Proposals of an Environmental Assessment Method: Environmental Accounting

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Proposals of an Environmental Assessment Method: Environmental Accounting[1]

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Evaluation of Development Aid Projects
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LCA
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Environmental accounting

I Objective, Significance and Theoretical Framework of the Proposal

I-1 Objective and Significance of Introducing Environmental Accounting

This proposal is aimed at expanding an assessment method of environmental impacts. This method is applied to development aid projects by using an environmental accounting theory.

The past has seen various methods applied to measure and assess environmental impacts of development aid projects, and precious knowledge has been gathered. Introduction of an assessment method based on the environmental accounting theory will enjoy a new development. Past assessment methods consider environmental impacts from the standpoint of “what kind of environmental impacts is caused as a result of implementing a certain project”. In other words, two situations are compared: the implementation and the non-completion of a project. This comparison bases environmental impacts assessment of a certain project.

[1] We would like to express our deep gratitude to Dr. Thumrongrut Mungcharoen and Ms. Viganda Varabuntoonwit of National Metal and Materials Technology Center (MTEC) and Ministry of Science and Technology for their precious support.

For instance, the PEDACS assessment of "electricity consumption efficiency improving project" in Thailand was conducted in parallel to research of this proposal. This assessment takes an orthodox approach, making assumptions about reductions of electricity consumption, fossil fuels, CO_2 emissions etc. that could be achieved by Demand Side Management (DSM), and considers such reductions as impacts of this project. In other words, common assessment methods focus on "environmental impacts of the project itself".

Even when the project itself reduces environmental impacts efficiently, the preparation stages where materials such as cement or steel products are produced could emit a great amount of environmental load substances. Therefore, the assessment of the project could be accordingly adjusted. It is also the case with disposal after the completion of the project. It is the viewpoint of environmental accounting to take preparation and disposal stages into consideration, and to grasp an exact overview of environmental impacts of the project.

Introducing the idea of environmental accounting enables to assume a decrease or an increase of environmental impacts in a broader spectrum as well as in a longer time span than a project itself. Thus, grasping all environmental impacts of the project including indirect ones would increase the accuracy of environmental impacts assessment of development aid projects.

To concretize the significance of environmental accounting, this proposal applies **Life Cycle Assessment (LSA)** that is the most appropriate to this objective among a group of environmental accounting theories. We apply LCA to "an electricity consumption efficiency improving project" (DSM project) in Thailand.

I-2 Theoretical Framework of LCA

LCA takes a holistic approach to measure and assess environmental impacts in the lifecycle of a certain project or product. These premise and framework are acknowledged as standards in ISO-140140. The following is the basic premise of LCA in line with the DSM project.
The main objective of the DSM project is to reduce energy consumption and to reduce the emission of environmental load substances such as CO_2 by introducing energy-saving products. These are direct effects of the project. In addition, LCA recognizes: i) production stage of raw materials used for producing energy-saving products, ii) production stage of energy-saving products, and iii) disposal stage after product use. At the same time, LCA also measures environmental impacts of these three stages concerning previous models of products that are not necessarily energy efficient.

LCA compares emissions of environmental load substances in the whole product life cycles of both energy efficient appliances (less energy consuming) and less efficient models. This comparison includes not only direct impacts but also indirect impacts. The total of direct and indirect impacts provides an overview of environmental impacts of a certain project. In the case of the DSM project, products are refrigerators and florescent lights.

［Total Environmental Impacts］ ＝ ［Direct Impacts］* ＋ ［Indirect Impacts］**
*environmental impacts measured by previous methods
**environmental impacts measured by LCA

This research applies LCA, focusing on the reduction of CO_2 (or CO_2-equivalent) emissions in the DSM project.

I-3 Remarks on the Application of LCA：Constraints of Assembling Information and Data from Emerging Countries

Although LCA helps diversify the viewpoint of environmental impacts assessment, there exist important constraints of LCA when applied to development aid projects. In comparison to developed countries, emerging countries lack information and data necessary for LCA. Thus, data availability plays a key role to apply LCA in emerging countries. The introduction of the LCA method to the DSM project in Thailand is marked as a pilot project to see the efficacy of LCA in emerging countries. Experiences of the pilot project will also help us find obstacles of conducting LCA in emerging courtiers.

When information and data necessary for LCA are not attainable, those of Japan or other experienced countries could help overcome constraint conditions.

I-4 Field Research of the DCM Project

4.1 Research Objective

Among energy-saving projects (or highly efficient products) developed in the name of the project, we focus on the following three products, especially refrigerators and florescent lights. We measure and compare energy consumption, material consumption and emissions of environmental load substances in three stages: material production, production of object products and product disposal. Data analysis is elaborated in the part II.

① Refrigerators
② Florescent lights
③ Low-loss ballast

4.2 Research Structure

The research team consists of three experts from Hosei University: expert in assessment of development aid projects, expert in environmental accounting, and expert in LCA, in collaboration with the research department (MTEC: National Metal and Materials Technology) under the Ministry of Science and Technology of Thailand which has been attempting to introduce LCA.

The collaboration with MTEC is useful for the continuous information gathering at site. Also, we can expect transfer of skills when stuff of MTEC gathers hands-on experiences. As mentioned before, the basic constraint in conducting LCA in emerging countries is the difficulty of attaining information and data. To overcome this constraint and to expand the application scope of LCA, enhancing technological standards concerning LCA in emerging countries takes precedence. To this aim, it makes much sense to expand the collaboration network as we do in this project.

4.3 Research Execution

The research team of Hosei University visited Bangkok in August, 2008. They collected information from the project executer, Electricity Generating Authority of Thailand (EGAT) and also from the following three companies which produce research object products.

Thai Toshiba Lighting：florescent lights, low-loss ballast
Sharp Appliances (Thailand) ：refrigerators
Philips Electronics (Thailand) ：florescent lights

The research team requested information and data in line with given formats that suit the objective of

LCA. After the return of the research team, MTEC stuff did the follow-up of information collection. This research required information and data the Thai companies do not deal with in everyday business and also confidential data, such as details of production processes. Therefore, we were concerned about the availability of data and information, but Sharp Appliances (Thailand) and Philips Electronics (Thailand) offered it to us.

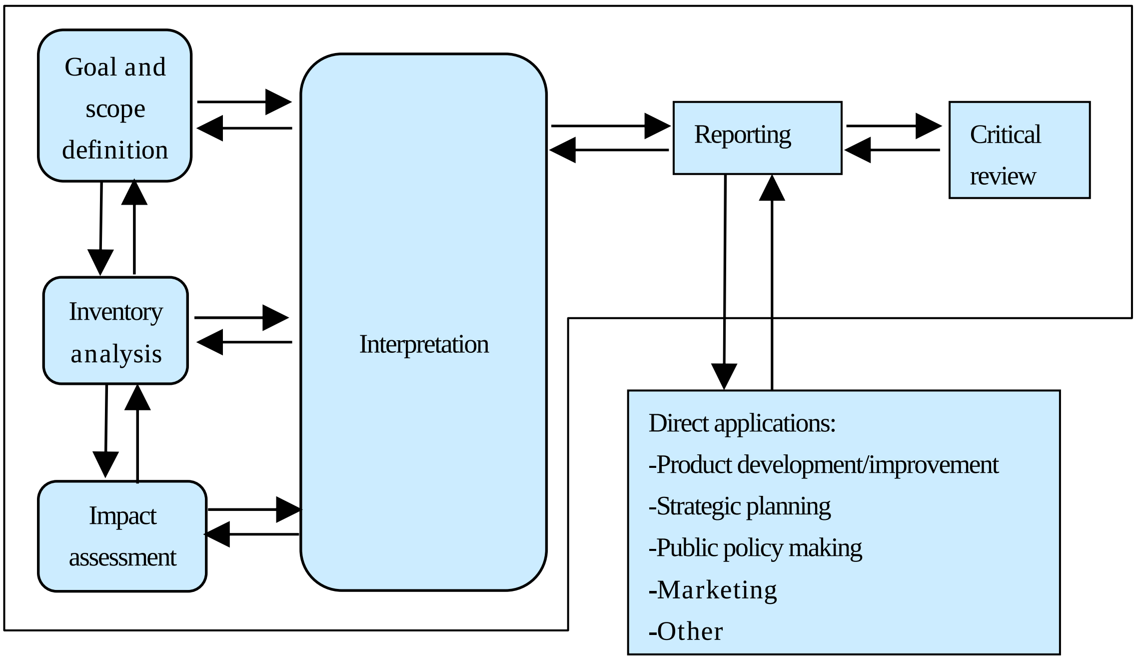
The part II describes research results based on collected information and data. The part III elaborates the significance of the DSM project assessment by LCA.

II Results of LCA Analysis concerning the DSM Project

II- 1 Overview of LCA

International Organization for Standardization (ISO) standardizes the framework of LCA in its ISO-14040 series. There, LCA is defined as "a methodology developed to better understand and reduce impacts generated by goods and services". Figure 2-1 clarifies four elements of LCA: "goal and scope definition", "inventory analysis", "life cycle impact assessment" and "interpretation".

Figure 2-1 Structural Elements of LCA (modified based on ISO14040)



1.1 Goal and Scope Definition

In this element, an industrial product or service as well as a goal of executing LAC are defined. These definitions are extremely important and results of LCA are heavily dependent on the decisions taken in this phase. The results are valid only within the defined system boundaries and should be used only under the underlying conditions. For instance, the goal of our DSM project is set to assess impacts of refrigerators on global warming. Accordingly, one decides on which emissions to measure and the extent to which the emissions are to be measured (system boundaries).

1.2 Inventory Analysis

Input (raw materials and energy resource) and output data (products, wastes and emissions) for all the processes of the defined product or service are collected. These data flow into an input-output-table which lists environmental impacts associated with the product or service.

1.3 Life Cycle Impact Assessment

This element generally consists of three further elements: classification, characterization, and total assessment. Classification sorts resources, emissions and wastes into impact categories according to their expected impacts on the environment. Characterization quantifies emission substances by multiplying the amount of emissions or wastes by corresponding weighting factors, and converts them into a common unit of “category indicators”. ISO-14040 necessitates classification and characterization in the impact assessment, and adds as an optional element normalization to understand the relative size of impacts by benchmarking each impact against the total impacts.

1.4 Interpretation

LCA leads to different results when the scope of research, definitions of system boundaries and allocation methods in the inventory analysis, or weighting factors in the impact assessment vary.
This project applies LCA to assess the reduction of CO2 emissions in the DSM project in Thailand. The goal is to calculate the reduced amount of CO2 emissions. Thus, the impact assessment is not necessary but the inventory analysis.

II-2 Life Cycle Inventory Analysis of Refrigerators

When conducting the inventory analysis, it is necessary to collect data directly associated with production, use and disposal of a target product. These data are called as “foreground data”. Next, we collect data on emissions in the production phase of raw materials for the target product as well as emissions from generating energy consumed in the use phase. These data are called as “background data”. Aggregating foreground and background data, we calculate CO2 emissions of the target product’s production, use and disposal stages. The following is the refrigerator’s inventory analysis.

2.1 Raw Materials and Energy Consumption in the Refrigerator’s Production and Use Stages (Foreground Data)[2]

Table 2-1 shows raw materials used to produce three models of refrigerators, and electricity consumption in the use stage. Three models include a model of 1997 and two current models. The data are provided by SHARP APPLIANCES (THAILAND) LTD.

[2] We would like to express gratitude to Mr. Takenaka of SHARP APPLIANCES (THAILAND) LTD.

Table 2-1 Raw Materials for the Production of Refrigerators

(Source: SHARP APPLIANCES (THAILAND) LTD.)

		Current	Current		Model-1997	
Model Name		43AT	47AT		40BP	
Storage Volume (L)		347	384		368	
Electricity Consumption (kWh/y)		708	744		804	
TTL NET Weight(kg)		70	72		73	
Material	Detail	Weight(g)	Weight(g)		Weight(g)	
GP-PS	PS	9,142	9,142		6,120	
HI-PS	PS	1,150	1,150		5,214	
EPS	PS	430	500		1,100	
PP	PP	1,895	1,895		4,707	
ABS	ABS	1,045	1,045		1,383	
ABS sheet	ABS	5,475	5,862		3,019	
PU	Poly Urethane	8,759	9,232		7,665	
Outer–shell	Colored steel	9,570	10,140		10,900	Body
Door—plate	Colored steel	4,420	4,750		4,450	
Back–plate	GI	2,440	2,630		2,060	
Bottom–plate	GI	1,435	1,435		1,128	
Others of GI	GI	6,671	6,671		6,964	
Cu–pipe	Cu	880	950		1,602	
Compressor	Fe:Cu=9:1	10,500	10,500		11,000	
Wireharness	Cu:PVC=30:1	550	550		700	
Paper		70	70		90	
Evaporator	43/47type All AL 40BP AL:Cu=3:5	521	521		830	
Door gasket	PVC:Magnet=2:1	750	850		1,100	
Fan motor	Fe:Cu:Other=5:3:1	500	500		500	
Others		3,797	3,607		2,468	
R134a		105	105		120	Refrigerant
Carton box		7,500	8,500		8,500	Packaging
EPS(Packing)		1,800	1,800		2,000	

Table 2-2 shows energy consumption in the production stage of refrigerators. Due to data unavailability in Thailand, we use data publicized by the Japan Electrical Manufacturers' Association (2004) on energy consumption of a 400 litter model at the time of 1999. Thus, we do not consider the differences in energy consumption among the three models indicated in Table 2-1. With regard to raw materials, we need to consider the material utilization factor (production efficiency) of the production phase, but neglect this point due to data unavailability.

Table 2-1 shows electricity consumption in the use stage. A current model of 43AT in Thailand consumes 708kWh/y, and this is slightly higher than electricity consumed by a Japanese model of the same size (640kWh/y). We assume the life span of refrigerators to be 10 years.

We also use data on disposal of refrigerators (400 litter) provided by the Japan Electrical Manufacturers' Association (2004). Refrigerators are disposed by shredding and 1.31kWh of electricity is consumed per refrigerator.

Table 2-2 Energy Consumption of Refrigerators (per unit)

Electricity (kWh)	29.90	kWh
Combustion･LPG (kg)	0.0055	kg
Combustion･city gas13A (m3)	1.50	m3
Combustion･bunker A (L)	0.97	L

Source: The Japan Electrical Manufacturers' Association, 2004

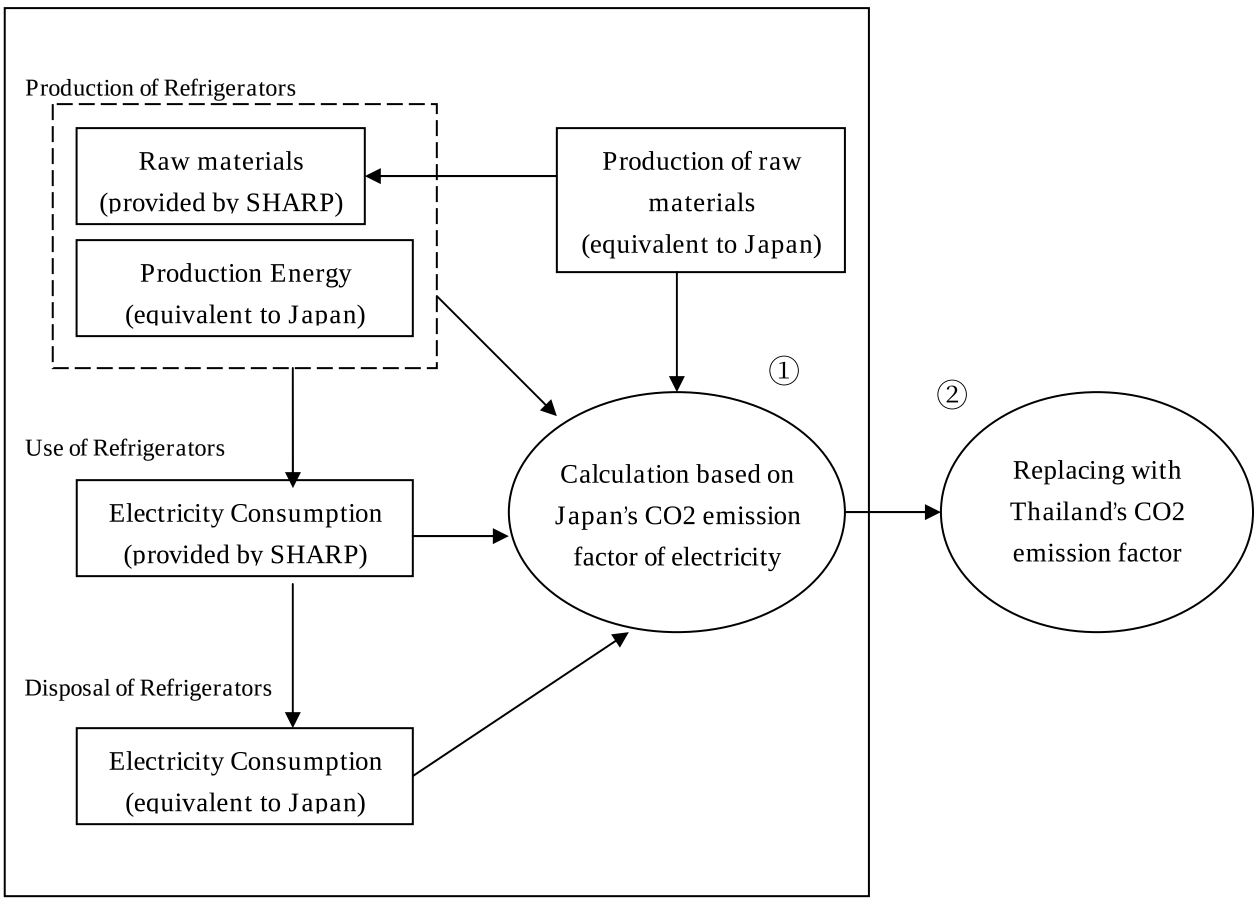
2.2 Calculation of CO2 Emissions in the Life Cycle

2.2.1 Calculation of CO2 Emission Reduction

To conduct the inventory analysis based on data of refrigerators' production in Thailand as above, we need to know CO2 emissions of each raw material when it is produced in Thailand. However, neither lifecycle inventory data on production of each raw material nor its CO2 emissions are available.

Therefore, we firstly assume that refrigerators in Table 2-1 are produced, used and disposed in Japan, and calculate their CO2 emissions. Next, we replace only CO2 emissions produced by electricity with those of Thailand. This assumption is equivalent to assuming energy consumption in the production stage of raw materials in Japan and in Thailand to be the same and assuming CO2 emissions from generating 1kWh of electricity to be different. Figure 2-2 details this calculation.

Figure 2-2 Calculation Steps of CO2 Emission



For the calculation of CO_2 emission, we use a LCA software JEMAI-Pro and its data. This software is developed by National Institute of Advanced Industrial Science and Technology and sold by Japan Environmental Management Association for Industry. This software presumes CO_2 emission from generating 1 kWh of energy in 2003 in Japan to be 0.4156kg in which the power structure, power generation efficiency and fuel transportation in Japan are considered. The CO_2 emission of 0.3995kg/kWh is emitted in Japan and 0.0161kg/kWh abroad. It is also assumed that nuclear electric power generation and hydro-electric generation do not emit CO_2.

Table 2-3 shows results of the inventory analysis under the assumption of the model 40BP (produced in 1997) being produced in 2003 and used for ten years. This is equivalent to ① of Figure 2-2. In the life cycle of refrigerators, CO_2 emissions in the use stage make up 94.35% and this results from electricity generation. CO_2 emissions in the production stage make up 5.51% in the life cycle, 19.4% of which results from electricity generation.

Table 2-3 CO_2 Emissions (kg) of 40BP (1997-model) produced and used in Japan (2003)

	Total	ex. Electricity	Electricity	Transportation
Production	195	149	37.8	8.52
Use	3,340		3,340	
Disposal	0.59	0.12	0.47	
Total	3,540	149	3,380	8.52

In contrast, CO_2 emissions from power generation in Thailand are shown in the following Table 2-4 according to the analysis of Cleaner Technology And eco-Product development group (CTAP). This group is responsible for LCA at National Metal and Materials Technology Center (MTEC). Loss from electric power transmission is not considered. Appendix 1 at the end of the report elaborates the power structure used to calculate the CO_2 emissions in Table 2-4.

Table 2-4 CO_2 Emissions from Electricity Generation in Thailand

Substance	Unit	Electric1993	Electric1995	Electric2003	Electric2004	Electric2005
CO2	**kg/kWh**	**0.660**	**0.627**	**0.527**	**0.590**	**0.592**
Ratio to Japan (2003)		**1.59**	**1.51**	**1.27**	**1.42**	**1.42**

Source：MTEC

Therefore, out of CO_2 emissions in Table 2-3 based on the assumption that Model 40BP (1997-model) is produced and used in Japan in 2003, only emissions from electricity generation are replaced with data of electricity generation in 1993 in Thailand. This leads to CO_2 emissions from producing refrigerators in 1993 in Thailand under the assumption that CO_2 emissions per kWh at the time of 1993 do not change for 10 years (equivalent to ② of Figure 2-2). Table 2-5 shows this result. Since CO_2 emissions per kWh decrease every year as shown in Table 2-4, CO_2 emissions during the 10-year life span of refrigerators are actually less than the figure shown in Table 2-5.

Table 2-5 CO2 Emissions (kg) of 40BP (1997-model) produced in 1993 in Thailand and used for 10 years with the CO2 emission factor of 1993

	Total	ex. Electricity	Electricity	Transportation
Production	218	149	60.1	8.52
Use	5,310		5,310	
Disposal	0.86	0.12	0.75	
Total	5,530	149	5,370	8.52

Next, Table 2-6 shows CO2 emissions when the current model of 43AT is produced, used and disposed in Japan (equivalent to ① of Figure 2-2).

Table 2-6 CO2 Emissions (kg) of 43AT (current model) produced, used and disposed in 2003 (now) in Japan

	Total	ex. Electricity	Electricity	Transportation
Production	190	145	37.1	8.04
Use	2,940		2,940	
Disposal	0.56	0.11	0.45	
Total	3,130	145	2,980	8.04

The same procedure leading to the results of Table 2-5 is applied to calculate CO2 emissions when 43AT (current model) is produced and used in Thailand for 10 years with the CO2 emission factor per kWh in 2005. The result is shown in Table 2-7. This table also indicates the difference between Table 2-5 and Table 2-7. Table 2-5 shows CO2 emissions when 40BT (model of 1997) is produced in 1993 and used for 10 years with the CO2 emission factor per kWh in 1993. Table 2-8 clarifies a reduction of 1150kg-CO2 emissions per refrigerator for 10 years. This results from the improved efficiency of refrigerators and reduced CO2 emissions per kWh.

Table 2-7 CO2 emissions of 43AT (current model) produced in Thailand (2005), used for 10 years with the CO2 emission factor of 2005, and the difference (kg) from 40BT (1997-model) produced (1993) and used for 10 years with the CO2 emission factor of 1993.

	Total	ex. Electricity	Electricity	Transportation	Difference from 40BT
Production	206	145	52.7	8.04	-12.0
Use	4,170		4,170		-1,140
Disposal	0.716	0.112	0.604		-0.147
Total	4,380	145	4,220	8.04	-1,150

2.2.2 Examination of Factors of CO2 Emission Reduction

43AT of Table 2-7 is a current model in Thailand. We recalculate CO2 emissions produced by electricity generation in Table 2-7, using CO2 emissions per kWh in 1993 in Thailand. This leads us to see a difference from 40BT (1997-model). Table 2-7 shows CO2 emissions when 43AT (current model) is produced in 1993 in Thailand and used for 10 years with the same CO2 emissions factor per kWh as in 1993.

Table 2-8 CO2 emissions of 43AT (current model) produced in Thailand (1993) and used for 10 years with the CO2 emission factor of 1993, and the difference (kg) from 40BT (1997-model)

	Total	ex. Electricity	Electricity	Transportation	Difference from 40BT
Production	212	145	59.0	8.04	-6.00
Use	4,670		4,670		-640
Disposal	0.829	0.112	0.717		-0.030
Total	4,880	145	4,730	8.04	-646

Table 2-8 indicates the difference from 40BT (1997-model, Table 2-5). CO2 emission reduction in the 10-year use phase due to efficiency improvement of refrigerators will amount to 640kg-CO2 per refrigerator, based on CO2 emissions per unit in 1993 in Thailand. At the same time, the production phase also sees CO2 emission reduction of 6.0kg-CO2 per unit.

Also in consideration of CO2 emission reduction in power generation in Table 2-7 as well as CO2 emission reduction due to efficiency improvement of refrigerators, reduction of CO2 emissions in the use stage amounts to 1140kg-CO2 per refrigerator. As in Table 2-1, 43AT (current model) consumes electricity ca. 12% less than 40BT (1997-model). Table 2-4 shows the reduction of CO2 emissions per refrigerator through power generation from 1993 to 2005 by ca. 10%. All these synergy effects together, we confirm a great amount of CO2 emission reduction.

2.3 Effect of CFC Emission on Global Warming

The DMS project does not target CFC emission reduction, but highly efficient appliances reduce emissions of greenhouse gases. Therefore, we consider this reduction in the DMS project as part of green house gases emission reduction. Refrigerators in Table 2-1 use HFC-134a (HFC：hydro fluorocarbon or CFC's substitute). According to SHARP APPLIANCES (THAILAND) LTD, the company started replacing CFC-12 (CFC: chlorofluorocarbon) with HFC-134a in 1996. Thus, at the beginning of the DMS project in 1993, CFC-12 was still in use. According to Japan Electric Machine Industry Association, 200g of CFC-12 was replaced by 180g of HFC-134a for the same model of refrigerators in Japan. 40BP (1997-model) uses 120g of HFC-134a. With the same substitution ratio of Japan being applied, the same model of refrigerators would need 133.3g (120x(200/180)) of CFC-12. At the time of 1993, all this amount of CFC was emitted in the air. In contrast, 105g of HFC-134a is emitted in the air now.

Both CFC-12 used in 1993 and HFC-134a used now emit green house gases. IPCC (Intergovernmental Panel on Climate Change) estimates that CFC-12 has an impact of 10600 times as big as CO2 on global warming, and that the impact of HFC-134a is 1300 time as big as that of CO2 on global warming.

Accordingly, Table 2-10 shows an estimation of the reduction of green house gases emission including CFC emission. Changing from 40BP (1997-model) to 43AB (current model) reduces green house gases emission by 2426kg-CO2 equivalent per refrigerator. It is approximately twice as high as CO2 emission reduction of 1140kg.

Table 2-9 Estimation of CO2-Equivalent Emission from CFC (unit:kg)

	40BP(1997-model)	43AT（current model）
CO2 emission in the life cycle	5530*)	4380**)
Emission of CO2-equivalent (133.3g CFC-12(GWP=10600))	1413	-
Emission of CO2-equivalent (105g HFC-134a(GWP=1300))	-	136.5
Total (kg-CO2-equivalent)	6943	4517

*) Assumption of production, 10-year use and disposal with the CO2 emission factor of electricity generation in 1993

**) Assumption of production, 10-year use and disposal with the CO2 emission factor of electricity generation in 2005

II-3 Life Cycle Inventory Analysis of Florescent Lights[3]

As with refrigerators, we estimate CO2 emission reduction of florescent lights.

3.1 Energy Consumption in Production, Use and Disposal of Raw Materials

Table 3-1 shows data on the production stage of florescent lights provided by Philips Electronics (Thailand) Ltd. The DMS project encouraged the replacement of T12 with T8.

Table 3-1 Data on Production and Use of Florescent Lights of Philips Electronics (Thailand) Ltd.

Model name		T8	T12
Watt		36	40
Total weight (g)		194	290
Lifetime (hr)		15,000	
energy consumption		10% saver	
Materials	Detail	weight (g)	weight (g)
glass	glass	180	270
fluorescent powder		2	3
inert gas	Kr/Ar (l)	0.02	0.045
mercury	Hg	0.003	0.0414
anode ring	Carbon steel strip with Al	0.5	0.75
electrode+emitter	Tangsten + suspension of Sr-Ca-Ba carbonate	0.05	0.075
lead wire	Pb	0.5	0.75
stem glass	glass	5	7.5
cappping cement	Ethanol, Phenol formaldehyde resin, calcium carbonate, methanol, phenol, shellac, methyl/phenyl silicone resin with alkoxygroups	2	3
cap	Al	2.5	3.75
contact pin	brass	1	1.5
electricity	kWh	0.0026	0.0026
natural gas	m3	0.02	0.02
opp tape	plastic	130m/1000 Pcs.	
sleeve tape	paper	0.31	0.465
outer box	paper	0.016	0.0024
corrugate paper	corrugate paper	0.032	0.048

For both T8 and T12, glass makes up ca. 95% in weight. Thus, production of glass plays the largest role in CO2 emission. Next glass, AL consists ca. 1.3% in weight. Energy consumption in the production stage stays the same for T8 and T12, but a decrease of glass including stem glass by 92.5g in weight contributes most to CO2 emission reduction. Replacing T12 with T8 decreases energy consumption in the use stage by 60kWh (4Wx15000h).

Moreover, the DMS project promotes low-loss ballast. According to EGAT, low-loss ballast reduces energy consumption from the normal 10W to 6W. Therefore, the application of low-loss ballast sees a further reduction in energy consumption by 60kWh.

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[3] We would like to express gratitude to Mr. Jatupong and Mr. Luono of Philips Electronics (Thailand) Ltd.

3.2 Estimation of CO2 Emission Reduction

For the calculation of CO2 emission reduction realized by the reduced use of glass in the production stage, we use a LCA software JEMAI-Pro and its data. This software is developed by National Institute of Advanced Industrial Science and Technology and sold by Japan Environmental Management Association for Industry. According to this software, 1.097kg of CO2 is emitted when 1kg of glass is produced, and only 0.0062kg out of 1.097kg is attributed to electricity generation. Therefore, in the production stage of raw materials, we ignore CO2 emission reduction realized by the efficiency improvement of electricity generation.

The use stage sees a total reduction of 120kWh by aggregating energy savings realized by the more efficient T8 model (60kWh) and savings from low-loss ballast (60kWh). Table 3-2 shows CO2 emission reductions by replacing T12 with T8. When electricity generation at the time of 1993 is considered, the CO2 emission reduction is calculated to be 79.3kg per florescent light. When electricity generation at the time of 2005 is considered, the CO2 emission reduction is estimated to be 71.1kg per florescent light. The difference of 8.2kg in CO2 emission reduction is attributed to efficiency improvement of power generation.

Table 3-2 CO2 Emission Reduction by Replacing T12 with T8

	CO2 emission reduction (kg-CO2/unit)
Decrease of glass in production (92.5g)	(1.097)x(0.0925)=0.101
CO2 reduction from electricity consumption reduction (120kWh) in the use stage with the CO2 emission factor of 1993 (0.66kg-CO2)	(0.66)x(120)=79.2
CO2 reduction from electricity consumption reduction (120kWh) in the use stage with the CO2 emission factor of 2005 (0.592kg-CO2)	(0.592)x(120)=71.04
Total	79.3 or 71.1

References: the Japan Electrical Manufacturers' Association (2004), LCA Data Base (2004), LCA Japan Forum (Organizer: Japan Environmental Management Association for Industry)

III Conclusion and Proposals

III-1 Environmental Improvement Effects of the DSM Project in the LCA Analysis

The LCA analysis focuses on effects of energy saving or highly efficient appliances: refrigerators and florescent lights. Results from Table 2-5, 2-7, 2-8 and 2-9 are summarized as follows.

Table III-1-1 Overview of CO2 reduction effects
(unit : kg)

		Use stage	(ratio:%)	Other stages	(ratio:%)	Total
Refrigerator	Efficiency improvement	640		6		646
	Decrease of CO2 emission from electricity generation	500		4		504
	(Subtotal)	1140		10		1150
	CFC emission reduction*	1276.5				1276.5
	Total	2416.5	99.59%	10	0.40%	2426.5
Florescent Light		8.16	98.79%	0.1	1.21%	8.26
	Total	2424.7	99.59%	10.1	0.41%	2434.8

*CO2-equivalent

Table III-1-1 implies the following points.

1) Energy saving or highly efficient appliances exert reduction effects such as in green house gases emission in the life cycle: production, use for 10 years and disposal. An efficient refrigerator reduces 2426.5kg of CO_2 equivalent and an efficient florescent light reduces 8.3kg of CO_2 equivalent. Based on these figures, we calculate macro reduction effects of green house gases as follows.

- Refrigerators

In the DSM project, about 5'160'000 units of highly efficient refrigerators were introduced in the time span of 1995 until March 2000[4]. The total green house gases reduction for 5 years and 3 months amounts to:

$$2{,}426.5\text{kg} \times 5{,}160{,}000\text{units} = 12.52 \text{ million tones}$$

- Florescent Lights

The market of florescent lights (T8 model) in Thailand is 1.3 billion units[5]. We make a moderate assumption that the dimension of replacing the conventional T12 with the highly efficient T8 is equivalent to the current market size of one year. This assumption leads to the following total reduction of green house gases.

$$8.3\text{kg} \times 1.3 \text{ billion units} = 10.79 \text{ million tones}$$

These calculations imply that introducing energy saving or highly efficient appliances would make a significant contribution to environmental policies of Thailand and would be effective for countermeasures against global warming.

2) For both refrigerators and florescent lights, there has not seen any negative impacts that would counterbalance effects of highly efficient appliances in the production as well as the disposal stages. The use phase makes the largest contribution to the reduction of green house gases emission. From the perspective of reduction effects in the life cycle, the concept of the DSM project attempting to encourage the introduction of energy saving appliances is proved to be appropriate.

3) As in Table 2-4, the time span of 1993 - 2005 has seen an improvement of ca. 10% of CO_2 emission in power generation in Thailand. 44% (504kg) of the total CO_2 emission reduction of refrigerators (1150kg) was achieved thanks to the improvement in power generation in Thailand. Aggregating also other improvements including such of the efficiency of appliances and such of the electricity infrastructure leads to the CO_2 reduction of 2426.5kg per refrigerator.

4) In the case of refrigerators, ca. 53% of CO_2 reduction, equivalent to 1276.5kg, resulted from the conversion of the refrigerant along with a new model. This suggests the significance of the improvement of the refrigerant for global warming, since it constraints emissions of CFC and its substitutes.

The separate research investigating fluctuations of CO_2 emissions by introducing highly efficient appliances clarifies that a certain level of impacts is caused by various assumptions about the life expectancy of appliances, loss during the electric power transmission, or CO_2 emissions through power generation[6]. This implies that appropriateness of assumptions should be especially paid attention to when interpreting impacts of LCA.

III-2 Efficacy of LCA Method

We recognize two significant points of this pilot project.

Firstly, the DSM project encouraged to replace old appliances with energy saving or highly efficient ones.

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[4] EGAT, Quarterly Progress Report (January1-March31, 2000), p.2

[5] Hearing from THAI TOSHIBA in the field survey in June 2006

[6] In a separate report, Prof. Siegenthaler conducted a detailed sensibility analysis.

We have gained an overview of direct as well as indirect impacts exerted on constraining the emission of green house gases.
Secondly, the collaboration with and support from affiliates in emerging countries enables the execution of LCA even in emerging countries. So far, introduction of environmental accounting theories ex ante and ex post development aid has not been done, but we have seen that application of environmental accounting theories opens up more diverse viewpoints on environmental impacts assessment of a specific project.

III-3 Proposals of the Environmental Impacts Assessment Method

Based on the results of this pilot project, we would like to make the following proposals for the improvement of environmental impacts assessment.

Proposal 1

Environmental accounting theories are useful to understand environmental impacts of development aid projects systematically and comprehensively. This pilot project was targeted at the DSM project within environmental-related ODA (Official Development Assistance) projects. The application of LCA is not limited to environmental-related ODA but extends to infrastructure projects that are the central arena of yen-loan-financed-projects (see Appendix). We should try applying LCA to assess environmental impacts of infrastructure projects.

Proposal 2

We should actively propose the application of environmental accounting to international aid organizations and take the initiative in the dissemination of LCA in the international aid community.

Proposal 3

As mentioned in Part I, the largest obstacle to introducing LCA in development aid projects is the limited availability of data and information in emerging countries. To cope with this problem, the long-term collaboration between emerging countries and their donors for the improvement of data availability is essential. As this pilot project indicates, ensuring reliable partners from emerging countries could expand the application arena of the LCA method significantly. Also for the realization of “a Japanese environmental assessment method”, we should expand and promote a technological cooperation, targeting the improvement of data and information, fostering human resources and establishing expert groups.