

7. ECO-DESIGN TOWARDS GREEN PRODUCTIVITY

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ABSTRACT

Hitachi is dedicated to emphasizing environmental considerations in all aspects of its products' lifecycles from design to disposal after use. Our goal is eco-design towards Green Productivity. We have thus incorporated life cycle assessment (LCA), disassembly evaluation (DEM) and recyclability evaluation (REM) methodologies into our product design process to achieve this goal. This paper outlines Hitachi's approach to eco-design and the application of the aforementioned methodologies to product design. Hitachi is actively promoting the transfer of these eco-methods (so-called "green-technology transfer") to the Asia-Pacific region.

INTRODUCTION

In order to achieve a sustainable economic system, industries must improve their Green Productivity (GP). Industries that can realize GP, which is defined as "a strategy for enhancing productivity and environmental performance for overall socio-economic development," will enhance their international competitiveness. Many Japanese industries are now incorporating GP concepts into their products by applying eco-design concepts to upgrade eco-efficiency. In line with the establishment of a corporate environmental management system, Hitachi has developed methodologies for life cycle assessment (LCA), disassembly evaluation (DEM) and recyclability evaluation (REM) to support its eco-design initiatives. This paper describes some examples of Hitachi's eco-design work and explains how these technologies are being transferred to the Asia-Pacific region.

THE RELATIONSHIP BETWEEN PRODUCTS AND THE ENVIRONMENT

Our economic system has been created by mass production and mass consumption. Therefore, to establish a sustainable economic system, we must consider product manufacturing from the viewpoint of the relationship between products and the environment. For example, manufacturers must use recycled materials to reduce the amount of unnecessary material consumption and must also manufacture products using fewer parts. It is also necessary to reduce the amount of waste by extending the life of products. Discarded products should be carefully sorted into their constituent materials at the point of recycling with the goal of returning materials to the manufacturing plant as

recycled materials. In addition, the parts of the discarded products should also be reused. Establishing a sound product circulation loop integrating concepts of reduction, reuse, and recycling can solve many global environmental problems, such as global warming, ozone-layer destruction, water and air pollution, excess waste, and depletion of resources.

In Japan, the principles of reduce, reuse, and recycle are now called the 3Rs and are the basis for creating a sustainable economic society. Note that the manufacturing plant is the starting point of the recycling loop that integrates the 3Rs into the economic system, and also note the overall importance of eco-design to achieving sustainability.

There are also many laws and standards which are relevant to eco-design. A product must be designed to meet domestic and international regulations which incorporate both safety and environmental protection. Landfills are now full, especially in metropolitan areas in Japan, and decreasing the amount of waste generated is an urgent national priority. To control the generation of waste and promote the creation of a recycling-oriented society, extended producer responsibility (EPR) was introduced into the “Basic Law for Promotion of a Recycling-Oriented Society” (enacted in May, 2000). This law stipulates that companies are responsible for the total life cycle of their products, which makes the eco-design of the products the most important stage in the production chain. In addition to domestic pressures, ISO/TC207, which is examining international standards of environmental management, is planning to publish a technical report on Design-for-the-Environment (DFE) by December 2001 to serve as a guideline for integrating environmental aspects into product development.

In considering the relationship between companies and society, there are two important activities for a “green” company. The first is to establish an environmental management system in compliance with the laws and use eco-design methods like life cycle assessment (LCA) and green product assessment to produce eco-friendly products. The other is to communicate with society in developing a green business by providing stakeholders with environmental information such as eco-labels or environmental reports. Such activities can be improved by cooperation with Asian Productivity Organization (APO) and Green Productivity Association activities. Enterprises that become involved in these activities will become “green” companies and will survive in the global market.

ENVIRONMENTAL ACTIVITIES AT HITACHI

There are three core areas of environmental activities. The first one is the “creation of green products”, also described as designing products to solve environmental problems. The second is “environmentally friendly production” which means taking environmental considerations into account during manufacturing. In establishing the corporate environmental management system, all of the Hitachi group received ISO 14001 certification. The third is the “development of environmental technologies to contribute to the world’s socio-economic well-being.”

To integrate all these environmental activities, Hitachi has written an environmental charter covering all members of the Hitachi group. Its basic principles are: “contribute to society, conduct corporate activities in a fair and open manner, and promote harmony with the natural environment.”

Hitachi’s organizational structure reflects the importance of environmental activities in Hitachi’s business. The senior executive committee for environmental policy

is comprised of board directors, the group presidents, and CEOs. This committee reports to president and director Etsuo Shoyama and is responsible for top-down implementation of policies affecting both production facilities and affiliated companies through the environmental management operational committee. The environmental management policy office, corporate manufacturing engineering, and environmental policy department serve as the coordinating body to promote the three core areas of Hitachi's environmental activities.

ECO-DESIGN METHODS

The basic principle of eco-design consists of three elements based on the lifecycle of a product (Yamamoto, 1999). The first element is the cost of the product, which represents economic value. The second element is impact, which represents environmental value and the influence on the global environment through global warming, ozone layer destruction, and depletion of resources. The third is performance, which represents consumer satisfaction and is related to safety, benefits, and convenience. The integrated value of an eco-design product is the total of cost, impact, and performance. A product's eco-efficiency is measured by dividing the value of performance by impact. Until recently, products have only been evaluated against the ratio of their performance divided by cost, which fails to recognize the impact of the product. However, it is a basic principle of eco-design that we must maximize the value of the ratio of performance divided by the multiple of cost and impact.

In applying eco-design to the design process, the product is assessed twice in terms of its environmental aspects. The first assessment follows completion of the initial product design. Environmental aspects are assessed a second time after confirmation of product quality and performance through tests of prototypes. If there is a problem at either assessment stage, the design process stops and repeats the previous stage. Furthermore, market information on products already sold in the market is utilized to improve the design of the product.

There are currently six evaluation methods and five tools in the current eco-design process (Yamamoto, 1999 – see Table 1). Generally speaking, the most popular methods in Japan are the checklist method for qualitative evaluation and life cycle assessment (LCA) for quantitative analysis. Both are practiced at Hitachi. These methods use the following tools: guidelines for eco-materials selection; chemical management for pollutant release and transfer registration (PRTR); disassemblability evaluations (DEM); recyclability evaluation (REM); packaging guidelines; and the ISO14000 series. "Eco-assist", a software sold by Hitachi, is used in eco-design and incorporates EMS, LCA, and DEM/REM.

PRODUCT ASSESSMENT CHECKLIST

An example of a Product Assessment Checklist is shown in Figure 1. The checklist helps designers evaluate a product according to various assessment categories. As part of the process, the designer evaluates whether the new product is superior to the previous model in terms of environmental considerations. There are eight assessment categories,

and a maximum of five points are given for each category. A score of two points indicates that the environmental impact is the same as that of the previous product. The eight categories are: product weight, length of product life, recyclability, disassemblability, ease of treatment, environmental conservation, energy efficiency, and internal/external communication. A standard personal computer is used to carry out the assessment and the results are shown as a radar chart.

Table 1. Eco-Design Methodologies and Tools

Methodologies	Tools
Checklist for product assessment - Qualitative assessment	Guideline for eco-material selection
DfX-CAD - Combining CAD and individual modules	Management for pollutant release and transfer registries (PRTR)
LCA - Quantitative assessment of environmental impact through the life-cycle of products	DEM/REM
MIPS	Packaging guidelines
Back casting	ISO 14000 series (ECO-ASSIST)
Macro-approach - On-site environmental management system	

Three additional components are used to support a checklist assessment. The first is an eco-material selection guideline to reduce the environmental impact of product disposal and make it easier to recycle products. The second is chemical substance management guidelines and activities. The third is the use of DEM/ REM to evaluate product disassemblability and recyclability. These components are discussed further in the following sections.

ECO-MATERIAL SELECTION GUIDELINES

Hitachi uses eco-material selection guidelines for key raw materials such as plastics. The plastics presently used by Hitachi are graded A through D based on the following factors: energy consumption, cleanliness, recyclability (e.g., appearance, molding, and regenerative properties), material properties (non-halogen, flame retardant, high-temperature use, etc.), and cost. Materials are evaluated with respect to future environmental impact. A and B grade plastics are deemed as usable, while C and D grade plastics are considered problematic regarding environmental factors. For example, the best studied plastic in the eco-material guidelines is PVC. Although PVC is valuable as a by-product of caustic soda preparation, it causes problems when burned. It is thus rated as a D-grade molding material until cleaner incineration technologies can be developed.

Figure 1. Sample Checklist

			Evaluation							Remarks	
Items		performance	Old	New	1	2	3	4	5		
				1st	2nd						
Smaller products											
?	Smaller ? Less area ?	m3 m2				up	same	<10%	<20%	≥20%	Evaluated by reduction %
?	Less weight ?	kg		3	3	up	same	<10%	<20%	≥20%	Evaluated by reduction %
Higher reliability											
?	Parts reliability	Successful %		2	3	down	same			up	
?	Materials reliability	Successful %		2	2	down	same			up	
Reduction of packaging compared with old product											
?	Smaller, lighter carton ?	m3		3	3	up	same	<10%	<20%	≥20%	
		kg	2	2	3	up	same	<10%	<20%	≥20%	
?	Less styrene foam?	m3		2	2	up	same	<10%	<20%	≥20%	
		kg	2	2	2	up	same	<10%	<20%	≥20%	
?	Smaller, less wooden frame ?	m3		2	2	up	same	<10%	<20%	≥20%	
		kg	2	3	3	up	same	<10%	<20%	≥20%	
?	Less polyethylene coverage ?	kg		2	2	up	same	<5%	<10%	≥10%	
Less production waste											
?	Wastes from production stage	kg		3	2	up	same			down	
Total average			2.0	2.3	2.4						

Input points



ACTIVITIES TO CONTROL CHEMICAL SUBSTANCES

Hitachi classifies potentially environmentally hazardous chemical substances into three classes for voluntary control. Class 1 and 2 chemical substances are covered by voluntary action plans to either reduce or eliminate use. Class 3 substances are controlled by laws on pollutant release and transfer registries as well as publication of material safety data sheets (MSDS).

An internal network for chemical management based on these classes has been developed to assist Hitachi staff in eco-design (Figure 2).

EVALUATION OF EASE OF PRODUCT DISASSEMBLY AND RECYCLING

For a product to be environmentally friendly and easy to recycle, it is important to not only develop recycling techniques, but also to design the product in such a way that it is easy to recycle. Accordingly, recycling-compatible design means selecting materials and designing structures that facilitate the collection, disassembly, sorting, and recovery of product components.

Hitachi has developed DEM and REM to quantitatively evaluate the ease of disassembly and recyclability of new products. An example of DEM is shown in Figure 3. After the basic product design is completed, the disassemblability is evaluated using Hitachi's DEM. If the evaluation is satisfactory at the first stage, detailed design work is started. Once the more detailed design is completed, DEM is repeated. If the detailed design is judged as satisfactory, the first sample is made and mass production is started. However, if the design is determined unsatisfactory, it must be improved before production can begin. In the example in Figure 3, the calculated disassemblability time of an automatic washing machine shows that the disassembly time is reduced by more than half by adopting the "front-opening" design. Therefore, DEM/REM can also be used to improve design.

LIFE CYCLE ASSESSMENT (LCA)

LCA is a means of deriving a quantitative evaluation of product design and thereby refining product quality and characteristics. In addition to its use in new product design, LCA is increasingly regarded as a useful technique for evaluating products already in use. LCA analyzes the total impact of a product on the environment from extraction of the raw materials that go into the product through manufacture, usage, and final disposal.

The steps in conducting an LCA are: definition of goal and scope; inventory analysis; impact assessment; and interpretation of results. Inventory analysis of LCA involves data collection and calculation procedures to quantify relevant inputs and outputs of a product system. The impact assessment phase of LCA is aimed at evaluating the significance of potential environmental impacts by using the results of the life cycle inventory analysis.

Figure 4 depicts the LCA system implemented at Hitachi. The system uses a standard personal computer to quantitatively calculate resource consumption and environmental discharges. Using a refrigerator as an example, the results of an LCA on

Figure 2. Network System for Chemical Management

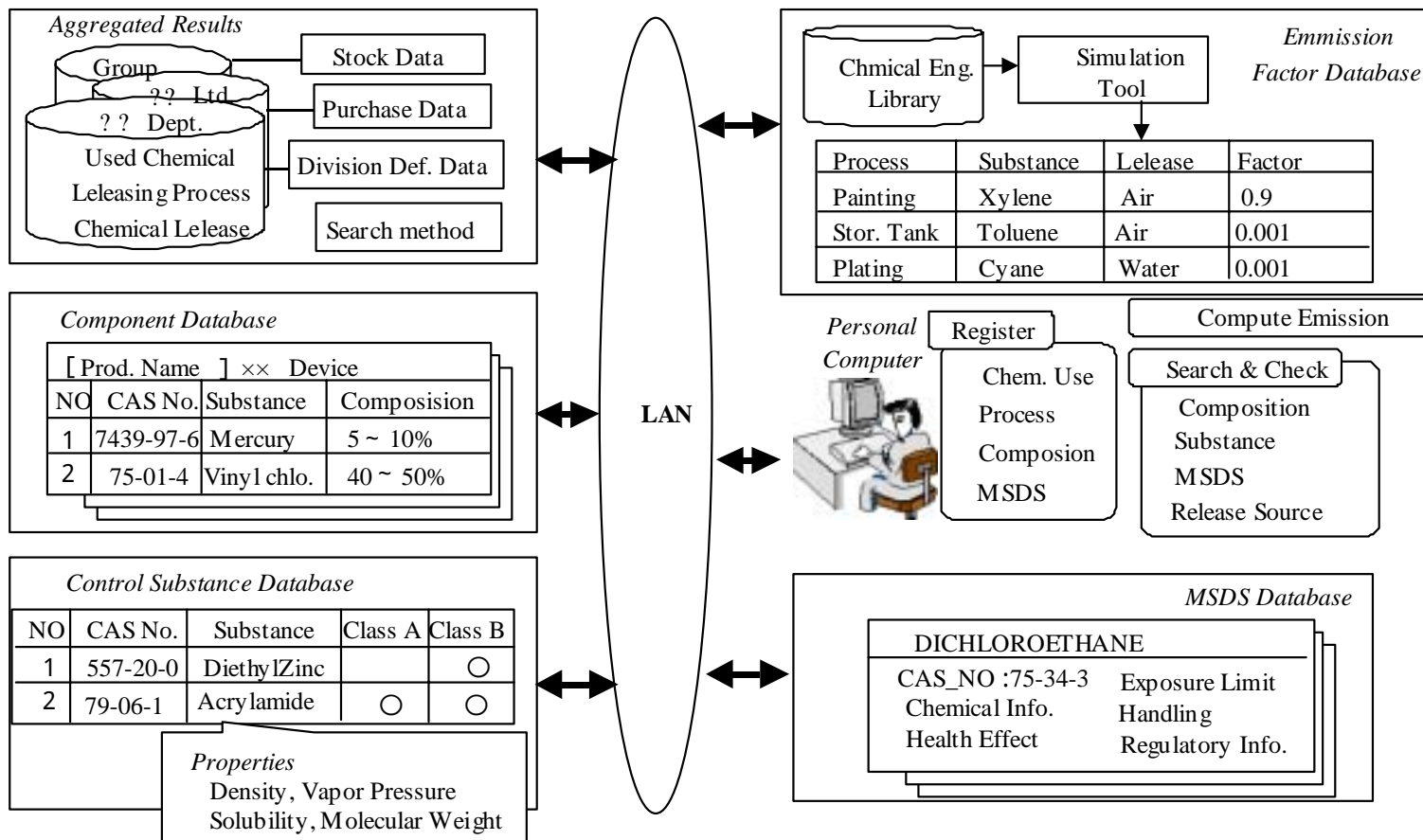


Figure 3. DEM Assessment of Washing Machine

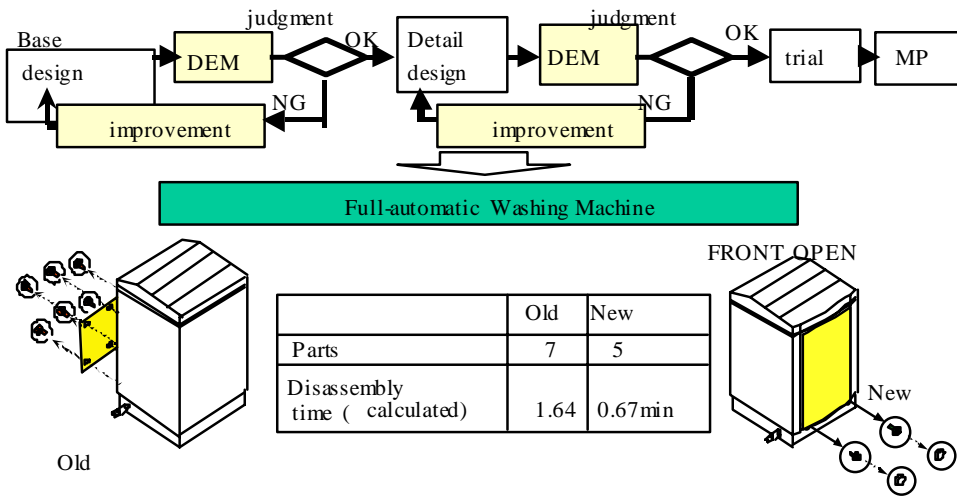
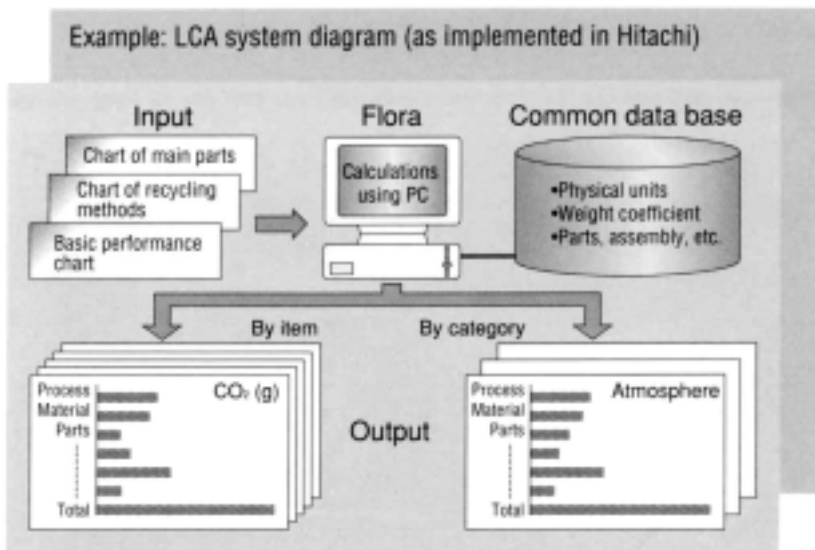


Figure 4. Hitachi LCA System Diagram

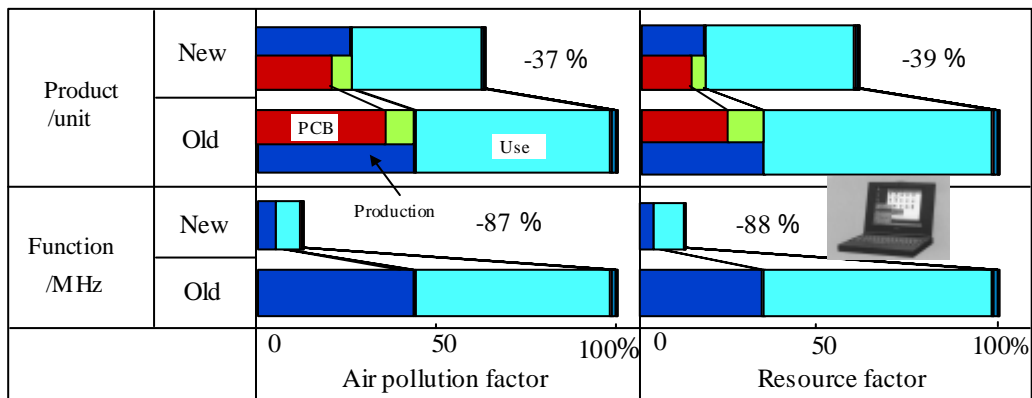


CO₂ discharge showed that most of the energy consumption during the life cycle of a refrigerator occurs during usage. As a result, energy-saving features have to be incorporated at the design stage.

Hitachi is doing this and is also making products that weigh less and last longer. The LCA results have been used in the development of a new type of eco-design refrigerator that reduces electricity consumption.

Figure 5 shows the LCA of a personal computer. It shows the air pollution factor and impact on resource depletion. It is clear that PCs have a significant environmental impact during both the production and usage stages. This LCA helped Hitachi design a new type of PC with lower environmental impact (37-39 percent per unit product and 87-88 percent per unit function) in both production and usage.

Figure 5. LCA of a Personal Computer



ECO-DESIGN PRODUCT EXAMPLES

Hitachi has already registered a number of eco-design products, and Figure 6 shows an example of Hitachi's eco-design refrigerator. As shown in the figure, by using a spiral fin condenser instead of a pulse fin condenser, the freezing cycle is simplified which reduces the disassembly time. In addition, the new model uses pulse-amplitude modulation control to save energy, minimize noise, and decrease freezing time. The use of PVC plastic is also reduced. The refrigerator's environmentally friendly design reduces disassembly time by 56 percent, increases recyclability by 48 percent, decreases amount of styrene foam packaging by 56 percent, and improves energy savings by 30 percent. The design received an Energy Conservation Program award from Japan's Ministry of International Trade and Industry (MITI).

Figure 7 shows another example of an eco-design product: a laptop computer. In the eco-design of this PC, the number of circuit boards was reduced, energy consumption was reduced by 34 percent, weight was reduced by 47 percent, and 90 percent of the metal parts are recycled.

VOLUNTARY ACTIONS IN THE JAPANESE COMPUTER INDUSTRY

In addition to actions by individual companies such as Hitachi, the Japanese computer industry as a whole is becoming more involved in eco-design. 40 kilotons of old personal computers (PCs) were discarded in Japan in 1999. Of these, 75 percent came from businesses and 25 percent from private users. It is estimated that the amount of waste PCs will increase to 100 kilotons in 2005 with business PCs accounting for 70

percent of this amount. It is thus clear from this trend that the industry should be more proactive in addressing the disposal of old PCs.

Figure 6. Hitachi Eco-Design Refrigerator

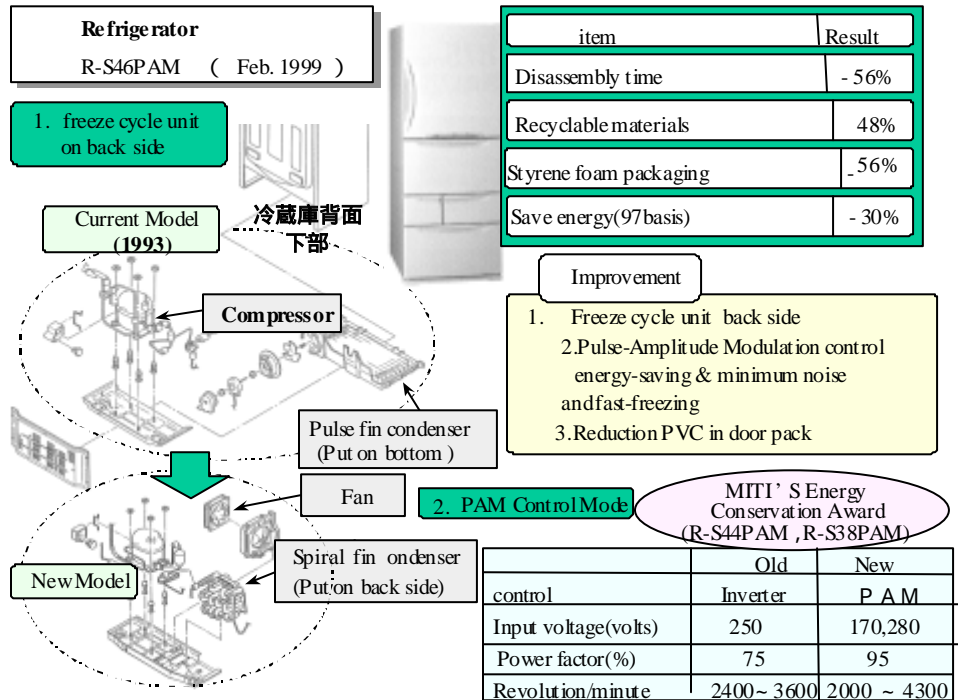
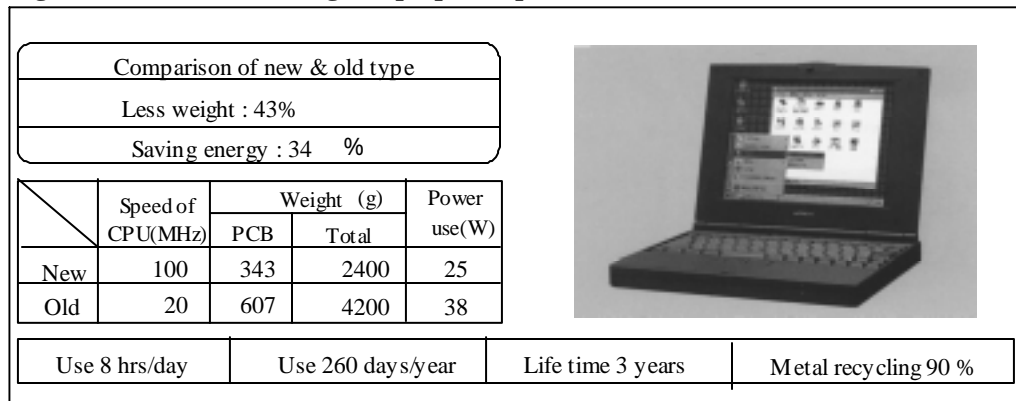


Figure 7. Hitachi Eco-Design Laptop Computer



The Japanese Electric Industry Development Association (JEIDA) has been promoting the 3Rs concept as a voluntary action plan. They are encouraging companies to reduce by-products (including packaging), reuse parts, and improve recycling of materials and thermal recovery. To promote the 3Rs concept, resolving the logistics of the

“take-back” of used products is important, and industry needs to establish goals and targets for the 3Rs. This voluntary action plan has been approved by 22 Japanese PC makers and related companies.

GREEN TECHNOLOGY TRANSFERS FROM JAPAN TO ASIA

One of the roles of Japanese companies is to promote Green Productivity in the Asia-Pacific region. Therefore, transforming eco-design towards Green Productivity is important. Hitachi is actively promoting GP technology transfer by inviting designers to come to Japan. Hitachi holds seminars and training programs on eco-design covering EMS, LCA, DEM/REM, chemical substance management, lead-free soldering, and PC weight reduction design. It is hoped that when these designers return to their countries with a better knowledge of eco-design technologies, they will promote these technologies throughout the Asia-Pacific region and help establish a sustainable economic society. To achieve this technology transfer, the support of Asian Productivity Organization is essential.

REFERENCES

- Hirano, M., “Hitachi’s Approach to Environmental Conscious Products” (in Japanese) from *Forum on Products Design for Environment*, Japan Society of Design Engineering, 2000.
- Hitachi Pamphlet, *The Environment and Hitachi*. Tokyo: Hitachi, Ltd, 1999.
- International Standards Organization, *ISO 14040 Environmental Management Life Cycle Assessment Principles and Framework*, 1997.
- Nagata, K. and Motoda, K., *Introduction on Design for Environmental Conscious Products (in Japanese)*, Tokyo, Ohmsha Co., 1998.
- Symposium Reference Material, *Life Cycle Assessment in Asian Countries*, Tokyo, LCA Japanese Forum, 2000.
- Takagi, T., *Transforming Eco-design, Eco-efficiency, Eco-material and LCA*, 2000.
- “Towards Green Productivity – The Japanese Experiences” from *APO Top Forum on Green Productivity*, Republic of China.
- Yamamoto, R, *Eco-design-Best Practice 100* (in Japanese), Tokyo, Diamond Co., 1999.
- Yokoyama, H., “Part of Japanese Industry for the Promotion of Green Productivity in Asia Pacific Region” from *Reference Material in Symposium on Green Productivity Promotion in Japan*, APO, 2000.