	1	1	1
22	2	26	1	1	3	2	2	1
23	2	23	1	3	2	1	2	1
24	2	26	2	3	2	1	2	1
25	2	19	1	3	3	1	2	1
26	2	20	1	3	3	2	2	1
27	2	19	1	3	3	1	2	1
28	1	20	1	1	3	3	3	2
29	2	25	2	2	3	2	2	2
30	2	23	2	3	3	3	3	1
31	1	27	1	3	3	1	2	1
32	2	26	2	3	3	1	2	1
33	2	23	2	3	3	2	2	2
34	2	24	2	3	3	2	2	2
35	2	26	2	2	2	1	2	1
36	2	23	2	2	1	1	2	1

Gender: Male=1
Female=2

Occupation: Student = 1
Worker = 2

ID	Gender	Age	Ocptn.	Q1	Q2	Q3	Q4	Q5
37	1	26	2	2	2	1	2	1
38	2	34	2	2	2	1	2	1
39	2	29	2	3	3	1	2	1
40	2	23	2	2	2	1	2	1
41	2	31	2	3	3	1	2	1
42	2	29	2	3	3	1	2	1
43	2	28	2	3	3	1	3	1
44	2	29	2	2	2	3	2	1
45	2	25	1	2	3	1	2	2
46	1	24	2	3	3	2	3	1
47	2	34	2	3	2	1	2	1
48	1	26	1	1	3	1	2	1
49	1	22	1	1	1	1	2	2
50	2	29	2	2	2	1	2	1
51	1	25	2	3	3	3	3	3
52	2	24	2	3	3	1	2	1
53	1	28	1		3	1	2	1
54	1	29	2	1	1	2	3	1
55	1	24	2	3	3	2	2	2
56	2	23	2	2	1	1	2	1
57	2	28	2	2	2	2	3	1
58	2	24	2	3	3	1	2	1
59	2	27	2	3	3	2	2	2
60	2	22	2	2	3	1	3	2
61	1	25	2	3	2	1	2	1
62	2	21	1	3	3	2	2	1
63	2	22	1	2	3	2	2	2
64	2	22	1	3	3	1	2	1
65	1	21	1	3	3	2	2	1
66	1	22	1	3	3	1	2	1
67	1	22	1	3	3	1	2	1
68	1	26	1	1	1	1	2	1
69	1	21	1	2	3	1	2	1
70	1	21	1	3	3	1	2	1
71	1	21	1	3	3	2	2	2
72	1	23	1	3	3	2	3	2
73	1	23	1	3	3	2	2	1
74	1	22	1	2	2	2	3	2
75	1	21	1	3	3	1	2	1
76	1	24	1	3	3	1	2	1
77	1	26	2	3	3	2	3	2
78	1	21		1	2	2	3	2
79	1	20	1	3	3	1	2	1
80	2	21	1	3	3	1	2	1
81	2	21	1	3	3	1	2	1
82	1	22	1	3	3	2	2	1
83	1	23	1	3	3	2	2	1
84	1	21	1	3	3	1	2	1

ID	Gender	Age	Ocptn.	Q1	Q2	Q3	Q4	Q5
85	1	23	2	2	3	1	2	1
86	1	23	1	2	3	2	2	2
87	1	21	2	2	3	2	2	2
88	1	19	1	3	3	1	2	1
89	1	20	1	3	3	2	2	2
90	2	24	2	2	2	3	2	1
91	1	23	2	3	3	1	2	1
92	2	21	1	3	3	2	2	2
93	1	20	1	3	3	1	2	1
94	1	22	1	2	3	2	2	2
95	2	20	1	3	3	1	2	1
96	1	22	2	1	1	2	2	2
97	1	19	1	3	3	1	2	1
98	1	24	1	1	2	1	2	1
99	1	19	1	3	3	2	2	2
100	1	19	1	3	3	2	2	2

Appendix B

AHP result for CU/Printer/Housewife in Thailand, Printer in Japan, Printer in Malaysia

AHP result of Thai Printers (members of Thai Printing Association)

	Gender	Occupation	1.Energy drain	2.Global warming	3.Ozone depletion	4.Acid precipitate	5.Resource consumption	6.Air pollution	7.Ocean & water pollution	8.Problem of waste disposal	9.Ecosystem effect
1	Male	Working	0.043	0.219	0.242	0.193	0.043	0.089	0.089	0.023	0.058
2	Female	Student	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
3	Female	Working	0.096	0.122	0.197	0.063	0.250	0.042	0.042	0.023	0.165
4	Female	Working	0.204	0.204	0.204	0.100	0.143	0.058	0.041	0.026	0.019
5	Female	Working	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
6	Male	Working	0.023	0.153	0.046	0.161	0.158	0.144	0.113	0.135	0.067
7	Female	Working	0.024	0.156	0.299	0.076	0.059	0.153	0.069	0.057	0.105
8	Male	Working	0.227	0.045	0.087	0.092	0.242	0.104	0.081	0.031	0.092
9	Female	Working	0.083	0.119	0.083	0.073	0.152	0.093	0.152	0.073	0.172
10	Male	Student	0.015	0.151	0.160	0.108	0.373	0.043	0.049	0.051	0.049
11	Male	Student	0.015	0.032	0.041	0.156	0.305	0.158	0.140	0.052	0.102
12	Male	Student	0.015	0.032	0.041	0.156	0.305	0.158	0.140	0.052	0.102
13	Female	Working	0.259	0.160	0.154	0.137	0.104	0.063	0.070	0.027	0.027
14	Female	Working	0.122	0.171	0.123	0.176	0.055	0.064	0.131	0.120	0.037
15	Male	Working	0.044	0.104	0.191	0.055	0.180	0.099	0.078	0.038	0.211
16	Male	Working	0.048	0.115	0.263	0.029	0.199	0.143	0.105	0.049	0.049
17	Male	Working	0.031	0.075	0.252	0.031	0.036	0.080	0.099	0.041	0.354
18	Female	Working	0.134	0.120	0.188	0.167	0.127	0.069	0.063	0.035	0.097
19	Female	Working	0.052	0.322	0.091	0.062	0.236	0.041	0.022	0.045	0.129
20	Male	Working	0.016	0.271	0.143	0.086	0.264	0.111	0.038	0.012	0.058
21	Male	Working	0.011	0.156	0.156	0.156	0.022	0.199	0.156	0.022	0.122
22	Female	Working	0.127	0.115	0.029	0.030	0.259	0.080	0.051	0.078	0.231
23	Male	Working	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
24	Male	Working	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
25	Female	Student	0.235	0.240	0.076	0.031	0.130	0.064	0.059	0.091	0.073
26	Female	Working	0.010	0.165	0.062	0.104	0.024	0.039	0.039	0.104	0.452
27	Female	Working	0.145	0.222	0.132	0.052	0.175	0.065	0.076	0.072	0.060
28	Male	Student	0.077	0.062	0.054	0.039	0.180	0.082	0.053	0.054	0.401
29	Female	Working	0.054	0.105	0.182	0.094	0.170	0.140	0.052	0.055	0.148
30	Male	Working	0.043	0.169	0.254	0.045	0.044	0.101	0.060	0.037	0.247
31	Female	Working	0.195	0.136	0.107	0.107	0.107	0.089	0.070	0.095	0.095
32	Female	Student	0.178	0.239	0.043	0.025	0.125	0.061	0.049	0.039	0.241
33	Female	Working	0.118	0.330	0.055	0.030	0.142	0.050	0.050	0.020	0.204
34	Male	Working	0.224	0.077	0.156	0.054	0.320	0.037	0.077	0.018	0.037
35	Male	Student	0.133	0.198	0.155	0.087	0.101	0.060	0.095	0.070	0.100
36	Female	Student	0.193	0.118	0.118	0.083	0.118	0.261	0.044	0.037	0.028
37	Male	Working	0.218	0.107	0.064	0.051	0.179	0.082	0.082	0.101	0.117
38	Male	Working	0.152	0.130	0.123	0.065	0.109	0.109	0.096	0.109	0.109
39	Female	Working	0.086	0.050	0.131	0.126	0.083	0.093	0.097	0.102	0.232
40	Male	Student	0.014	0.079	0.076	0.039	0.341	0.091	0.065	0.051	0.245
41	Female	Working	0.078	0.180	0.068	0.024	0.252	0.101	0.101	0.021	0.173
42	Female	Working	0.043	0.136	0.194	0.043	0.133	0.107	0.066	0.062	0.215
43	Male	Working	0.021	0.089	0.046	0.040	0.112	0.178	0.205	0.149	0.160
44	Male	Student	0.086	0.062	0.062	0.041	0.281	0.075	0.107	0.050	0.235
45	Female	Student	0.323	0.072	0.095	0.111	0.082	0.143	0.080	0.039	0.055
46	Female	Student	0.042	0.120	0.262	0.090	0.125	0.114	0.095	0.032	0.121
47	Female	Student	0.095	0.019	0.029	0.020	0.189	0.084	0.075	0.441	0.049
48	Female	Student	0.032	0.113	0.168	0.087	0.180	0.128	0.044	0.032	0.215
49	Female	Student	0.014	0.106	0.102	0.037	0.369	0.106	0.064	0.024	0.179
50	Female	Student	0.038	0.086	0.210	0.099	0.358	0.088	0.052	0.029	0.040

AHP result of Thai Printers (members of Thai Printing Association)

ID	Age	Gender	1.Energy drain	2.Global warming	3.Ozone depletion	4.Acid precipitate	5.Resource consumption	6.Air pollution	7.Ocean & water pollution	8.Problem of waste disposal	9.Ecosystem effect
1	27	male	0.277	0.123	0.141	0.085	0.126	0.076	0.046	0.051	0.076
2	24	female	0.022	0.380	0.081	0.053	0.092	0.102	0.075	0.071	0.123
3	50	male	0.032	0.020	0.013	0.046	0.228	0.141	0.145	0.117	0.258
4	32	female	0.023	0.225	0.241	0.014	0.029	0.234	0.052	0.080	0.102
5	25	male	0.130	0.179	0.080	0.125	0.137	0.172	0.034	0.056	0.086
6	59	male	0.220	0.270	0.166	0.166	0.044	0.066	0.017	0.027	0.025
7	46	male	0.120	0.291	0.169	0.169	0.018	0.078	0.048	0.055	0.053
8	36	male	0.298	0.212	0.183	0.073	0.031	0.049	0.059	0.052	0.045
9	38	male	0.097	0.058	0.150	0.090	0.111	0.289	0.070	0.094	0.041
10	51	male	0.118	0.187	0.333	0.049	0.079	0.065	0.055	0.090	0.024
11	57	male	0.187	0.260	0.055	0.040	0.145	0.223	0.014	0.035	0.042
12	40	male	0.127	0.073	0.130	0.057	0.088	0.123	0.274	0.086	0.041
13	49	male	0.022	0.060	0.215	0.202	0.087	0.078	0.196	0.053	0.087
14	46	male	0.284	0.142	0.102	0.040	0.032	0.075	0.201	0.077	0.046
15	58	male	0.106	0.107	0.167	0.015	0.056	0.103	0.222	0.139	0.086
16	48	male	0.133	0.063	0.160	0.377	0.032	0.099	0.033	0.023	0.080
17	44	male	0.327	0.015	0.063	0.106	0.158	0.233	0.052	0.023	0.024
18	54	male	0.327	0.167	0.116	0.074	0.058	0.137	0.061	0.038	0.022
19	53	female	0.331	0.120	0.054	0.110	0.180	0.095	0.066	0.031	0.014
20	45	male	0.084	0.453	0.018	0.119	0.130	0.062	0.043	0.057	0.035
21	40	male	0.146	0.245	0.188	0.074	0.059	0.137	0.050	0.066	0.037
22	59	male	0.298	0.087	0.038	0.122	0.064	0.084	0.093	0.123	0.090
23	49	male	0.106	0.213	0.065	0.079	0.102	0.161	0.167	0.059	0.046
24	48	female	0.284	0.142	0.102	0.040	0.032	0.075	0.201	0.077	0.046
25	42	female	0.134	0.196	0.109	0.325	0.026	0.082	0.027	0.052	0.049
26	39	female	0.012	0.364	0.123	0.021	0.083	0.052	0.116	0.041	0.187
27	23	male	0.016	0.091	0.041	0.035	0.122	0.114	0.144	0.053	0.383
28	24	female	0.051	0.140	0.093	0.061	0.142	0.091	0.086	0.142	0.194
29	39	male	0.055	0.017	0.021	0.020	0.252	0.223	0.285	0.063	0.063
30	55	male	0.041	0.304	0.313	0.024	0.079	0.040	0.036	0.029	0.134
31	63	male	0.289	0.143	0.051	0.042	0.144	0.063	0.046	0.078	0.144
32	72	female	0.368	0.030	0.075	0.070	0.164	0.161	0.039	0.046	0.047
33	49	female	0.030	0.042	0.043	0.011	0.025	0.355	0.242	0.151	0.100
34	55	male	0.176	0.324	0.112	0.142	0.024	0.073	0.061	0.057	0.032
35	57	female	0.114	0.071	0.080	0.154	0.027	0.093	0.087	0.029	0.346
36	44	male	0.018	0.058	0.022	0.047	0.034	0.205	0.232	0.296	0.088
37	51	male	0.040	0.077	0.159	0.182	0.027	0.232	0.156	0.019	0.108
38	29	female	0.307	0.042	0.182	0.039	0.079	0.108	0.156	0.048	0.039
39	33	male	0.297	0.151	0.135	0.212	0.020	0.069	0.032	0.022	0.063
40	58	male	0.023	0.086	0.088	0.126	0.110	0.280	0.103	0.131	0.053
			0.152	0.156	0.117	0.096	0.087	0.130	0.103	0.071	0.089

AHP result of Thai Housewives

ID	Age	Gender	1.Energy drain	2.Global warming	3.Ozone depletion	4.Acid precipitate	5.Resource consumption	6.Air pollution	7.Ocean & water pollution	8.Problem of waste disposal	9.Ecosystem effect
1	42	female	0.158	0.260	0.191	0.029	0.030	0.088	0.046	0.107	0.092
2	25	female	0.427	0.135	0.086	0.035	0.051	0.108	0.056	0.056	0.047
3	61	female	0.292	0.155	0.015	0.186	0.021	0.115	0.041	0.108	0.067
4	54	female	0.233	0.139	0.022	0.233	0.024	0.098	0.045	0.171	0.034
5	33	female	0.108	0.172	0.135	0.063	0.230	0.135	0.091	0.020	0.046
6	28	female	0.039	0.184	0.260	0.092	0.051	0.092	0.076	0.132	0.074
7	31	female	0.122	0.058	0.106	0.033	0.231	0.091	0.098	0.139	0.121
8	35	female	0.061	0.067	0.032	0.017	0.139	0.214	0.172	0.226	0.072
9	51	female	0.111	0.226	0.100	0.111	0.062	0.049	0.202	0.066	0.073
10	52	female	0.105	0.189	0.036	0.038	0.203	0.234	0.103	0.040	0.050
11	52	female	0.149	0.208	0.064	0.131	0.050	0.043	0.214	0.072	0.070
12	59	female	0.132	0.170	0.124	0.068	0.048	0.104	0.135	0.145	0.074
13	47	female	0.150	0.208	0.064	0.127	0.050	0.045	0.214	0.072	0.070
14	56	female	0.096	0.149	0.034	0.033	0.165	0.241	0.162	0.045	0.074
15	52	female	0.276	0.165	0.097	0.046	0.053	0.047	0.055	0.135	0.125
16	51	female	0.159	0.139	0.166	0.026	0.138	0.035	0.030	0.075	0.233
17	41	female	0.276	0.165	0.097	0.046	0.053	0.047	0.055	0.135	0.125
18	49	female	0.039	0.269	0.129	0.030	0.104	0.051	0.044	0.101	0.232
19	43	female	0.011	0.372	0.117	0.174	0.026	0.079	0.054	0.082	0.085
20	30	female	0.011	0.234	0.076	0.025	0.105	0.126	0.240	0.091	0.091
21	35	female	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
22	24	female	0.022	0.380	0.081	0.053	0.092	0.102	0.075	0.071	0.123
23	32	female	0.023	0.225	0.241	0.014	0.029	0.234	0.052	0.080	0.102
24	53	female	0.331	0.120	0.054	0.110	0.180	0.095	0.066	0.031	0.014
25	48	female	0.284	0.142	0.102	0.040	0.032	0.075	0.201	0.077	0.046
26	42	female	0.134	0.196	0.109	0.325	0.026	0.082	0.027	0.052	0.049
27	39	female	0.012	0.364	0.123	0.021	0.083	0.052	0.116	0.041	0.187
28	24	female	0.051	0.140	0.093	0.061	0.142	0.091	0.086	0.142	0.194
29	72	female	0.368	0.030	0.075	0.070	0.164	0.161	0.039	0.046	0.047
30	49	female	0.030	0.042	0.043	0.011	0.025	0.355	0.242	0.151	0.100
31	33	female	0.307	0.042	0.182	0.039	0.079	0.108	0.156	0.048	0.039
32	53	female	0.114	0.071	0.080	0.154	0.027	0.093	0.087	0.029	0.346
33	44	female	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111	0.111
34	52	female	0.125	0.214	0.107	0.116	0.150	0.108	0.041	0.068	0.072
35	39	female	0.117	0.090	0.168	0.014	0.101	0.036	0.240	0.127	0.108
36	52	female	0.183	0.121	0.110	0.053	0.069	0.210	0.138	0.049	0.068
37	58	female	0.051	0.101	0.156	0.221	0.069	0.082	0.190	0.062	0.068
38	38	female	0.101	0.089	0.112	0.162	0.090	0.222	0.140	0.037	0.046
39	35	female	0.198	0.189	0.303	0.028	0.071	0.059	0.083	0.037	0.032
40	42	female	0.057	0.280	0.035	0.045	0.063	0.052	0.051	0.175	0.241
			0.142	0.168	0.109	0.083	0.089	0.112	0.110	0.089	0.099

AHP result of Japanese Printers (members of Japan Waterless Printing Association)

	1.Energy drain	2.Global warming	3.Ozone depletion	4.Acid precipitate	5.Resource consumption	6.Air pollution	7.Ocean & water pollution	8.Problem of waste disposal	9.Ecosystem effect
1	0.292	0.141	0.119	0.021	0.042	0.150	0.088	0.065	0.082
2	0.142	0.390	0.115	0.049	0.148	0.060	0.042	0.035	0.019
3	0.186	0.090	0.245	0.111	0.076	0.104	0.075	0.019	0.094
4	0.105	0.021	0.062	0.040	0.281	0.062	0.062	0.050	0.317
5	0.102	0.154	0.154	0.102	0.035	0.096	0.079	0.044	0.234
6	0.197	0.043	0.054	0.037	0.141	0.161	0.257	0.065	0.045
7	0.281	0.089	0.074	0.033	0.250	0.094	0.106	0.042	0.031
8	0.068	0.307	0.180	0.027	0.021	0.057	0.192	0.091	0.057
9	0.169	0.081	0.046	0.043	0.146	0.129	0.129	0.129	0.128
10	0.018	0.158	0.158	0.158	0.018	0.158	0.158	0.018	0.156
11	0.023	0.180	0.167	0.167	0.023	0.174	0.059	0.023	0.184
12	0.290	0.203	0.082	0.077	0.118	0.050	0.057	0.061	0.062
13	0.196	0.076	0.026	0.039	0.092	0.124	0.158	0.081	0.208
14	0.248	0.188	0.173	0.057	0.083	0.041	0.131	0.036	0.043
15	0.047	0.099	0.139	0.139	0.046	0.166	0.176	0.041	0.147
16	0.154	0.285	0.297	0.037	0.066	0.044	0.058	0.030	0.029
17	0.021	0.190	0.168	0.101	0.037	0.105	0.188	0.048	0.142
18	0.109	0.110	0.109	0.067	0.124	0.124	0.109	0.124	0.124
19	0.105	0.320	0.059	0.046	0.070	0.062	0.062	0.062	0.214
20	0.167	0.255	0.015	0.038	0.106	0.046	0.093	0.078	0.202
21	0.208	0.137	0.049	0.028	0.173	0.084	0.066	0.120	0.135
22	0.075	0.153	0.084	0.038	0.196	0.128	0.128	0.070	0.128
23	0.058	0.173	0.106	0.120	0.073	0.135	0.135	0.106	0.094
24	0.197	0.043	0.054	0.037	0.141	0.161	0.257	0.065	0.045
25	0.120	0.163	0.136	0.094	0.107	0.101	0.121	0.051	0.107
26	0.074	0.043	0.163	0.184	0.042	0.129	0.184	0.033	0.148
27	0.078	0.043	0.058	0.172	0.062	0.136	0.127	0.062	0.262
28	0.320	0.164	0.154	0.136	0.046	0.084	0.030	0.040	0.026
29	0.183	0.344	0.035	0.035	0.144	0.085	0.085	0.024	0.065
30	0.034	0.195	0.153	0.135	0.030	0.121	0.127	0.070	0.135
AVG.	0.142	0.161	0.114	0.079	0.098	0.106	0.118	0.059	0.122

AHP result of Malaysian Printers (employees of Nets Print)

	1.Energy drain	2.Global warming	3.Ozone depletion	4.Acid precipitate	5.Resource consumption	6.Air pollution	7.Ocean & water pollution	8.Problem of waste disposal	9.Ecosystem effect
1	0.093	0.080	0.112	0.110	0.123	0.161	0.094	0.091	0.137
2	0.112	0.169	0.169	0.087	0.204	0.068	0.053	0.042	0.098
3	0.061	0.148	0.129	0.148	0.057	0.124	0.104	0.070	0.159
4	0.044	0.161	0.189	0.092	0.070	0.134	0.143	0.052	0.117
5	0.072	0.280	0.209	0.018	0.059	0.049	0.054	0.082	0.176
6	0.098	0.347	0.065	0.082	0.068	0.201	0.085	0.036	0.018
7	0.206	0.283	0.116	0.023	0.081	0.055	0.057	0.050	0.131
8	0.070	0.314	0.046	0.060	0.043	0.095	0.253	0.074	0.046
9	0.039	0.100	0.100	0.106	0.042	0.096	0.186	0.235	0.096
10	0.311	0.170	0.054	0.146	0.039	0.023	0.080	0.102	0.075
11	0.017	0.062	0.125	0.085	0.021	0.108	0.193	0.014	0.376
12	0.019	0.108	0.122	0.055	0.163	0.067	0.049	0.015	0.402
13	0.113	0.259	0.147	0.041	0.086	0.203	0.064	0.047	0.039
AVG.	0.097	0.191	0.122	0.081	0.081	0.106	0.109	0.070	0.144

Appendix C

Members for The Greenhouse Gas Protocol Initiative

<Corporate Users>

Automobile Manufacturers
Daimler Chrysler, Germany
Ford Motor Company, USA
General Motors, USA
Volkswagen, Germany

Cement companies
Cemex, Mexico
Cia. de Cimento Itambé, Brazil
Cimpor, Brazil
Heidelberger Cement, Germany
Holcim, USA (and worldwide Holcim facilities)
Italcementi, Italy
Lafarge, France and North America
RMC, UK
St. Lawrence Cement Inc., Canada
Siam Cement, Thailand
Taiheiyo, Japan
Votorantim, Brazil

Consumer Goods Manufacturers
Bank of America
Body Shop, UK
Cargill, USA
Eastman Kodak, USA
Fetzer Vineyards, USA
IBM, USA
IKEA International, Sweden
Johnson & Johnson, USA
Miller Brewing Company, USA
Nike, USA
Norm Thompson Outfitters, USA
Pfizer Inc., USA
Raytheon, USA
SC Johnson, USA
Sony Electronics, Japan
Starbucks Coffee, USA
Staples Inc., USA
Sun Microsystems
Target Corporation, USA
Timberland Company, USA
Unilever HPC, USA
United Technologies Corporation, USA

Energy Services
American Electric Group, USA
Birka Energi, Sweden
Calpine, USA
Cinergy, USA
Constellation Energy Group, USA
Duke Energy, USA
Edison Mission Energy, USA
ENDESA, Spain
Entergy, USA
Exelon Corporation, USA
First Energy, USA
FPL Group, Inc., USA
General Electric, USA
Green Mountain Energy, USA
Kansai Electric Power, Japan
Mirant, USA
N.V. Nuon Renewable Energy, Netherlands
PSEG, USA
Seattle City Light, USA
Tokyo Gas, Japan
Wisconsin Electric, USA
We Energies, USA

Oil and Gas
BP, USA
Norsk Hydro, Norway
Shell Canada, Canada
Suncor, USA

Industrial Manufacturers/ Mining
ABB Group, Switzerland
Abitibi-Consolidated, Canada
Air Products and Chemicals, Inc.
Alcan Aluminum Corporation Inc., USA
Alcoa, USA
Anglo American, UK
Arch Coal, USA
Ball Corporation, USA
Baltimore Aircoil, USA
BASF, Germany
Baxter International, USA
Bayer, Germany
Bethlehem Steel Corporation, USA
BHP Billiton, Australia
Caterpillar, USA
CODELCO, Chile
Cia. de Cimento Itambé, Brazil
Deere & Co., USA
DuPont, Inc.
Georgia-Pacific, USA
Imperial Chemical Industries, UK
Interface, Inc., USA
International Paper, USA
ITC Inc., India
Javierre, S.L., Spain
Lockheed Martin Corporation, USA
Philips & Yaming, China
Praxair, US
Rio Tinto, UK
Simplex Paper & Pulp, India
STMicroelectronics, Switzerland
StoraEnso, Finland
Tata Steel, India
United States Steel Corporation
Weyerhaeuser, USA

Services
500 PPM GmbH, Germany
AstraZeneca, UK
Casella Waste Systems, Inc., USA
DHL, USA
European Bank for Reconstruction & Development
FedEx, USA
ifPeople, USA
PE Europe, Germany
PowerComm, Canada
Price Waterhouse Coopers, New Zealand
Royal Bank of Canada: Finanacial Group, Canada
United Parcel Service, USA
Verizon Communications, USA

Business Associations
AERES (France)
American Pulp and Paper Association, USA
Australian CIF (Cement Industry Federation), Australia
Canadian Cement Association, Canada
Cembureau (Europe)
Japanese Cement Industry Association, Japan

Business Initiatives
Aluminum Institute Protocol & Calculation Tools
REGES Protocol, France
International Council of Forest and Papers Association's
Pulp & Paper Sector Calculation Tools
NZ Business Council for Sustainable Development
Proposed WEF Global GHG Registry
Respect Europe Business Leaders Initiative for Climate Change (BLICC)
WBCSD Sustainable Cement Initiative

<Non-Corporate Users>

Non-Government Organizations
World Business Council for Sustainable Development, Switzerland
World Resources Institute, USA

Government (U.S. Federal, State, and International)
1605(b) Program (U.S.)
Australia Greenhouse Gas Challenge Plus
California Climate Action Registry
Canadian GHG Challenge Registry
CarboNZero (NewZealand)
China Energy and GHG Management Program
The Climate Registry (U.S.)
Greenhouse Gas Emission Information System (South Korea)
Mexico GHG Program
Philippine Greenhouse Gas Program (PhilGARP)
The Regional Greenhouse Gas Initiative (RGGI)
U.S. EPA Climate Leaders

NGO Initiatives
Carbon Disclosure Project
Climate Neutral Network, USA
Fundacion Ecologia y Desarrollo, Spain
Global Reporting Initiative
World Wildlife Fund Climate Savers, USA

Trading Schemes
Chicago Climate Exchange, USA
EU Emissions Trading Scheme, EU
UK Emissions Trading Scheme, UK

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Document	Title	Journal/Conference	Year	Authors
Paper	Integrated LCA for Printing Service in an emerging country	Eco Design 2011	Dec. 2011	SHIIMIZU Hirokazu, NAGATA Katsuya, HANSUEBSAI Aran
	Integrated LCA approach for Printing Service by Environmental Load Point	Japanese Society of Printing Science and Technology	June 2010	SHIIMIZU Hirokazu, NAGATA Katsuya
	The comparison of paper-based book and electronic book from the viewpoint of LCCO2	Japanese Society of Printing Science and Technology	May 2010	SHIIMIZU Hirokazu, NAGATA Katsuya
	Establishment of quantitative assessment method for Printing Service	Japanese Society of Printing Science and Technology	Dec. 2009	SHIIMIZU Hirokazu
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