ISSN 1345-3041
MITSUBISHI ELECTRIC Jun. 2008 / Vol.122

ADVANCE

Mitsubishi Electric Group "Environmental Vision 2021"

MITSUBISHI ELECTRIC
Changes for the Better

Jun. 2008 / Vol. 122

MITSUBISHI ELECTRIC

ADVANCE

Mitsubishi Electric Group "Environmental Vision 2021"

Cover Story

Environmental Vision 2021 is a long-term environmental management vision of the Mitsubishi Electric Group. It establishes a framework for the Group in order to realize a sustainable society, and defines long-term initiatives to prevent global warming and to create a recycling-based society. See http://global.mitsubishielectric.com/company/csr/environment/vision/2021/index.html

• **Editorial-Chief**
Takeshi Sugiyama

• **Editorial Advisors**
Chisato Kobayashi
Shinji Iwasaki
Makoto Egashira
Koji Yasui
Hiroaki Kawachi
Masayuki Masuda
Satoshi Itoda
Kiyoji Kawai
Kazuhisa Hemmi
Taizo Kittaka
Hidenori Takita
Itsuo Seki
Katsuhiro Hase
Kazumasa Mitsunaga

• **Vol. 122 Feature Articles Editor**
Motohiro Tanaka

• **Editorial Inquiries**
Makoto Egashira
Corporate Total Productivity Management & Environmental Programs
Fax +81-3-3218-2465

• **Product Inquiries**
Motohiro Tanaka
Corporate Environmental Sustainability Group
Fax +81-3-3218-2465

Mitsubishi Electric Advance is published on line quarterly (in March, June, September, and December) by Mitsubishi Electric Corporation.
Copyright © 2008 by Mitsubishi Electric Corporation; all rights reserved.
Printed in Japan.

CONTENTS

Technical Reports

Technical Highlights

Note: Mitsubishi Electric's fiscal year ends March 31. References to "FY 2008" are for the fiscal year ending March 31, 2008.

Overview

Author: *Michio Hiruta**

Environmental Management and Long-Term Vision

Issues related with the prevention of global warming are being actively discussed worldwide today, involving not only advanced countries but also developing nations. Matters related with global warming are to be discussed as one of the main topics at the G8 Summit Conference which is scheduled to be held at Lake Toya, Hokkaido Prefecture, on July this year. Effective utilization of resources is also considered to be essential for the realization of a recycling-based society. In other words, environmental issues are very important challenges for all of us, including national governments, companies, and individual citizens, to consider and act on properly.

Up to now, the environmental initiatives taken by companies have typically focused on cost efficiency. However, the time has come for companies to establish "environmental management systems" which are designed to support both environmental and corporate operations. Environmental considerations and profit generation are both targeted under such environmental management systems, while laying the essential foundation for the sustainable development of corporations.

Mitsubishi Electric Group has continuously established an "Environmental Plan" every three years since 1993. At present, the "Fifth Environmental Plan" is being promoted. The Environmental Plan has been improved and extended by conforming more strictly to related laws and regulations and expanding the scope of voluntary environmental measures. In addition to these efforts, Mitsubishi Electric Group has developed its own "Environmental Vision 2021," the targets of which are aimed to be achieved in 2021, the 100th anniversary of the founding of Mitsubishi Electric. The "Environmental Vision 2021" represents Mitsubishi's view on the prevention of global warming and realization of a recycling-based society, while defining the ideal position of Mitsubishi Electric Group for realizing a sustainable society. Mitsubishi Electric Group is going to contribute to the realization of a sustainable society on the basis of Mitsubishi's widely-recognized, extensive and highly advanced "technologies" and the positive and continuous "actions" of Mitsubishi's employees.

* *Corporate Environmental Sustainability Group*

Mitsubishi Electric Group "Environmental Vision 2021"

Author: *Michio Hiruta**

Article Introduction

The Mitsubishi Electric Group has formulated an Environmental Plan every three years since 1993 for reducing environmental load levels and improving environmental management. The Fifth Environmental Plan, which started in 2006, calls for both defensive and offensive measures to improve globally-linked environmental management as well as to enhance the environmental performance of the entire supply chain.

On the other hand, since environmental preservation requires a global, long-term approach, companies must adopt a long-range perspective. Mitsubishi Electric Group has therefore developed its own Environmental Vision 2021 aiming to achieve particular targets by 2021, the 100th anniversary of the founding of Mitsubishi Electric.

Environmental Vision 2021 represents Mitsubishi's long-term efforts toward the prevention of global warming and creation of a recycling-based society, and defines the ideal position of the Mitsubishi Electric Group for realizing a sustainable society. Based on the guiding principle of "Making Positive Contributions to People and the Earth with Technology and Action," the Mitsubishi Electric Group will continue to work hard toward creating a sustainable society using its extensive range of sophisticated technologies and the collective might of action by all its employees.

Going forward, Mitsubishi will take practical measures in accordance with its Environmental Plan formulated every three years and Environmental Vision 2021.

1. Introduction

In 2007, the Intergovernmental Panel on Climate Change (IPCC) concluded that "global warming is now an indisputable reality", indicating that the global environment is undergoing serious changes. Environmental problem was also discussed as one of the most important global issues at the G8 Summit Meeting at Heiligendam. The summit meeting agreed to a common global target of halving total CO_2 emissions by 2050. Meanwhile, design for environment, recycling, and regulations on the management of chemical substances for the construction of a sustainable society have been promoted in Europe and subsequently in the Americas and Japan. International standardization for the same purpose has also been underway.

Immediate action for curbing global warming and creating a recycling-based society is required. All companies and every person around the world must pay attention to environmental conservation and try to reduce their environmental footprint with a sense of responsibility.

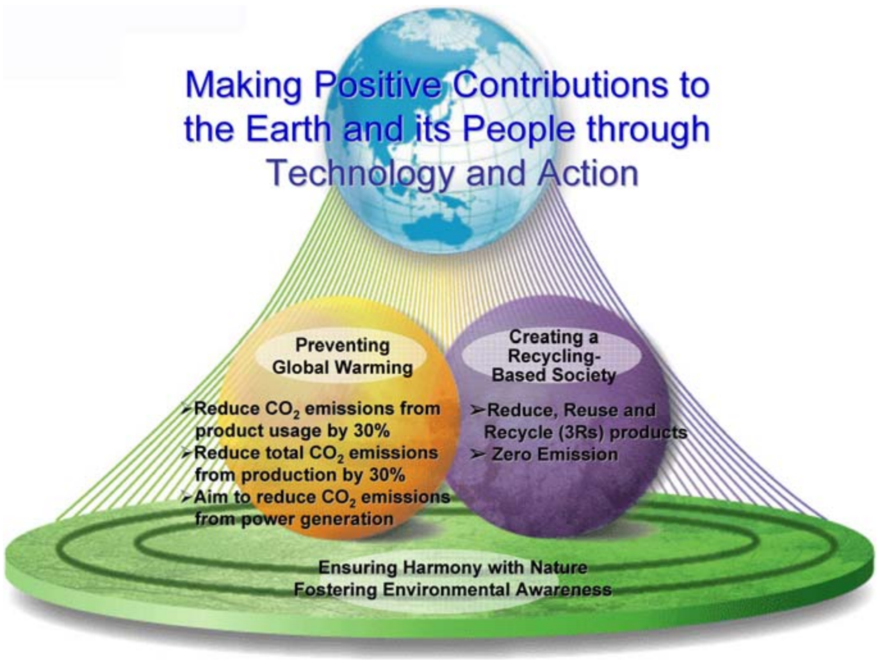

Fig. 1 Concept of the vision

The Mitsubishi Electric Group recently announced its Environmental Vision 2021 which sets 2021 as the target year, commemorating the 100th anniversary of the founding of the company. As an electric manufacturer, the Mitsubishi Electric Group is helping to reduce global environmental load through its technologies and actions. Specifically, it has set the following targets.

2. Initiatives to Prevent Global Warming

To help meet the global common goal of halving total CO_2 emissions by 2050, we will reduce CO_2 emissions resulting from product usage by 30% and total CO_2 emis-

*Corporate Environmental Sustainability Group

Fig. 2 Background to establishing environmental vision

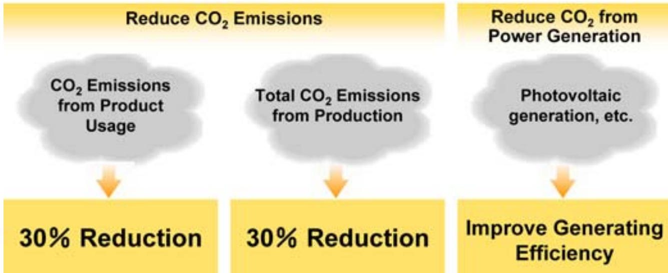

Fig. 3 Initiatives to prevent global warming

sions resulting from production by 30%. We will also aggressively reduce CO_2 emissions resulting from power generation by introducing photovoltaic power generation, increasing our social contribution, and strengthening our business operations.

2.1 Initiatives for reducing CO_2 emissions resulting from product usage by 30%

We will develop technologies and encourage the use of energy-saving products, aiming to reduce the CO_2 emissions resulting from product usage by 30% by 2021 compared with the level in 2000. The CO_2 emissions resulting from using Mitsubishi's products are typically 40 to 50 times those resulting from production, so the CO_2 reduction effect of improving the energy efficiency of products while in use will be extremely large. It is important to set a target for reducing CO_2 emissions associated with product usage for effective measures.

Specific measures include: (1) improving our core technologies developed over the years (motor technologies, heat pump and air-conditioning technologies), (2) innovating inverter/power semiconductor technologies that can be applied extensively across all operations, and (3) developing system solutions that help save energy such as e-F@ctory[*1].

2.2 Initiative for reducing total CO_2 emissions resulting from production by 30%

The Mitsubishi Electric Group aims to reduce total CO_2 emissions by 30% (520 thousand tons) by 2021, assuming the group will grow annually by 3% in the domestic market and 5% in the international market. (The base year for Mitsubishi Electric's independent performance in the domestic market is fiscal 1991; for subsidiaries and affiliates in the domestic market is fiscal 2001; and for subsidiaries and affiliates in the international market is fiscal 2006.) In order to achieve these targets, the following measures will be taken.

(1) Continuously invest in energy efficiency at all key locations throughout the group at a target rate of 0.1% of production value and assign top priority to introducing high-efficiency equipment such as energy-saving air conditioners and inverters.
(2) Set energy efficiency targets for all key locations and reinforce energy efficiency diagnosis and inspection activities, to detect and improve energy losses associated with both facilities and operating conditions.
(3) Install photovoltaic power systems at model factories, accumulate know-how, and then expand the systems to all group companies.

2.3 Aiming to reduce CO_2 emissions from power generation

We will help prevent global warming by reducing CO_2 emissions from power generation, and will supply our products and systems to power generation operations that do not emit CO_2, such as photovoltaic and nuclear power generation.

We will encourage the use of photovoltaic power generation and improve the conversion efficiency of solar cell modules (NEDO's target value: 25% for PV2030). For nuclear power generation, we will step up initiatives to reduce CO_2 emissions from power generation with existing and newly constructed power plants by providing our electric equipment and control systems on a package deal basis spanning from design and manufacture to maintenance.

NEDO "PV2030": "PV Roadmap Toward 2030" formulated by the New Energy and Industrial Technology Development Organization, which sets a target value of 25% efficiency by 2020.

3. Initiatives to Achieve a Recycling-Based Society

For the realization of a recycling-based society, it is crucial to enforce the 3R (Reduce, Reuse, and Recycle) principle for using resources to maintain the eco-system and build a prosperous society.

*1 An IT-based solution for production lines proposed by Mitsubishi Electric

Fig. 4 Motor

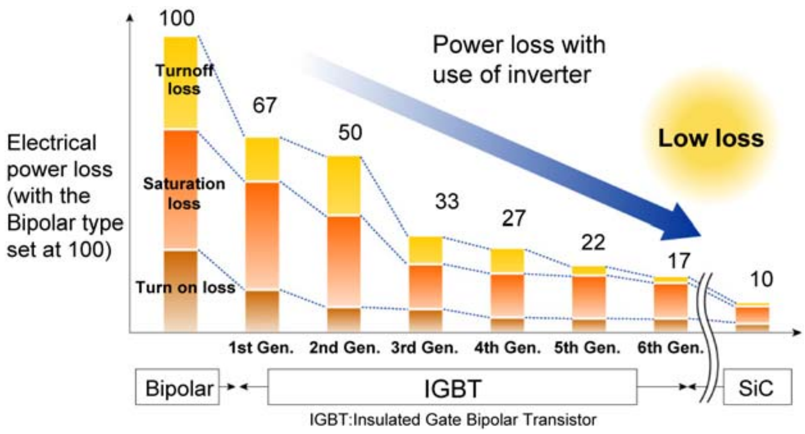

Fig. 5 Electrical power loss of power semiconductors in inverters

3.1 Promotion of 3R (Reduce, Reuse, and Recycle) through Mitsubishi's DfE*2 and LCA*3 technologies

We will strengthen the 3R principle throughout the life cycle of products.

Reduce: We will set a size/weight target for each product and use an optimum amount of raw materials, aiming to reduce resource inputs by 30%.

Reuse: We will expand product lease and rental programs and maintenance services.

Recycle: We will improve our closed-loop recycling program for our own use of the plastics recovered at home appliance recycling plants by using Mitsubishi's advanced plastic sorting technologies for a target recycling rate of 100%.

We will also build an information system containing the details of chemical substances used in all of our products to ensure traceability throughout the supply chain.

3.2 Efforts for zero emissions

To reduce direct landfill to zero for the wastes generated from production processes, we will take measures to eliminate emissions in the true sense. This requires continuously taking measures for soil contamination prevention, waste water control, control of VOC*4 release to the atmosphere, and restriction of the generation of wastes while promoting efficient reuse and recycling of wastes. We will also share the waste data and cases throughout the group by using a waste database system for enhanced recycling operation. We must also forge alliances with waste-recycling companies outside the group as well as with affiliate companies to establish a waste processing system that takes regional characteristics into consideration.

4. Ensuring Harmony with Nature and Fostering Environmental Awareness in Employees

To create a sustainable society, it is important to preserve the inherent purifying ability of nature; forests are the source of biodiversity. However, most of the forests in Japan are neglected and degraded. Between 2000 and 2005, the global area of forests decreased at a rate of about 7.3 million hectares per year; it is too late now to depend merely on natural regeneration to recover these lost forests.

The foundation of a sustainable society in harmony with nature is people having environmental awareness. The Mitsubishi Electric Group will ensure harmony with local communities and nature by promoting programs to foster environmental awareness, which is also indispensable for achieving the Environmental Vision 2021. We will engage in nature conservation activities and environmental education involving about one million participants, including the families of our employees and local residents. We will foster environmental awareness through programs for teaching the significance of living in harmony with nature through real-life experiences. In addition, to convey these activities to the next generation, we will train 1,000 nature conservation leaders (from the entire Mitsubishi Electric Group) who will run nature education activities for children involving natural observation and experience. As for nature conservation activities, we will focus on forests in particular which are the source of biodiversity and promote forest development and woodland preservation activities to maintain the inherent purifying ability of nature, including at our overseas locations.

*2 Design for Environment
*3 Life Cycle Assessment
*4 Volatile organic compounds

5. Conclusion

Today, humankind faces the challenges of attaining both economic affluence and environmental conservation. It is difficult to achieve, and requires unimaginable efforts from everyone. However, the Mitsubishi Electric Group will steadily work toward our Environmental Vision 2021 with technologies and actions, through continuous innovation of products as expressed in our corporate motto “Changes for the Better.”

We hope this report may help improve the global environment.

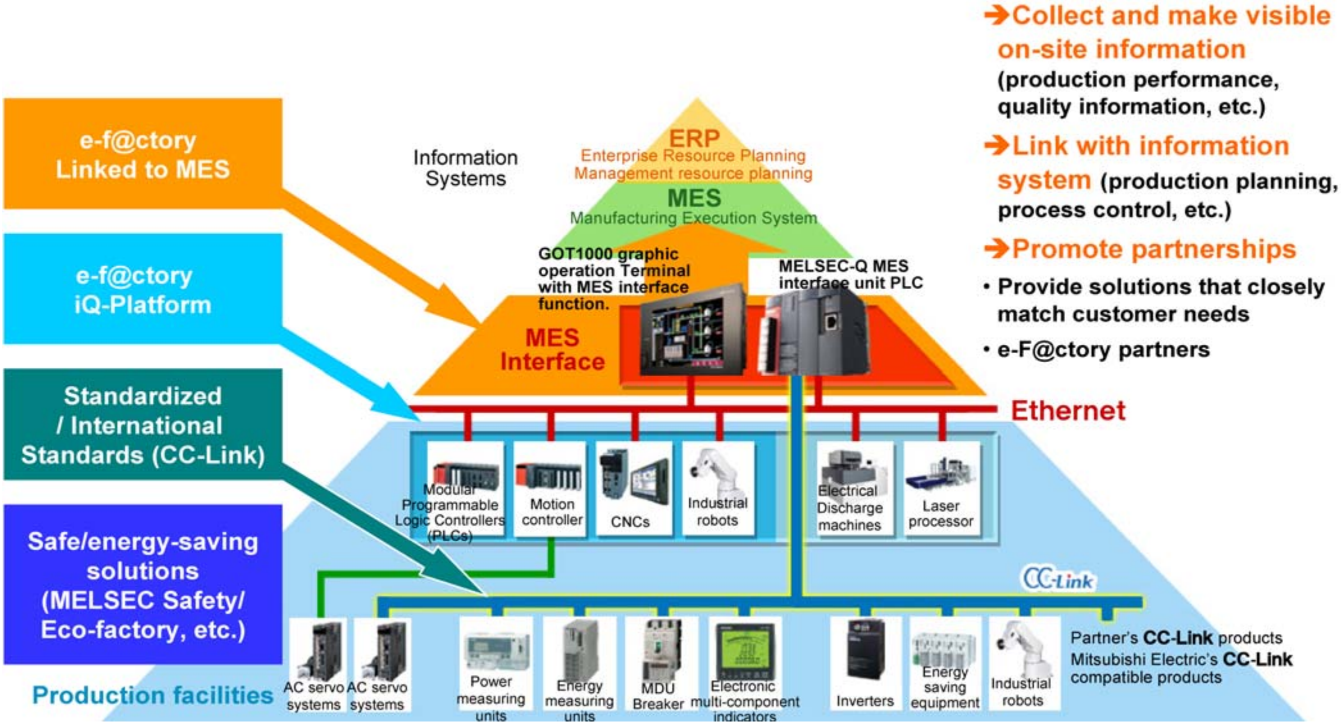

Fig. 6 e-F@ctory solution

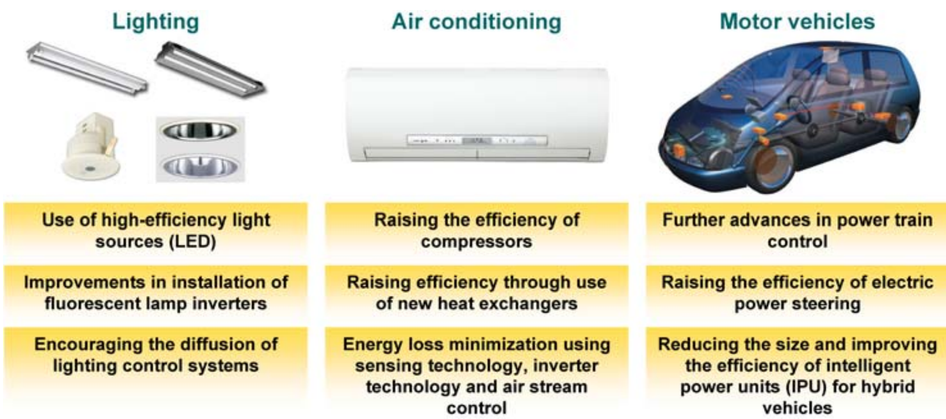

Fig. 7 Recent examples of initiatives to reduce CO_2 during use

HVIC: high Voltage IC DIP-IPM:Dual-In-Line Package Intelligent Power Module
IGBT:Insulated Gate Bipolar Transistor ASIPM:Application Specific Intelligent Power Module

Fig. 8 Power semiconductors

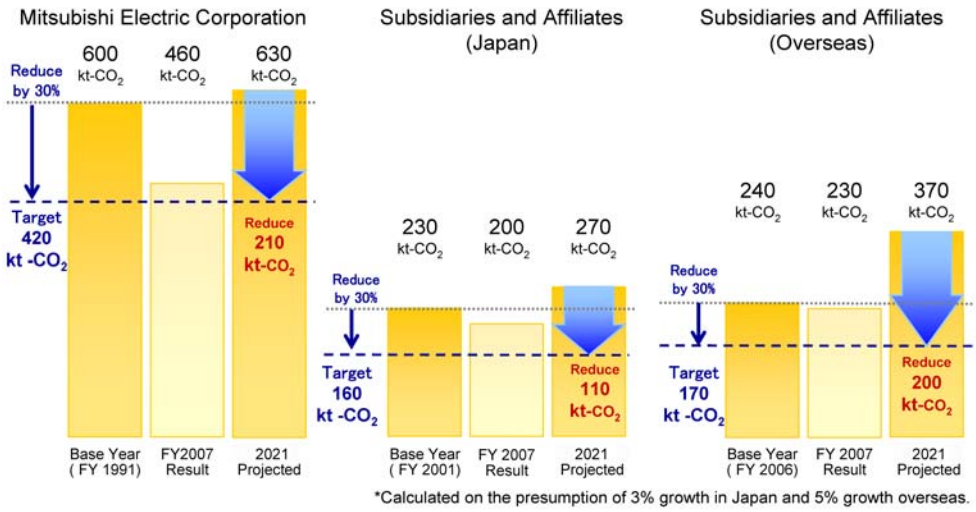

Fig. 9 Aim to reduce total CO_2 emissions from production by 30%

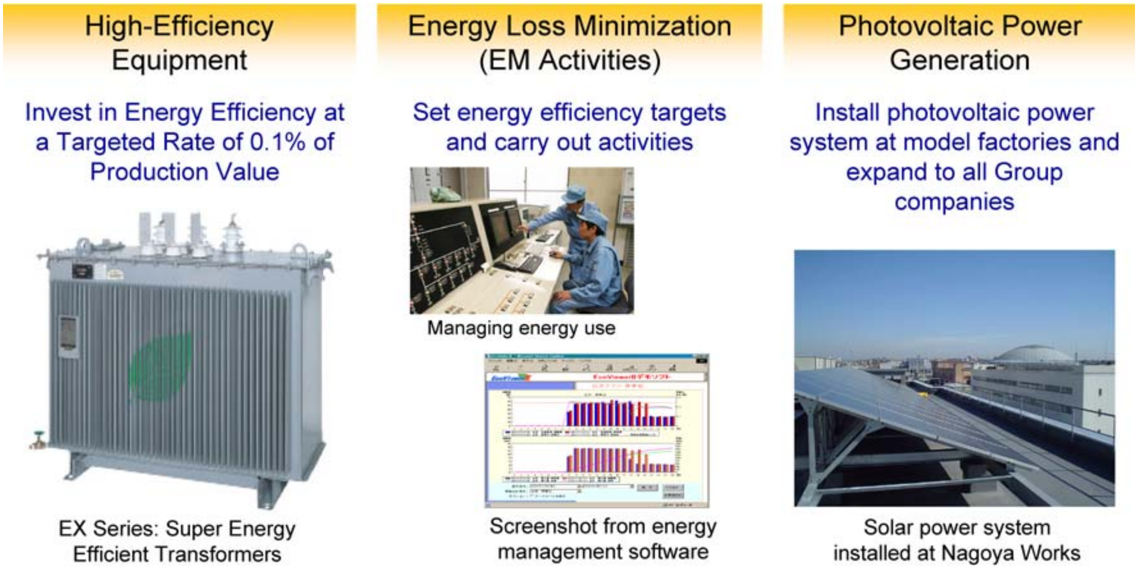

Fig. 10 Reduce total CO_2 emissions from production by 30%

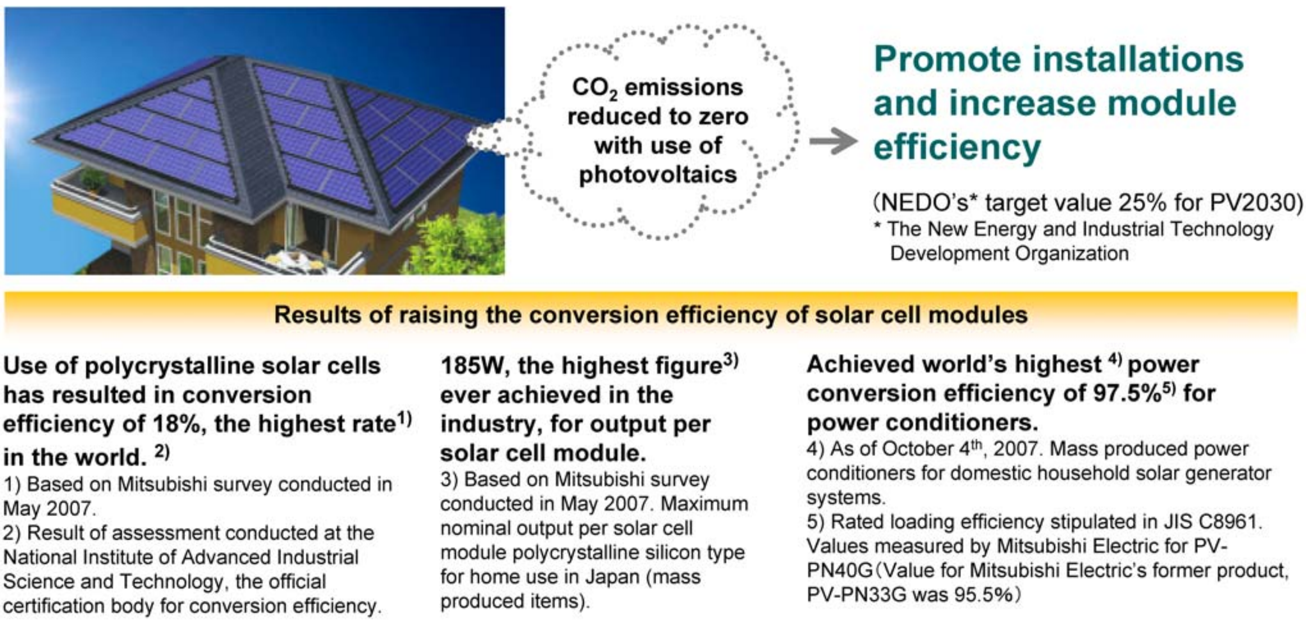

Fig. 11 Photovoltaic system

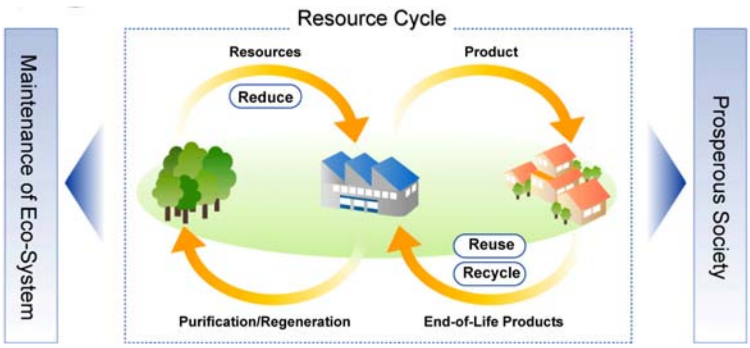

Fig. 12 Initiatives to achieve a recycling-based society

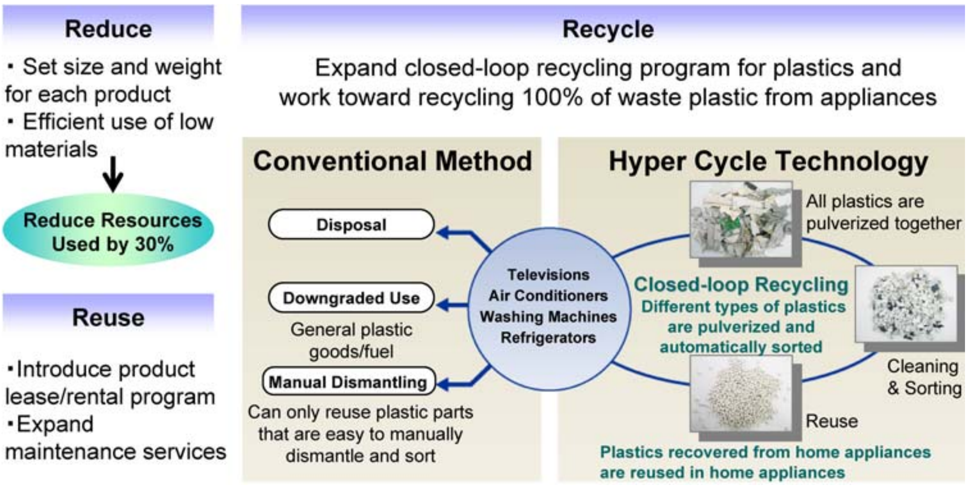

Fig. 13 The 3Rs: reduce, reuse and recycle products utilizing DfE and LCA technologies

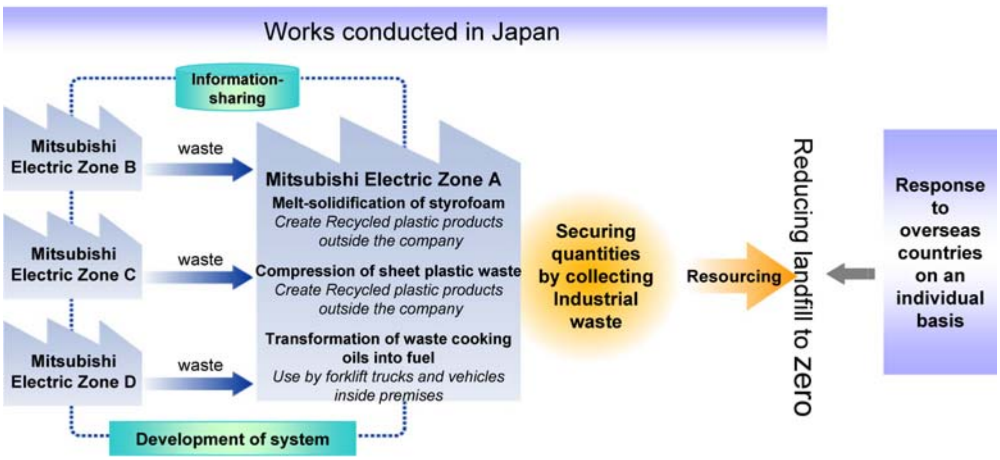

Fig. 14 Zero emissions

Fig. 15 Ensuring harmony with nature and fostering environmental awareness

Mitsubishi Electric's Measures for Environment-Conscious Products

Author: *Motohiro Tanaka**

1. Introduction

To reduce the environmental load of products, Mitsubishi Electric has done the following: (1) developed technology for assessing products, and introduced it to the company's management system, (2) developed a Factor X indicator for comprehensively quantifying and improving the environmental performance of products, and (3) ranked products based on Factor X as an evaluation indicator ("Eco-Products" or "Hyper Eco-Products"). We have been implementing basic measures for the environmentally friendly design of products, and are now entering a new phase toward "Environmental Vision 2021."

2. Product Assessment

2.1 Concept of "Design for Environment"

In December 1999, Mitsubishi Electric formulated its "Policy Related with the Definition and Idea of Design for Environment" that takes into account the idea of designing for the environment, as shown in Figure 1.

As shown, the principles are to consider all stages of the product life cycle, including the manufacturing process, disposal process, and recycling process, and for the company and external suppliers and vendors to cooperate to reduce the total environmental load. The three points described below are called the "MET perspective." "M" for Material means effective use of resources; "E" for Energy means efficient use of energy; and "T" for Toxicity means reduce use of substances potentially harmful to the environment. These perspectives are emphasized in order to reduce the environmental load associated with products and production.

2.2 Product assessment regulation

We established the "Product Assessment Regulation" in October 2001 in response to the enforcement of the "Basic Law for Establishing a Recycling-Based Society" in April 2001. Product assessment means assessing the environmental impact of the production and use of products, before production begins. If the assessment shows that the environmental impact of a product is found to be greater than that of the conventional model, the product is returned to the design phase for modification to reduce the environmental load. If the environmental load of a product is too high, the product will not be produced. By incorporating this product assessment in the production phase, Mitsubishi Electric is working to reduce the environmental load.

2.3 Product assessment procedure

The product assessment procedure is as follows:

(1) Product assessment is conducted in the product

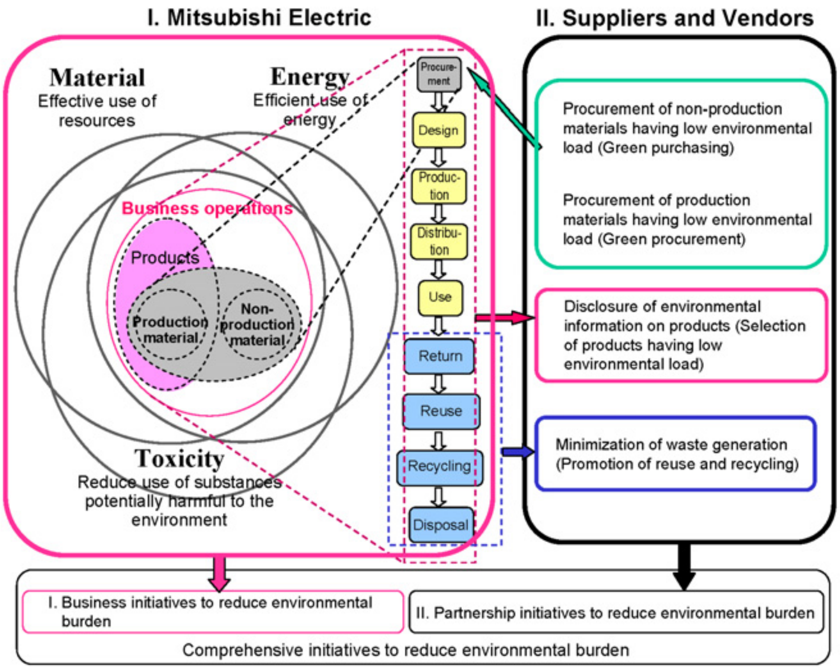

Fig. 1 Concept of Mitsubishi's design for environment

*Corporate Environmental Sustainability Group

development and design phase.

(2) Baseline products are selected.
(3) Products are assessed individually for the respective assessment items.
(4) The total score is assessed in accordance with the individual assessment.
(5) The necessity of measures such as design change is determined (total judgment).
(6) Assessment records are stored.

The acceptance/rejection decision (total judgment) is first made by the design division, then by a division providing an objective evaluation, and finally by the plant manager. A baseline product is selected for comparing how the environmental load of products has been reduced relative to the baseline product. The baseline products are selected from Mitsubishi's products of 1990 corresponding to the current products. When targets of environmental load reduction are determined for phase-based achievements over the medium and long term, the same baseline product is used for a series of development phases. Otherwise, assessment of a product in each development phase based on a previous model as the baseline product is permitted, providing the policy of "better than the previous model" is followed.

Table 1 shows the individual assessment items.

Table 1 Individual assessment items of product assessment

Assessment item	Main targets of assessment
1) Weight reduction	Reduction of the amount of materials to be finally discarded by downsizing and/or reducing the weight of products
2) Service life	Reduction of the amount of materials to be finally discarded by extending the lifespan of products by improving durability, using upgradeable design, and/or improving the repair system
3) Resource reuse	Reduction of the amount of materials to be finally discarded by recycling metals and resin materials
4) Reusability	Reduction of the amount of materials to be finally discarded by reusing parts, etc.
5) Product crushing	Easier crushing procedure
6) Ease of dismantling/separation of materials	Easier dismantling and separation for reuse, recycling, and disposal processing
7) Recovery/transport	Easier recovery and transportation of products by waste disposers
8) Product safety and environmental friendliness	Prohibition, reduction, or safety measures for harmful, toxic, or dangerous substances
9) Product packaging	Reduction in the volume of packaging, reuse and recycling of packaging material
10) Energy conservation	Reduction of energy consumption and reduced use of consumable materials
11) Information disclosure	Disclosure of information for reuse, recycling, and disposal
12) Manufacturing process	Reduced emissions of harmful/toxic substances from the manufacturing process and energy saving and reduction of waste associated with manufacturing
13) Distribution	Reduction of environmental load by improving and increasing the efficiency of distribution systems
14) LCA	Establishing a guideline for product development to reduce environmental load by clearly identifying the environmental load indicators of the respective phases of raw material arrangement, product manufacturing, transportation, usage, and disposal

3. Method of Assessing the Environmental Performance of Products

We have developed a unique "Factor X" indicator to assess the degree of improvement achieved in reducing the environmental load of a product.

3.1 General concept of Factor X

The "X" is a variable to indicate the multiples (i.e. multiple number) of the value of "environmental efficiency" of a product at a time against the value of the "environmental efficiency" of the baseline product at the baseline time. The factor is expressed by:

Factor = Environmental efficiency of the product under assessment/Environmental efficiency of the baseline product

This equation was announced officially in the "Guideline" published by the Japan Environmental Management Association for Industry in 2004 [(1)].

Performance factor = Performance of new product/Performance of old product

Environmental load factor = (Degree of environmental load reduction) – 1 = Environmental load of old product/Environmental load of new product

If the above expressions are true, then the following expressions are also true for the factor:

Factor = Environmental efficiency of new product/Environmental efficiency of old product

= Degree of performance improvement/Degree of environmental load reduction

= Performance factor × Environmental load factor

The expressions indicate that the factor assesses not only the degree of environmental load reduction but also the degree of improvement in product/service performance. In short, it is reasonable to use Factor X to measure the degree of improvement in environmental performance of products.

3.2 Mitsubishi Electric's Factor X

Mitsubishi Electric's Factor X is unique in that the calculation follows the "MET" perspective mentioned above (Reference 1).

(1) The expression "Factor X = Performance factor × Environmental load factor" does not represent the factor value by means of a single item; it indicates clearly the contribution of both environmental load reduction and performance improvement to the value of the factor.
(2) The environmental load factor integrates the degrees of reductions of all environmental load reduction items into a single value. Multiple environmental load reduction items are classified on the basis of the MET perspective, and the degree of reduction of each perspective is numerically expressed as (the square root of the sum of the

squares of multiple reduction degrees of individual items), and finally integrated into a single value by vector synthesis of M, E, and T indicators.

(3) The performance factor adds up the degree of improvement in the performance of basic functions and product service life. If multiple basic functions are to be assessed, the degrees of improvement in the performance are integrated into a single value by calculating the arithmetic mean. Basic functions are defined for the types of products.

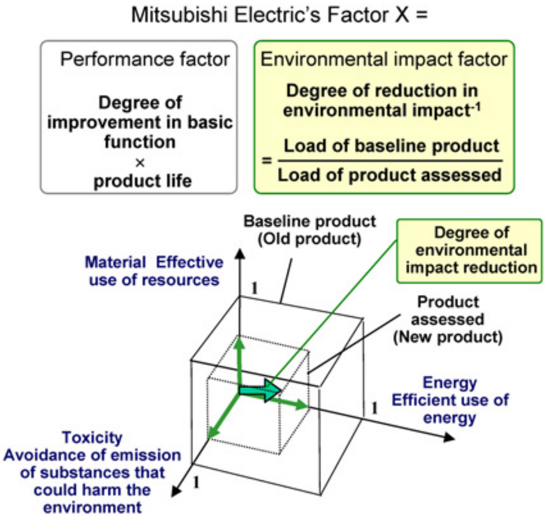

Fig. 2 Mitsubishi Electric's factor X

4. Ranks of Environment-conscious Products

Mitsubishi Electric established an "Environmental Plan" for the medium and long term starting in 1993 and has been working to reduce environmental load and promote environmental management. The Fourth Environmental Plan for fiscal 2004–2006 and the Fifth Environmental Plan for fiscal 2007–2009 included the establishment of the ranking of environmental products: "Product assessment," "Eco-Products," and "Hyper Eco-Products" (Fig. 3).

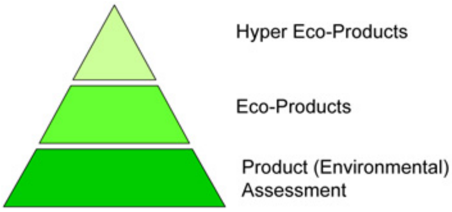

Fig. 3 Ranking of environment-friendly products

With Eco-Products and Hyper Eco-Products, Factor X is used as a quantitative indicator and a certification criterion (Table 2). The candidate groups of products for Eco-Products are selected and registered by respective business headquarters; they are considered as a parent population. The ratio of Eco-Products to the parental population is determined from the production output and weights and is defined as the "Eco product ratio." The target values of the environmental plan for the respective business headquarters and the whole of Mitsubishi Electric are determined in order to encourage the development and sale of Eco-Products. In fiscal 2007, 79 product groups were designated as "Design for Environment"; as a result, the Eco-Product ratio reached 82%.

Table 2 Definitions of eco-products and hyper eco-products

Definition of Eco-Products
1. "Environment-friendly products" satisfying any of the following items: (1) Products satisfying predetermined quantitative criteria including degree of Factor improvement and social contribution (The standard values of respective product groups are to be defined by relevant business headquarters.) (2) Products which have been recognized as the best products (top-runner products) in their class or received an environment-related award of excellence 2. "Environmentally effective products" whose use directly leads to environmental improvements
Definition of Hyper Eco-Products
1. Products certified by in-house certification procedure, employing a new concept or innovative technology that contributes to sustainability 2. Products which have obtained a Factor value of 2 or higher 3. Products which have received a prestigious environment-related award of excellence

5. Environmental Vision 2021 and Measures for Products

5.1 Completion of Eco-Product promotion

The target Eco-Product ratio in the Fifth Environmental Plan is 100% for mass-produced products, which are comparatively high in the development cycle and produced in large quantities. This means that the product design and manufacturing phases are continuously subject to environmental consideration for all the products. We believe that the basic target can be achieved within six years of the Fourth and Fifth Environmental Plan, and that promotion of Eco-Products will be completed simultaneously.

5.2 Future measures for products

The Environmental Vision 2021 aims to reduce CO_2 emissions from product use by 30% and the material input volume by 30% by the year 2021. With key environmental initiatives now incorporated in all our products, technological innovations are indispensable for achieving these targets. The measures for products taken in the past were incremental improvements made mainly by defining the environment-friendly performance in the form of indicators (visualization). We must continue to improve our efforts so that they will be important activities in the management of the company.

Reference:

(1) Takahashi T. et al.: Evaluation methods and Applications of Factor X Indicator for Realization of a Sustainable Society, 4th International Symposium on Environmentally Conscious Design and Inverse Manufacturing 3D-2-1F (2005)

LCA Technology to Support Design for Environment –Application of LCA Standard Tool –

Author: *Etsuko Hirose**

1. Introduction

The Mitsubishi Electric Group has employed Life Cycle Assessment (LCA) as a product assessment item to secure Design for the Environment while verifying the effects of improvements employed throughout the life cycles of products. For the introduction of LCA, we have constructed a database and assessment procedure and made efforts to diffuse and establish LCA technology. This paper reports the outline of "Company standard data directory" which has been developed by the designers for evaluating environmental load from the initial stage of development.

2. Trend of LCA

Today, to reduce greenhouse gases and create a recycling-based society which promotes zero emission, reduction of environmental load should be considered from the initial stage of product development, namely the design stage. To do this, great emphasis has been placed on LCA technology that can quantify environmental load in all stages of the product or service life cycle, including resource mining, design, manufacture, transportation, usage, and disposal. As shown in Fig. 1, LCA is a technique to analyze the environmental load on the global environment throughout the life cycle stages; LCA technology is specified as an ISO 14040 series standard by the International Organization for Standardization (ISO) and also as a JISQ 14041 standard in JIS (Japanese Industrial Standards).

A five-year national LCA project "Development of Assessment Technology of Life Cycle Environment Impacts of Products and so forth," sponsored by the Ministry of Economy, Trade and Industry, started in 1998. The project ended in March 2003, achieving objectives such as constructing a Japanese public database and establishing a Japanese version of the assessment method. Following on from this, the second phase LCA project "Development of Technology to Assess and Verify Life Cycle CO_2 Emissions" was started. Some of the project activities have been developed to be applicable to practical LCA. The progress and achievements of the projects are introduced on the Web[1].

On the other hand, the EuP Directive, which effectively makes LCA in product design compulsory, was enacted in Europe, for reducing product-related loads on the environment. At the same time, clients have increasingly requested that LCA data be submitted as a green procurement requirement. Furthermore, with the ECO LEAF and Swedish EPD program, as a Type III Environmental Label, LCA results have increasingly been disclosed publicly[2],[3].

The Mitsubishi Electric Group has also performed LCA on the basis of "3R (Reduce, Reuse, and Recycle) Product Assessment" standards consisting of 14 major

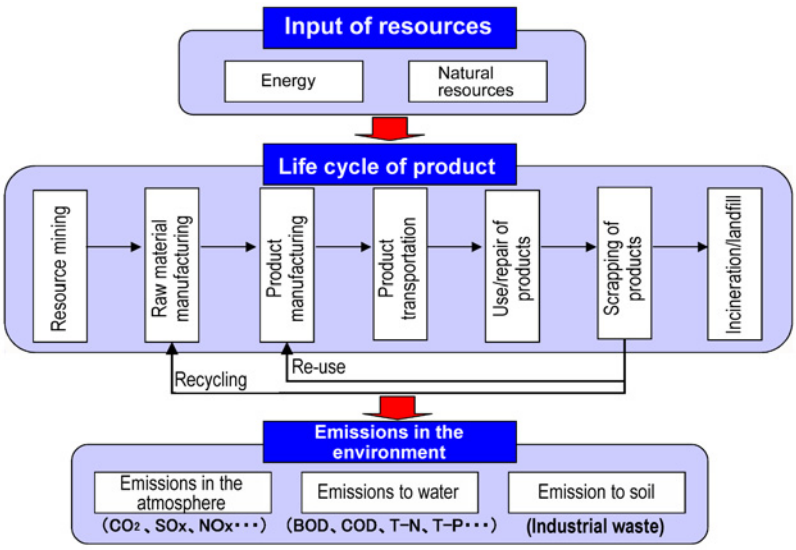

Fig. 1 Concept of LCA

*Advanced Technology R&D Center

division items and 51 medium division items, which are defined from the MET (Material, Energy, and Toxicity) perspective to promote the Design for Environment while verifying the effects on reducing environmental load throughout all stages of product life cycles.

3. Outline of Company Standard Data Directory

Figure 2 shows the execution procedure of LCA specified in ISO 14040.

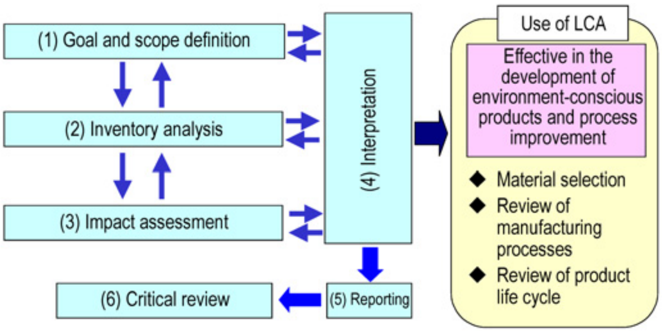

Fig. 2 Execution procedure of LCA

The first step is "Goal and scope definition," in which the scenario of the life cycle subject to assessment in accordance with the objective is defined. In the central step of LCA "Inventory analysis," the input and output data related with the environment in each phase of products are collected and processed. In "Impact assessment," the results obtained from the inventory analysis are divided into "Global warming," "Acid rain", and other division items for quantitative assessment of the items on the basis of the characterization coefficients defined for the respective division items. In the step "Interpretation," the results of the inventory analysis and impact assessment are interpreted and concluded in accordance with the goal and scope of the assessment. This procedure will clarify how to effectively improve and modify the product. Furthermore, preparation of reports and verification through the steps of "Reporting" and "Critical review" ensure the objectivity of the LCA results. Mitsubishi Electric has compiled the LCA execution procedure based on practical cases that conforms to the ISO requirements in "LCA Assessment Manual." In addition, Mitsubishi Electric has created an "Company standard data directory" so that designers can assess the environmental burden from the initial stage of development and has also constructed Company standard LCA tools.

The data directory we have developed this time consists of the database of the LCA project of the Ministry of Economy, Trade and Industry which has been rapidly introducing standardization and Mitsubishi's original database covering a total of 796 items, which include the data on Corporate common parts and the disposal process at Mitsubishi's Higashihama Recycling Center. The data are stored in the in-house standard LCA software and classified into six main categories: (1) material, (2) energy, (3) transportation, (4) processing, (5) waste product scenario, and (6) waste processing. Furthermore, the data are associated with the types of common materials and released on the intranet, together with the emission unit energy requirements. At least three substances such as CO_2, NOx, and SOx, are referred to as emitted substances, in compliance with the 14 substances stated in the LCA projects (emissions to the atmosphere: CO_2, CH_4, HFC, PFC, N_2O, SF_6, NOx, and SOx; and Suspended Particulate Matter/aquatic emissions: BOD, COD, total phosphorous, total nitrogen, and suspended solids).

3.1 LCA project database

The present LCA project database contains data provided by 53 industrial organizations(5). Figure 3 shows the flow chart of the scope of data collection by data type. The figure indicates that the data on aluminum-rolled products contain only the environmental load generated during the "domestic transportation" and "aluminum rolling" processes that are enclosed in the double line. The unit energy requirements have been calculated by integrating the data on "primary aluminum manufacturing," "secondary aluminum manufacturing," and "aluminum scrap transportation." The database has been constructed by defining the scope of data collection for relevant elements and parts on the basis of the

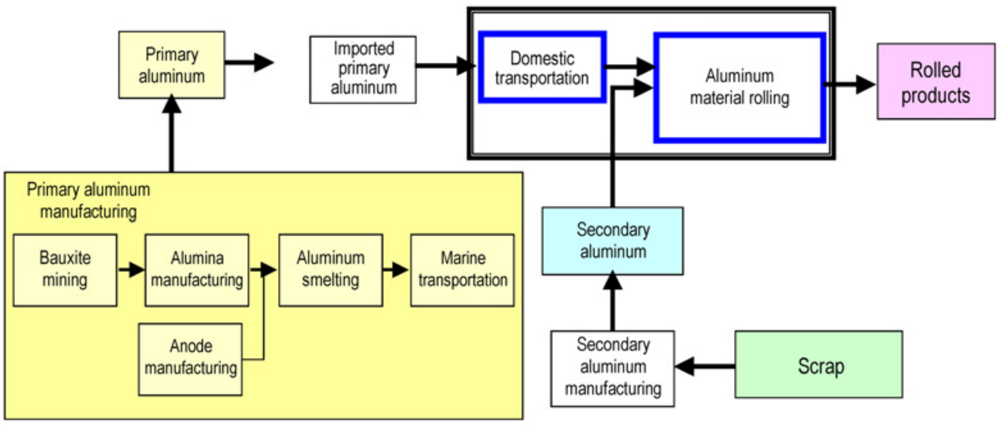

Fig. 3 Flow of aluminum rolling goods

flow charts and the like and collecting the data from public sources.

3.2 Embodied environmental intensity of Corporate common parts[6]

For the construction of the database of major parts used commonly in Mitsubishi, parts which are used in large quantities and whose material and manufacturing data can be obtained were identified. The applicable assessment range is defined as the steps from material preparation to parts manufacturing, including multiple parts for multiple model types. The environmental load of each type of part was assessed on the basis of those data, and also the energy unit requirement per unit weight of each part was determined. As a result, for example, it has become possible to calculate the environmental load of a motor by multiplying the motor weight by the unit energy requirement, without needing to investigate the constituent materials or weight.

On the other hand, IC packages were classified in accordance with the package sealing methods, package implementation methods, and types of framing materials. The environmental load of five to eight types having different pin-numbers was assessed for both plastic QFPs and glass-epoxy substrate type BGAs. As a result, it was found that IC packages cannot be unified on a 1-kg basis. The reason is that the environmental load is divided proportionally on the basis of unit weight between the extraordinarily large electric power consumption during the wafer manufacturing process and the greenhouse gas emissions, and that the environmental load is determined by the weight of chips (= Si weight) in each IC package.

Accordingly, the unit energy requirements of IC packages were defined on the basis of the weight of chips instead of the total weight of the IC package. This makes it possible to calculate the environmental load of each IC package from the chip dimensions, which can be obtained based on the manufacturer's model names.

4. Implementation of LCA

The Mitsubishi Electric Group today is using the standard LCA tool we have developed as described above to assess a variety of products, including heavy electric system devices, industrial system devices, household appliances, and electronic devices for enhanced environmental compatibility of the products. Taking household appliances for example, we conducted LCA of 11 major product models (air conditioners, Lossnay and the like) of the "Uni & Eco" series for the whole house, and hence reduced CO_2 emissions by about 49% (from the level in 1990). The results of LCA were exhibited at the Eco Products Exhibition and are included in the Uni & Eco product catalogs to publicize Mitsubishi's environmental activities, which include the development of environment-conscious products.

Furthermore, the Mitsubishi Electric Group has conducted LCA by focusing on the transition of environmental load associated with technological innovation. As a result, the environmental load has been reduced by 40% with power modules and by 30% with transformation systems[7],[8]. Mitsubishi Electric won an "Incentive Award" of the LCA Japan Forum for its outstanding achievements in LCA activities[9].

In its Environmental Vision 2021, the Mitsubishi Electric Group states its commitment to considering the 3Rs throughout the life cycle. As part of this, the Mitsubishi Electric Group is conducting recycling process assessments using the LCA approach[10], [11].

The Mitsubishi Electric Group is building the foundation for sharing and using product environmental information in its supply chain operations and promoting Design for Environment based on the results of LCA as well as disclosure of related information.

References:

(1) LCA project
http://www.jemai.or.jp/lcaforum/project/03_01.cfm
(2) Japan Environmental Management Association for Industry: Eco Leaf environmental label
http://www.jemai.or.jp/ecoleaf/index.cfm
(3) Japan Gas Appliances Inspection Association: EPD (Environmental Product Declaration)
http://www.jia-page.or.jp/jia/epd/index.html
(4) LCA Japan Forum: LCA database
http://www.jemai.or.jp/lcaforum/index.cfm
(5) JLCA-LCA database, Ver. 4, 2007
(6) E. Hirose et al.: Estimation of the Environmental Load of Electricity and Electronic Parts and Case Study, Abstracts of lectures at the first meeting of the Institute of Life Cycle Assessment, Japan, 22-23 (2003)
(7) E. Hirose et al.: Environmental Assessment of Power Modules Based on LCA, Mitsubishi Electric Technical Report, 77, No. 5, 359-362 (2003)
(8) E. Hirose et al.: Environmental Assessment of Power Modules Based on LCA, Mitsubishi Electric Technical Report, 79, No. 5, 325-328 (2005)
(9) E. Hirose: Development and Standardization of LCA Assessment Technology for the Mitsubishi Electric Group, the Third LCA Japan Forum Seminar
(10) Y. Endo et al.: Recycling Technology for Mixture of Residual Plastics from Waste Household Appliances, Mitsubishi Electric Technical Report, 81, No. 6, 385-388 (2007)
(11) E. Hirose et al.: Environmental Assessment of Used TV, Abstracts of lectures at the third meeting of the Institute of Life Cycle Assessment, Japan, 282-283 (2008)

Measures to Reduce CO_2 Emissions and Energy-Saving Solutions for Plants and Offices

Authors: *Masaaki Ikegami** and *Kenji Ohta**

1. Efforts in the Past and Achievements

Since the two oil shocks, Mitsubishi Electric has been conducting energy-saving activities in its production processes. This is done by organizing energy-saving promotion systems led by a general manager in each site, and includes such activities as energy-saving patrols once a month and energy-saving study meetings. Actual activities include washing the heat-exchange fins of air-conditioners before summer, turning off the entire power supply on premises during long holidays, and removing unnecessary fluorescent tubes. In 1997, Mitsubishi Electric drew up its voluntary action plan to reduce energy usage by 25% per unit sales compared with the level in fiscal 1991 by 2011 to help prevent global warming, in response to the Voluntary Action Plan by the Japan Federation of Economic Organizations. Energy-saving efforts were therefore stepped up and CO_2 emission reduction activities continued efficiently till fiscal 2001. However, Mitsubishi Electric's production decreased in a deflationary spiral starting in the latter half of 2000, and yet energy consumption did not decrease in proportion to the decrease in sales because air-conditioning and lighting energy requirements were fixed, independent of the production level. As a result, the energy requirement per unit sales actually worsened. To reduce fixed energy consumption, Mitsubishi Electric investigated all energy-consuming equipment at all of its sites, to identify each installation year, rating, rate of operation, failure frequency, and the like of equipment. The results revealed that 50% of power transformers had been used for more than 30 years and 40% of air-conditioners had been used for more than 20 years. To reduce fixed energy, all old and inefficient equipment had to be replaced by state-of-the-art efficient (top runner) equipment. Mitsubishi Electric established four action plans in fiscal 2005 and set a target of reducing CO_2 emissions by 46,000 tons by 2011. The four action plans are: (1) replacement with equipment of higher efficiency (CO_2 reduction of 25,000 tons), (2) Energy-loss minimization (EM) activities (CO_2 reduction of 8,000 tons), (3) introduction of cogeneration system (CO_2 reduction of 9,000 tons), and (4) fuel conversion for boilers (CO_2 reduction of 4,000 tons). In fiscal 2005 and 2006, CO_2 emissions were successfully reduced by 12,700 tons, which is approximately twice the annual reduction achieved previously.

For the fifth three-year environmental plan beginning in fiscal 2007, Mitsubishi Electric decided to use the real energy requirement unit as the energy control indicator in line with the unit widely used in the electric and electronics industry, and changed its voluntary

Table 1 Progress of energy savings action plans

Action plan	Target of reduction by 2011 (tons of CO_2)	Fiscal year 2005		Fiscal year 2006		Fiscal year 2007		Cumulative sum		Fiscal year 2008	
		Actual achievement		Actual achievement		Actual achievement		Actual achievement		Plan	
		Reduction (tons of CO_2)	Investment (million yen)	Reduction (tons of CO_2)	Investment (million yen)	Reduction (tons of CO_2)	Investment (million yen)	Reduction (tons of CO_2)	Investment (million yen)	Reduction (tons of CO_2)	Investment (million yen)
Introduction of higher-efficiency equipment	34,800	4,091	1,439	5,910	1,468	8,842	2,481	18,843	5,388	9,389	2,590
EM activity	8,000	214	41	266	76	890	156	1,370	273	759	94
Introduction of cogeneration	0	7	4	0	0	0	0	7	4	0	0
Fuel conversion	3,200	1,872	48	334	49	320	25	2,526	122	52	40
Total	46,000	6,184	1,532	6,510	1,593	10,052	2,662	22,746	5,787	10,200	2,724
Cumulative sum	–	6,184	1,532	12,694	3,125	22,746	5,787				

*Corporate Environmental Sustainability Group

action plan target to reduce the real energy requirement per unit sales by 60% or more compared with the level in fiscal 1991 by 2011. To achieve this target, it was necessary to review the four action plans established in fiscal 2005 to reduce CO_2 emissions by 46,000 tons over seven years. A CO_2 reduction of 12,700 tons has already been achieved, so a further 33,000 tons must be reduced over the remaining five years. Of the four action plans, cogeneration systems have not been introduced since most of Mitsubishi Electric's plants do not need heat, resulting in a low level of energy efficiency. So the CO_2 reduction of 9,000 tons by introducing cogeneration systems was achieved by replacing equipment with higher-efficiency equipment. The CO_2 emission reduction expected in the action plan by introducing higher-efficiency equipment for the remaining five years was thus increased from 15,000 tons to 24,000 tons. As a guideline for introducing higher-efficiency equipment, we requested plants to invest 0.1% of production of the previous fiscal year for introducing energy-saving technologies in the next fiscal year. As a result, fiscal 2007 saw a CO_2 reduction of 10,052 tons throughout the company. In addition, the target of the voluntary action plan was achieved four years ahead of schedule.

The CO_2 emissions associated with production in fiscal 2007 were 45,900 tons. With a reduction of 10,052 tons by investing in energy-saving facilities, the energy consumption was limited to an increase of 12,000 tons of CO_2 (up 2.6%) compared with the previous year. On the other hand, sales rose 5.1% from the previous fiscal year, yielding a sharp improvement in real energy requirement per unit sales and achieving the target of the voluntary action plan. The real energy requirement per unit sales decreased by 63% compared with the level of fiscal 1991, achieving the original target ahead of schedule. Efforts to reduce CO_2 emissions further will be continued from fiscal 2008.

2. Major Measures and Effects

Mitsubishi Electric's three measures for reducing CO_2 emissions in the past are described below.

[CO_2 emission reduction measures]
- Replacement with higher-efficiency equipment
- Energy-loss minimization activity
- Fuel conversion

2.1 Replacement with higher-efficiency equipment

Replacement with higher-efficiency equipment means replacing facilities such as power mechanisms, air-conditioners, and lighting facilities which are necessary for the operation of plants, with state-of-the-art equipment that is more energy-efficient.

Most of such facilities can be used for longer than 10 years and many have been used for more than 20 years. The power consumption of today's air-conditioners is around 60% of those produced 10 years ago. With transformers, the newest models offer about 40% less CO_2 emissions than older models. In short, replacing plant facilities with state-of-the-art energy-efficient equipment is extremely effective. Today, Mitsubishi Electric invests the equivalent of 0.1% of production for renewal of plant facilities.

2.2 Minimizing energy loss

Activities to minimize energy loss involve making improvements through detailed measurement of the energy consumed by respective production processes in plants, by using energy measurement tools and through the identification and elimination of wasteful use of energy. ECO Monitors developed by Mitsubishi Electric are installed in plants and offices throughout the company to continuously monitor the electricity

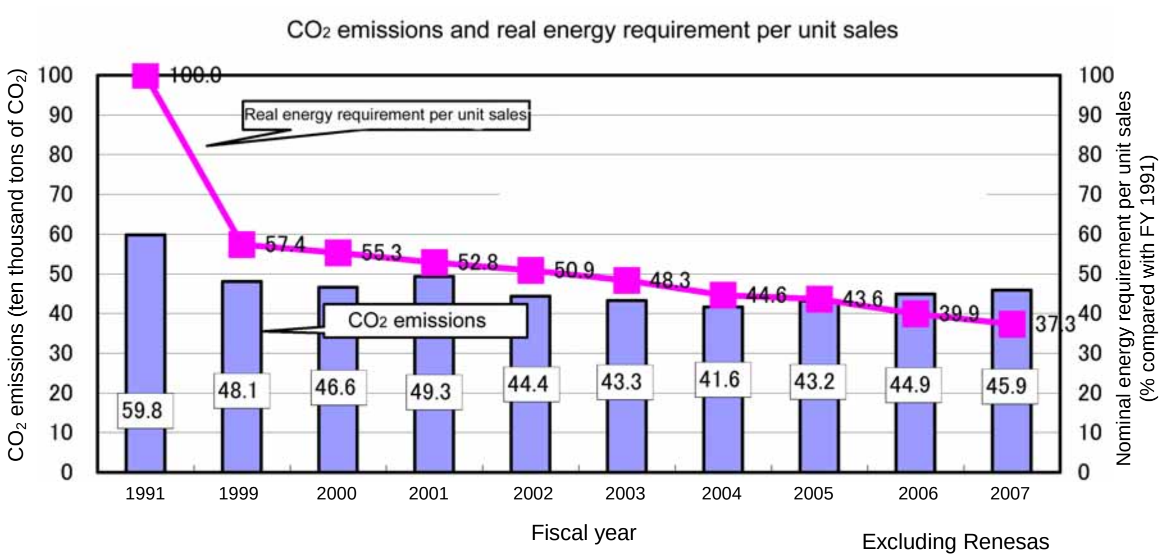

Fig. 1 Changes in CO_2 emissions and real energy requirement per unit sales

consumption and the like. In addition, the monitored data can be viewed by Internet browser via the network and so the data is made available to a wide range of people, including managers as well as site operators.

The measurement data shows the energy consumption at measurement intervals of five minutes. Graphic representation of the data clearly reveals wasteful use of electricity, such as consumption during rest periods or at night. The reasons for such wasteful operation of facilities are then analyzed and necessary action is taken, such as suspension of power to the facilities. By repeating this process, wasteful consumption of power and costs are reduced.

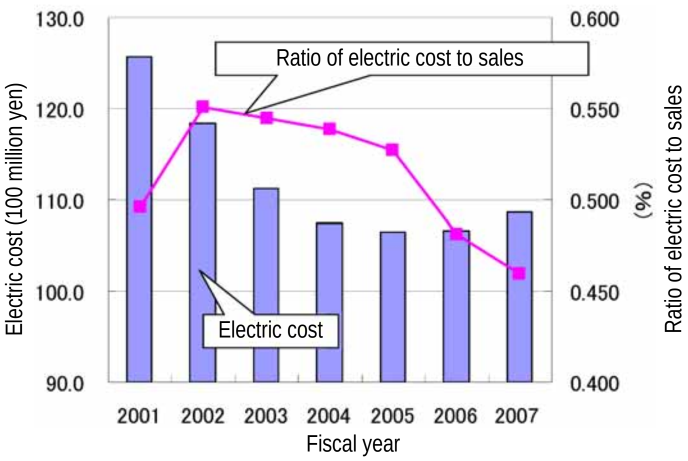

Fig. 2 Changes in electric cost and ratio of electric cost to sales

2.3 Fuel conversion

Fuel conversion means switching from fuels that emit a large amount of CO_2 to other fuels that emit less CO_2. An example is switching from boilers that use heavy oil to boilers fueled by city gas. In one such case, CO_2 emissions were successfully reduced by about 1,769 tons per annum. Mitsubishi Electric aims to reduce CO_2 emissions by approximately 40% by changing the water heaters from the conventional combustion method to the heat-pump method from now on.

2.4 Effect of the reduction of fixed energy

Reduction of fixed energy, which started in fiscal 2005 as mentioned above, has led to a decrease in the ratio of electric energy cost to sales.

It is necessary to continuously reduce the fixed energy since this improves management vitality. Therefore, even though the target of the voluntary action plan was achieved, we will continue the policy of investing 0.1% of the production of the previous fiscal year in energy-saving facilities in the next fiscal year.

We have witnessed our own potential for reducing fixed energy as a result of investigating all energy consuming equipment in fiscal 2005. On the basis of the results, we may be able to reduce CO_2 emissions by a total of 30% through production in accordance with Environmental Vision 2021.

Advanced Technologies for High Efficiency Photovoltaic Systems

Authors: *Shigeru Matsuno*, Akihiko Iwata** and *Hirofumi Fujioka**

1. Introduction

A typical photovoltaic system consists of a module containing multiple photovoltaic cells and a power conditioner that converts the generated DC into AC. Since photovoltaic power generation does not emit CO_2, a number of nations, particularly those in Europe, have announced special support measures and so photovoltaic systems are being rapidly introduced. Since multicrystalline silicon photovoltaic modules have the lowest power generation cost, these modules are the mainstream in photovoltaic cells for electricity generation; production of these modules accounts for 60% of all photovoltaic modules, but for further expansion, the power generation cost must be greatly reduced. The key to achieving such low generation cost is to improve the power generation efficiency of the photovoltaic cells and power conversion efficiency of the power conditioners. These technological activities are also closely associated with Mitsubishi Electric's "Environmental Vision 2021."

Mitsubishi Electric's multicrystalline silicon photovoltaic system is the most efficient in the industry thanks to the development of efficiency-enhancing technologies for both the cell and power conditioner. This report discusses the efficiency-enhancing technologies used in the multicrystalline silicon photovoltaic cells of Mitsubishi Electric's photovoltaic power system, the next generation technologies, and gradationally-controlled voltage type inverter technologies for raising the efficiency of power conditioners.

2. Development of High-Efficiency Multicrystalline Silicon Solar Cells

2.1 Efficiency improvement by low-reflectivity texture structure

To increase the conversion efficiency of photovoltaic cells, the photovoltaic cells must capture as much solar light as possible. A low-reflective structure that combines a rough surface structure (called "texture") and antireflection film is therefore used on the light-receiving surface of the multicrystalline silicon photovoltaic cell. This texture structure effectively confines the light and enhances light absorption, especially for long wavelength light. To improve the conversion efficiency by fully using this increased amount of light by lowered reflectivity, it is necessary to reduce the surface recombination loss of electrons by minimizing the increase in surface area through optimization of the texture configuration.

Typical multicrystalline silicon photovoltaic cells employ a concave-convex surface structure, called an alkaline texture, prepared by anisotropic etching with alkali solution (Fig. 1a). However, since almost no rough structure is formed depending on the orientation of respective crystal grains that constitute a multicrystalline silicon substrate, a texture forming method that does not depend on crystal orientation is necessary. Mitsubishi Electric examined a texture forming (plasma texture) method using plasma etching with spray-type masking material. The results indicated that a somewhat larger texture size is suitable for enhancing the efficiency while optimizing the reproducibility, process margin, and diffusion layer. By using a mixed masking material consisting of a material several nm to several μm in diameter and applying a special spraying method, textures of comparatively large size, on the order of several μm, were formed on a full-size substrate (150-mm square) with good reproducibility (Fig. 1b).

(a)

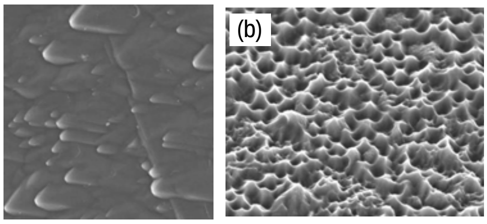

Fig. 1 Comparison of textures made by (a) alkaline and (b) plasma etching

We experimentally manufactured high-efficiency cells by using this plasma texture for high-quality multicrystalline silicon substrates. Other than the texture the surface grid electrode was made narrower and the baking conditions were optimized. Figure 2 compares the appearance between the current product alkaline texture cell and plasma texture cell. In the plasma texture cell, the appearance is dark due to the reduced reflectivity. As a result, according to the characteristic evaluation conducted by a public certification organization (Research Center for Photovoltaics of the National Institute of Advanced Industrial Science and Technology), the world's highest conversion efficiency of 18.0% was achieved by a 150-mm full-size cell.

*Advanced Technology R&D Center

2.2 Next-generation texture technologies

To improve the conversion efficiency still further, we studied a next-generation texture technology that uses honeycomb texture structures for greatly reduced reflectivity without needing to increase the surface area[1]. The conventional honeycomb texture cell uses photoengraved patterning; the experimental cells are limited to 1-cm square in size. However, we have succeeded in forming a honeycomb texture structure on a 150-mm square multicrystalline substrate with comparably large roughness of ±3 to 5μm by using laser patterning. This technology involves high-speed multiple point simultaneous patterning of the etching mask by YAG laser (basic wave to triple wave) and wet etching with hydrofluoric nitric acid to form a honeycomb structure. Figure 3 shows the scanning electron microscope image of the honeycomb texture structure formed on a multicrystalline silicon substrate. The photo clearly indicates that this method can form honeycomb textures without using photo engraving. We have also confirmed that honeycomb textures reduce reflectivity further than plasma textures in the entire wavelength range, so efficiency will be improved by using honeycomb textures.

3. High-efficiency Photovoltaic Power Conditioner

3.1 Configuration of gradationally controlled voltage type power conditioner

The system employs a gradationally controlled voltage type inverter in the power conditioner for the first time in the industry to achieve a power conversion efficiency of 97.5%. Typically, power is lost when the inverter in the power conditioner converts the DC power generated by photovoltaic cells into AC power. In conventional systems, one inverter is used to form rectangular waves and the waves are made sinusoidal through a filter circuit. In the gradationally controlled voltage type inverter method employed in the new system, three inverters of different voltages are com-

Fig. 2 Appearance of solar cells with an alkaline (left) and plasma (right) texture

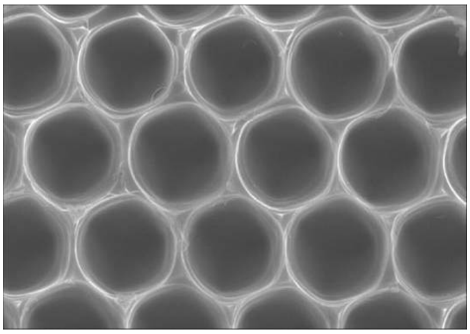

Fig. 3 Scanning electron microscope image of honeycomb texture structure formed on multicrystalline silicon substrate

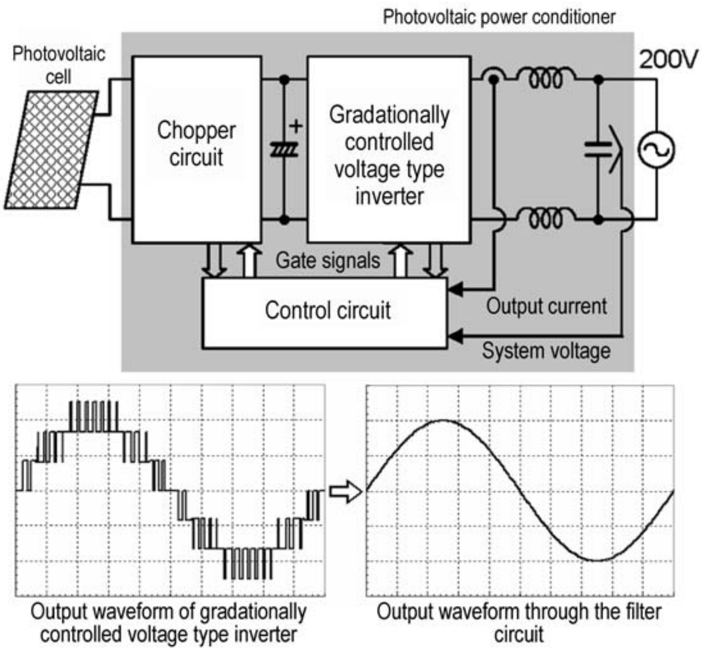

Fig. 4 Schematic diagrams of the output waveform and circuit configuration of gradationally controlled voltage inverter

bined to directly generate pseudo-sinusoidal waves gradationally. This technology makes it possible to downsize the filter circuit, reduce the power conversion loss by 44% compared to the conventional system, and attain a power conversion efficiency of 97.5% which is the highest in the industry. Furthermore, a much higher conversion efficiency (97.5% or higher) compared with the rated efficiency has been achieved over a wide output power range, proving that the DC power generated by photovoltaic cells can be used effectively.

3.2 Features of gradationally controlled voltage power conditioner

Figure 5 shows the appearance of a gradationally controlled voltage power conditioner. With less heat generated due to power loss during power conversion, the air-inlet port for heat radiation is no longer needed, resulting in better air-tightness. As a result, humidity resistance has increased greatly, allowing the system to be installed in a dressing room or rest room, which was impossible with conventional models. In addition, for a reduced voltage amplitude with the gradationally controlled voltage inverter, the noise generated from the reactor (coil) in the filter circuit is also suppressed. Now the system features a low noise level of 30 dB during operation, which is the lowest level in the industry. Furthermore, the new system has a wider input voltage range of VDC 50 to 380, compared with VDC 115 to 380 in the conventional systems.

Fig. 5 Power conditioner for residential photovoltaic system

4. Conclusion

Improved power generation efficiency of photovoltaic cells and power conversion efficiency of power conditioners are directly associated with power generation cost, which is key to increasing the use of photovoltaic systems in the future. Therefore, Mitsubishi Electric will continue with R&D on improving the efficiency.

We conducted this study in cooperation with the Nakatsugawa Works Photovoltaic Power System Department. The study of higher-efficiency cells was conducted as part of the “Research and development of innovative photovoltaic technology” project and “Research and development for future technologies of photovoltaic power system” (entrusted by NEDO).

Reference:

1) J. Zhao, A. Wang, M. A. Green, 2nd World Conference and Exhibition on Photovoltaic Solar Energy Conversion (1998) 1681.

Control Technology for Renewable Energy Sources and Micro-Grid

Authors: *Tomihiro Takano** and *Yasuhiro Kojima**

1. Introduction

To curb global warming, renewable energy sources such as wind power, solar power and biomass generation are dramatically increasing. The use of cogeneration systems is also growing to reduce energy costs for factories, buildings and homes where thermal loads tend to be high.

However, as these dispersed generators grow, their negative impact on the quality of the commercial power system becomes non-negligible: their unstable output causes the network voltage and frequency to fluctuate. Micro-grid technology is one approach to solve the problem and many demonstration field tests are now being conducted around the world.

2. Control of Micro-Grid

2.1 Concept of Micro-Grid

The micro-grid concept can be generally defined as follows: "A small-scale power supply system, which consists of small electrical power and heat facilities, loads, and their controller, and which manages them as a group and has one connection to a commercial power system." Figure 1 shows the typical configuration of a micro-grid, which consists of renewable energy generators, cogeneration facilities, electric storage facilities, thermal storage facilities, distribution network facilities, thermal infrastructure, communication networks, control devices including protection devices, thermal loads, and electric loads. The energy management system, which is a control device, plays an important role in a micro-grid and has the following effects:

- Efficient operation of electric and thermal energy
- Power flow control on the tie line (to protect power utilities from disturbances in the micro-grid)

2.2 Control System of Micro-Grid

To strike a balance between economics and power quality, optimum operation control of facilities, called "supply and demand control" is essential. To design the optimum solution, it is necessary to consider many variables including long-term factors such as efficiency and short-term ones like power quality. The authors have developed four stage control algorithms: 1) weekly operation planning, 2) economic load dispatching, 3) tie-line control, and 4) local frequency control, as shown in Fig. 2. The first and second serve to improve the economics and environment, in other words, to minimize the fuel cost and CO_2 emissions, while the third and fourth compensate for the power quality.

The operation planning and economic load dispatching are formulated as a combinatorial optimization problem including both continuous and discrete variables, and so the Problem Space Search method and QP (Quadratic Programming Problem) method can be applied. For tie-line control and frequency control, PID (Proportional Integral Derivative) control theory can be applied.

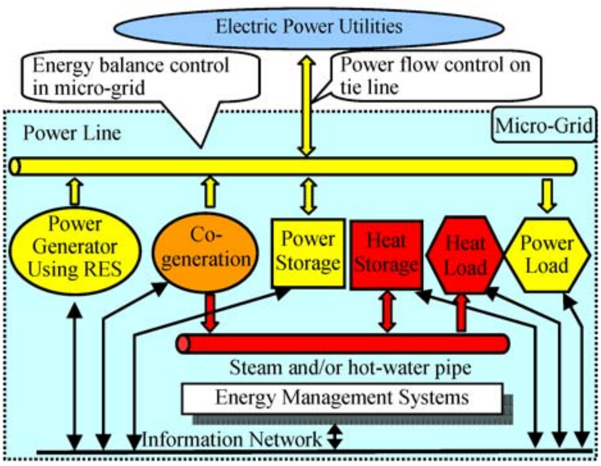

Fig. 1 Basic structure of micro-grid with RES

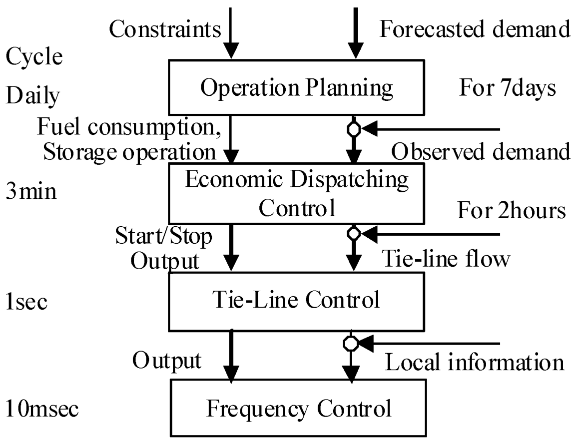

Fig. 2 Control hierarchy of micro-grid

*Advanced Technology R&D Center

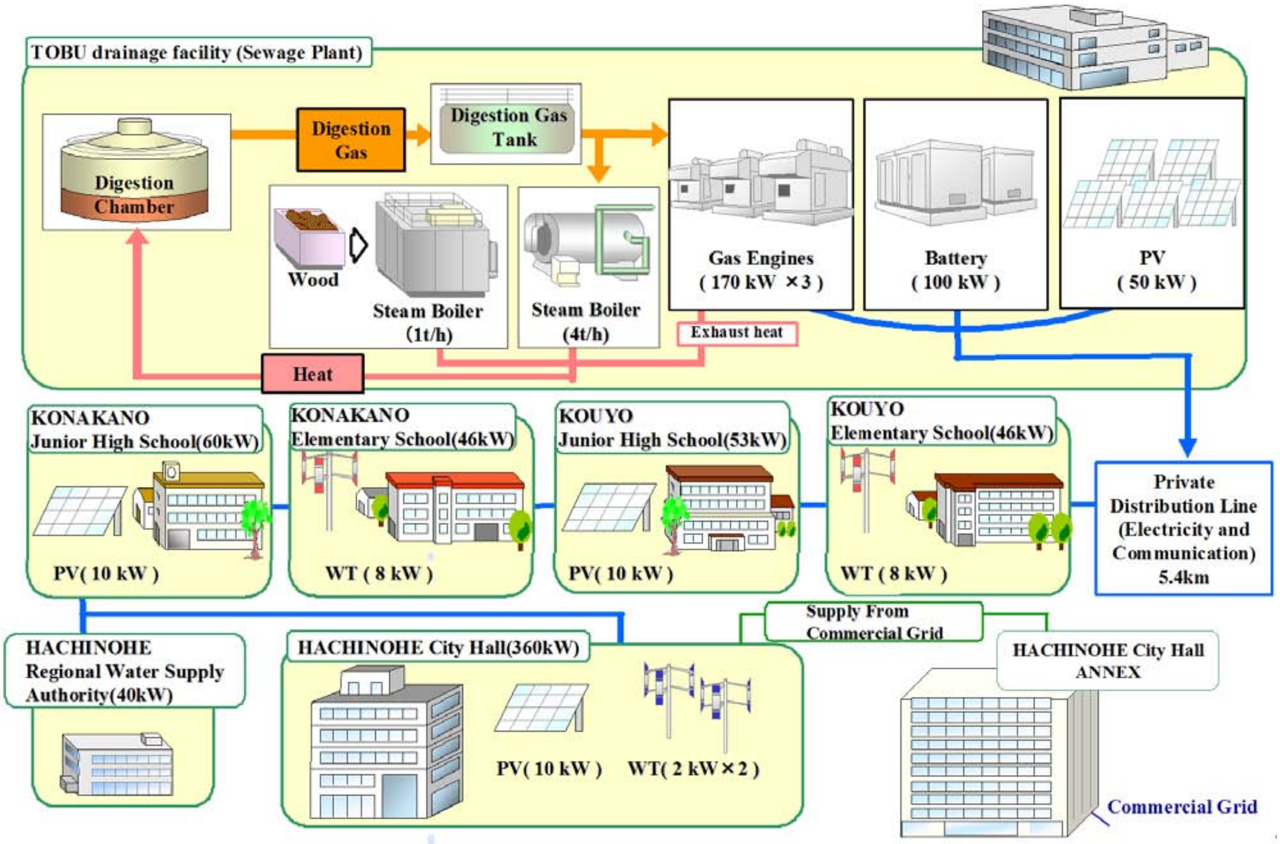

Fig. 3 Hachinohe-city micro-grid

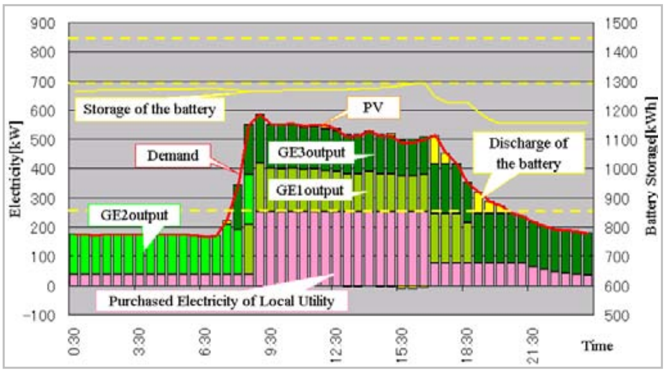

Fig. 4 Electric power operation planning

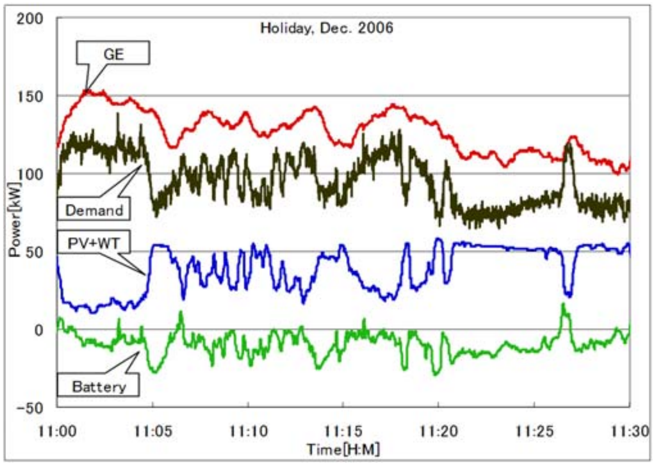

Fig. 5 Follow-up control for quick load change

3. Activities on Micro-Grid

3.1 Hachinohe Micro-Grid Project

The above control algorithm was first developed for the Hachinohe city micro-grid project, which is a joint project among Mitsubishi Research Institute, Hachinohe City and Mitsubishi Electric Corporation, under the Demonstration Projects for Regional Power Grids with Various New Energies, supported by NEDO (New Energy and Industrial Technology Development Organization). This demonstration field test ran from October 2005 to March 2008.

Electricity is supplied to six end-users through a private 6.6-kV overhead distribution line with a total length of about 5.4 km. Laid along the power distribution line is an optical-fiber cable carrying an IP network for monitoring and controlling the system. Both the power network and the information network have a radial configuration.

The system connects to the utility distribution grid at a single point, Hachinohe City Hall Annex, where reverse power flow into the utility grid is not allowed according to an agreement with the utility. The energy management system controls the power flow at the point between Hachinohe City Hall and its annex, where the power flow is to be maintained at a scheduled value.

The system can transfer to isolated operation, disconnected by manual control from the utility grid at the point between Hachinohe City Hall and its annex. Under the isolated operation, the gas engines, which are synchronous machines, take over as the "frequency source" within the system.

Although the calculation time span of the weekly operation planning is seven days, we focus on the day-ahead schedule that is carried over into the online economic dispatching control. Figure 4 is an example of electric power operation planning in the winter season when the load reaches a peak.

In this case, the planning results in an increase in purchased power in the daytime because of a limitation on the total amount of available digestion gas. For usage of the battery, the system compares loss of battery charge/discharge and the low efficiency of generators under partial load, and the minimum output of the battery is obtained. A similar result is obtained by thermal planning, considering reusing the waste heat energy from the gas engines. All constraints such as supply and demand balancing and the upper/lower limits of the chamber's temperature are met.

Figure 5 shows the results of cooperative control of the Economic Dispatch Control and the Tie-line Control stages during the interconnection operation, illustrating the control performance for fluctuations of demand throughout a typical day.

Changes in demand and output of weather-dependent generators can be roughly classified into six types: (1) demand increases in the morning and decreases in the evening, (2) weather-dependent energy (PV) output increases in the morning and decreases in the evening, (3) demand fluctuations over a few minutes, (4) sudden output fluctuations caused by weather changes, (5) spikes at the start-up of equipment lasting a few seconds, and (6) spikes at the start-up of equipment that last less than one second (too slight to be seen in Fig. 5). Of these six types, the control system deals with types (1) through (4) when the system is interconnected to the utility grid. In Fig. 5, the six-minute moving average of the control error (the difference between scheduled and actual power flow) is also shown. The target set by this project of maintaining the error within ±3% of the total demand was achieved with a probability of 99.99% during the latest two months.

3.2 Residential Micro-Grid

This is another example of a micro-grid project, which is a collaborative development with Japan Research Institute under the Development Work of the Global Warming Prevention Technology supported by the Ministry of the Environment, for cluster housing. In recent years, home cogeneration systems are being introduced in the private sector to reduce energy bills and CO_2 emissions. Unlike industrial or commercial consumers, however, the characteristics of power and heat loads differ among homes, so the effect of these cogeneration systems greatly depends on the daily load. For instance, in the case of large power but small heat consumption, the family does not reap economic benefits from the cogeneration system because it will soon stop when the heat demand is satisfied for the family and it can not be used at full value.

This project attempts to solve this problem by integrating some residential users to form a residential micro-grid. This enables residential users to extend the cogeneration working time through flexible energy interchange among a cluster of houses, and thus to reduce CO_2 emissions.

Figure 6 shows an overview of a residential micro-grid. The control center handles some cluster sites. One micro-grid site can handle up to 100 homes and their cogeneration systems. Each site is connected to a commercial distribution system as Hachinohe city and many other micro-grids do, and buys any shortfall of power from the electric power company. Especially in this project, the micro-grid has two physical control layers to reduce the control system cost. The functions of operation planning and economic load dispatching for several sites are combined at a central controller, whereas the functions of data aggregation from homes and dispatching for cogeneration systems are retained at each site.

Table 1 shows an example of environmental assessment for three energy supply types: 1) conventional supply without cogeneration, 2) with cogeneration, and 3) with micro-grid. A micro-grid reduces CO_2 emissions by 28.6% compared with the conventional type.

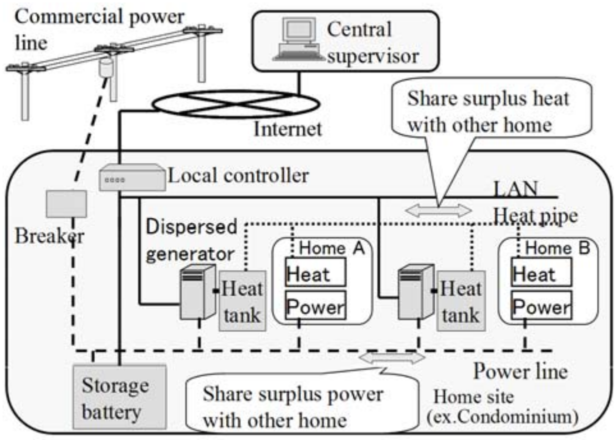

Fig. 6 Outline of residential micro-grid

Table 1 CO_2 emission for one home (kg-CO_2/year)

Conventional	Cogeneration	Micro-Grid
4,490	3,399 (-24.3%)	3,207 (-28.6%)

3.3 Wind Farm Control

As an extension of a micro-grid, the control technology is used to stabilize the output from wind farms. The Japanese government has set a target of installing 3,000 MW of capacity of wind power generators by 2010, but capacity had reached only 926 MW by 2004.

Wind power generation completely depends on the weather. As the proportion of wind and solar power generation increases, the potential imbalance between power supply and demand rises. This leads to frequency fluctuations from the reference 50/60 Hz. Some electric utilities recently published their assumption of wind power boundaries in their power systems. According to them, the amount introduced has almost reached the limit in Hokkaido and Tohoku where wind conditions are good, so Tohoku Electric Co. has begun to place strict constraints on new wind farms to stabilize their power output with storage batteries. Wind farms must keep a financial balance, while complying with the constraints by minimizing the storage battery capacity and the energy losses of charging and discharging.

The micro-grid technology predicts the generation for each source based on weather forecast simulations, and controls the actual output and storage battery to smooth the output as shown in Fig. 7.

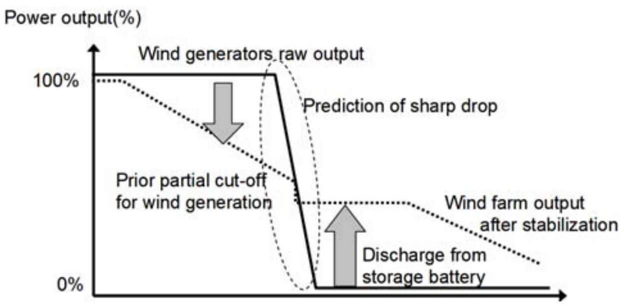

Fig. 7 Wind power stabilization using output prediction

4. Conclusion

The use of dispersed generators will continue to increase to improve energy efficiency as environmental awareness grows. The micro-grid concept is regarded as an essential technology for the efficient and reliable use of dispersed and renewable generators. Many demonstration test projects are now underway not only in Japan but also in Europe, the US, Australia and Korea.

These control technologies could be extended to saving energy in factories and office buildings through further development for practical use.

References

(1) Y. Fujioka, H. Maejima, S. Nakamura, Y. Kojima M. Okudera and S. Uesaka: "Regional Power Grid with Renewable Energy Resources: A Demonstrative Project in Hachinohe", Conference International des Grands Reseaux Electriques (CIGRE), C6-305, 2006

(2) Y. Kojima, M. Koshio, S. Nakamura, H. Maejima, Y. Fujioka and T. Goda: "A Demonstration Project in Hachinohe: Microgrid with Private Distribution Line", IEEE International Conference on System of Systems Engineering (SoSE), 2007

(3) H. Maejima, Y. Fujioka, Y. Kojima, S. Nakamura, S. Uesaka and T. Goda: "Structures of small power supply networks and practical example with renewable energy resources", IEEE Power Engineering Society (PES) General Meeting, 2007

(4) H. Iwasaki, Y. Fujioka, H. Maejima, S. Nakamura, Y. Kojima, M. Koshio: "Operational Analysis of a Microgrid: the Hachinohe Demonstration Project", Conference International des Grands Reseaux Electriques (CIGRE), C6-109, 2008 (accepted)

Technology for Recycling Mixtures of Residual Plastics from Waste Household Appliances

Authors: *Yasuhiro Endo*, Etsuko Hirose** and *Shinobu Ogasawara***

1. Introduction

Material recycling of plastic mixtures recovered from waste household appliances requires separation of plastics by type. This study found that acrylonitrile-butadiene-styrene (ABS) and polystyrene (PS) can be separated with high purity by an electrostatic separation method, and verified that material recycling reduces CO_2 emissions compared with other disposal methods.

2. Background and Challenges

The Law for Recycling of Specified Kinds of Home Appliances came into effect in April 2001, since when four categories of home appliances (air-conditioners, TV sets, refrigerators/freezers, and washing machines) have been actively recycled. The total recycling ratio of these four types of products (ratio of total weight of products that can be handed over to external dealers at cost or no cost from the recycling plant to the total weight of waste home appliances) in fiscal 2007 was 77%, far exceeding the required legal standard ratios (60% or higher for air-conditioners, 55% or higher for television sets, and 50% or higher for refrigerators/freezers and washing machines)[(1)]. Metals in particular achieved a high recycling ratio of approximately 90%. To further improve the total recycling ratio, it is necessary to recycle plastics, which account for more than 25% of the material composition ratio among the four items. From the viewpoints of environmental load and depletion of resources, the closed-loop recycling of plastic from waste home appliances is necessary, by using the plastic as a new raw material for home appliances.

Mitsubishi Electric has established Hyper Cycle Systems (HCS), the first plant for recycling household electric appliances in the industry, in Ichikawa City, Chiba ahead of legislation and has actively been developing plastic recycling technologies. Figure 1 shows an outline of the HCS closed-loop system for recycling plastics. HCS aims to achieve high-quality recycling and a closed-loop recycling system for reusing the plastics as a raw material for household appliances, by scrapping waste plastic items manually [(2)]. HCS has also developed a separation technology based on the difference in specific gravity to recover polypropylene

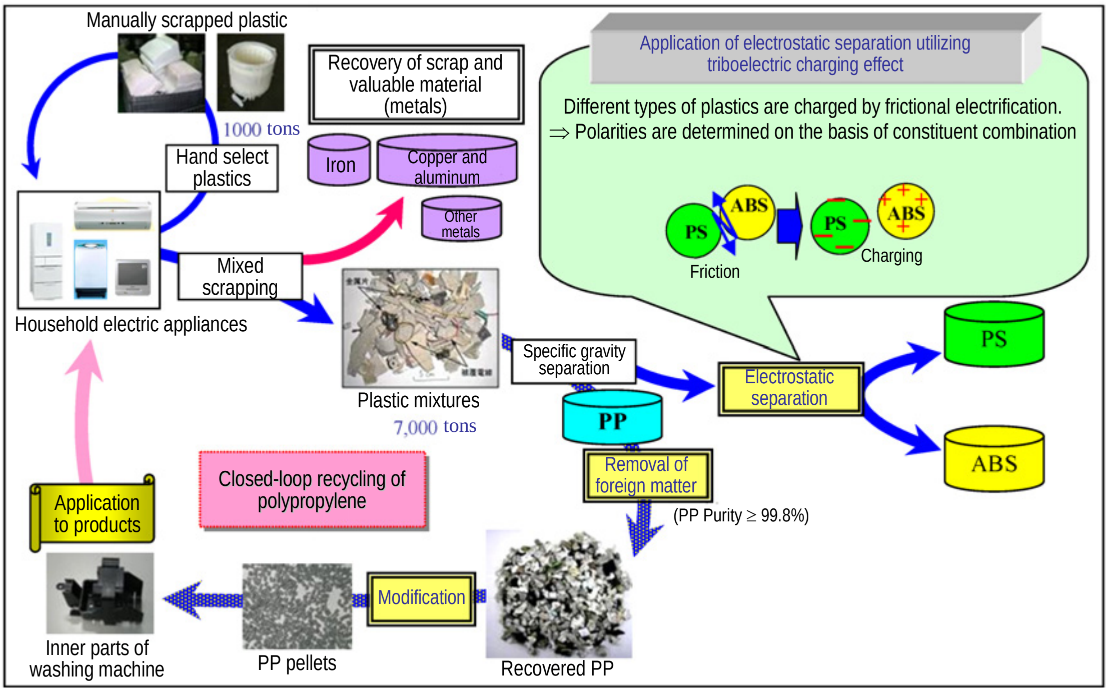

Fig. 1 Closed-loop recycling system for plastics

*Advanced Technology R&D Center **Living Environment & Digital Media Equipment Group

(PP) plastics with a purity of 99% or more. Polypropylene plastics account for approximately 30% of plastic mixtures from waste household appliances, which mostly consist of plastic parts that cannot be scrapped manually and that have been landfilled or incinerated as shredder waste[2]. However, ABS and PS, which account for about 40% of the plastic mixtures, have almost no difference in specific gravity and so need to be separated by a new separation technology.

This paper discusses the current situation of the development of an electrostatic separation method[3] that utilizes the difference in charging characteristic of ABS and PS to separate plastic mixtures containing ABS and PS. The results of an evaluation on how much the closed-loop recycling method can reduce environmental load compared with landfill, incineration, and chemical recycling[4] are also described.

3. Electrostatic Separation Technology

3.1 Principle of electrostatic separation

Figure 2 shows the principle of electrostatic separation. ABS/PS plastic mixture is stirred in a rotating cylindrical triboelectric charger (made of ABS) for triboelectric charging. The polarities in triboelectric charging of different types of plastics are determined in accordance with the combinations of constituents as shown in Fig. 3. ABS plastic is charged positively (+), while PS plastic is charged negatively (–). After being charged, ABS and PS are separated by electrostatic force while they descend between electrodes.

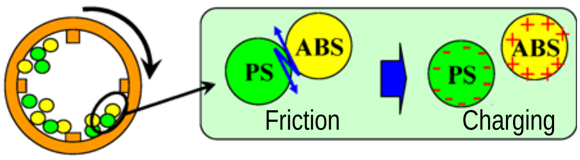

Fig. 2 Principle of electrostatic separation

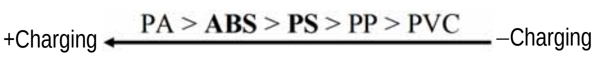

Fig. 3 Relative position in triboelectric series of plastics

3.2 Verification of electrostatic separation accuracy

Table 1 shows the weight ratios of constituents of ABS/PS plastic mixture after specific gravity separation. PP, the specific gravity of which became 1.0 or higher because of the amount of fillers, accounts for 5% or more of the approximately 6% for "others" shown in the table. Figure 3 shows an electrostatic separator. The first-step electrostatic separation of ABS/PS plastic mixture is performed, and then the second-step electrostatic separation is applied to the material recovered in the recovery containers after the first-step electrostatic separation, and finally the composition of the material recovered after the second-step electrostatic separation is analyzed.

Table 1 Weight ratio of plastic mixture after specific gravity separation

ABS	32.4%
PS	61.3%
Others	6.3%

Figure 5 shows the purities and recovery ratios of ABS and PS in the material collected from high-purity portions after the first-step electrostatic separation and the second-step electrostatic separation. The recovery ratios indicate the ratios of the ABS and PS contained in the collected material to their total amounts, respectively. Both the purities and recovery ratios of ABS and PS after the second separation were higher than those after the first separation. The highest purities of ABS and PS recorded after the second separation were 99.2% and 94.7%, respectively. However, their purities decreased to about 90% when the recovery ratios were above 90%. To increase both purities and recovery ratios, it is necessary to increase the degree of electrostatic charge of both ABS and PS. The reason why the purity of PS was lower than that of ABS is that the separation of PP which was charged with the same polarities as PS was not sufficient due to the relative

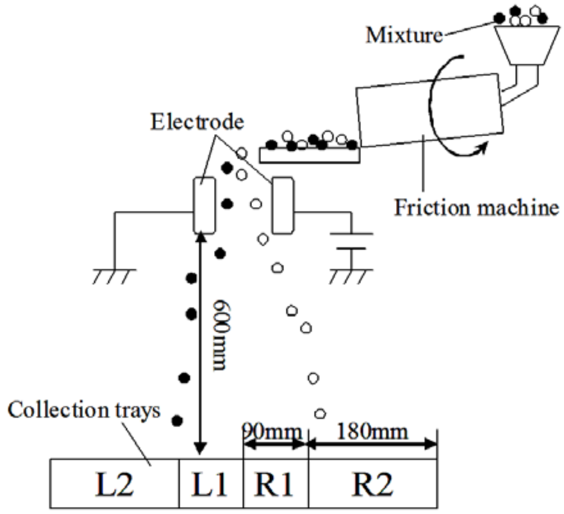

Fig. 4 Schematic diagram of electrostatic separation system

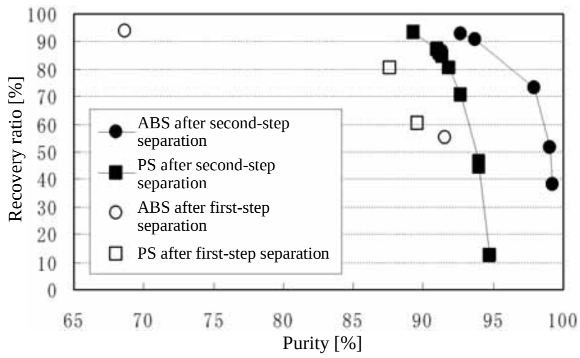

Fig. 5 Relation between purity and recovery after separation

position in the triboelectric series. It is clear that to improve the purity of PS, a method of improving the accuracy of PP separation is needed.

4. Life Cycle Assessment of Plastic Mixture Disposal Methods

Mitsubishi Electric's original material recycling technology, which can recycle PP, ABS, and PS contained in plastic mixtures from waste household appliances, was quantitatively assessed for its effectiveness in reducing the environmental load, in comparison with the conventional landfill method, incineration method, and chemical recycling method (for blast furnace material). For this assessment, we collected HCS data on the material balance, amount of energy required by processes, and so forth, and calculated CO_2 emissions during the plastic mixture disposal operation. The assumptions for the assessment included that PP, PS and ABS were obtained from material recycling, plastics of heavy specific gravity were obtained by incinerating PVC, while others were used for material and fuel for cement, and copper among metals was recycled. Figure 6 shows the results of LCA. The CO_2 emissions from the material recycling method were more than a third less than those from other disposal methods, proving that the material recycling method was the most efficient.

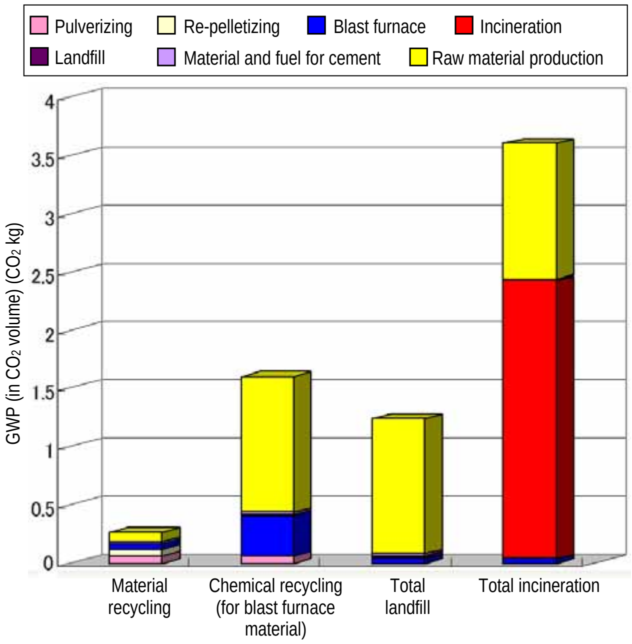

Fig. 6 Results of LCA of process to dispose of plastic mixture

5. Conclusion

PP separated from plastic mixtures of waste household appliances is already used for parts of washing machines and refrigerators. We will actively expand the scope of application to more parts, develop ABS/PS separation technologies as discussed in this paper, and promote the production of products designed for the environment by employing the closed-loop recycling method which was shown to be more advantageous than other disposal methods in terms of environmental load.

References:

(1) Association for Electric Home Appliances: 2006 Annual Report of Home Appliances Recycling, July 2007

(2) Yuichi Matsuo et al.: Material Recycling Technologies for Plastic Mixtures from Waste Household Appliances, ECO Design 2006 Asia-Pacific Symposium, pp. 247-248 (2006)

(3) Yasuhiro Endo et al.: Development of Electrostatic Separation System for Mixtures of Styrene Resin, ECO Design 2006 Asia-Pacific Symposium, pp. 249-250 (2006)

(4) Etsuko Hirose et al.: LCA of Plastic Mixtures from Waste Household Appliances, Abstracts of lectures at the second meeting of the Institute of Life Cycle Assessment, Japan, pp. 288-289 (2007)

Overseas Activity of Photovoltaic Power Business

Author: *Fujio Fujita**

Article Introduction

Today, photovoltaic power, which does not emit CO_2, is attracting considerable attention around the world as an effective means of combating global warming. Mitsubishi Electric entered the photovoltaic power business starting with applications for space satellites in 1976 and has been developing related technologies ever since. We started commercial mass production of multicrystalline silicon cells in 1998 and have expanded the business worldwide from Japan to Europe, the U.S., and Asia, to help preserve the global environment.

1. Introduction

Today we face unprecedented problems such as global warming and depletion of fossil fuels such as petroleum. In the 21st century, we must reduce our dependence on fossil fuels and focus on renewable energy.

2. Photovoltaic power: Demand is increasing worldwide

The needs for renewable energy, particularly photovoltaic power, are rapidly increasing. The work underway in advanced countries is described below.

- Europe: Improvement of FIT (Feed-In-Tariff = trading system for renewable energy in Germany, Italy and other countries)
- U.S.: Improvement of RPS (Renewable Portfolio Standard = special law for using new energy by electric power businesses) and tax benefits
- Japan: Administrative guidance and assistance by the national government and local public authorities
- Asian countries and Australia: Promotion of introduction of power generation facilities in unelectrified regions by the government

Table 1 Worldwide market demand (estimate by Mitsubishi Electric)

Global demand by district (estimated by MELCO)		
District	Demand scale in 2008 (percent distribution)	Demand scale in 2010 (percent distribution)
North America	310MW (12.3%)	660MW (18.2%)
Europe	1,810MW (71.8%)	2,280MW (63.0%)
Asia and Oceania	150MW (6.0%)	330MW (9.1%)
Japan	210MW (8.3%)	290MW (8.0%)
Others	40MW (1.6%)	60MW (1.7%)
Total	2,520MW (100%)	3,620MW (100%)

- Middle East countries: Construction of power generation facilities to reduce dependence on oil

The scale of demand has been estimated by many organizations; Mitsubishi Electric estimates that actual demand will grow by 20 to 30% annually, reaching about 2.5 GW in 2008 and 3 to 4 GW in 2010.

3. History of Mitsubishi Electric's photovoltaic power business

Mitsubishi Electric entered the photovoltaic power business starting with applications for space satellites in 1976 and has been developing various types of photovoltaic cells ever since. We started commercial mass production of multicrystalline silicon cells in 1998, and have steadily improved the conversion efficiency and introduced new technologies and products, including a lead-free solder module for the first time in the industry. In 2007, Mitsubishi Electric positioned the photovoltaic power business as the core of its "Strategic Business Solutions for Global Warming" and reinforced related programs. The detailed history of Mitsubishi Electric is presented below.

4. Mitsubishi Electric's measures for overseas businesses and future challenges

4.1 Technologies and products

The most important factors to promote photovoltaic power are to reduce the power generation cost and create a wide range of products to meet diverse needs. Accordingly, Mitsubishi Electric has engaged in various business plans and projects.

- Multicrystalline cells: The present experimental cells have reached a conversion efficiency of 18.0%, and the technology will continue to be developed toward commercial mass production. A wafer thickness of 180 μm has almost been achieved, and will be reduced to 160 μm in the future.
- Module: Currently eight types are available including a 190-W model (max. output). We plan to improve output levels by using high-conversion efficiency cells, and to expand the product line-up.
- Power conditioner: We have achieved a conversion efficiency of 96.2%, which is the highest level in the industry for products for export to Europe. We will further improve the efficiency and expand the product line-up.

**Living Environment & Digital Media Equipment Group*

Table 2 History of Mitsubishi Electric's photovoltaic business

History of Mitsubishi Electric's Photovoltaic Power Business			
1974	Started related research in response to the Sunshine Project led by the government.	2001	Started overseas business.
1976	Involved in space satellite applications.	2003	Started selling lead-free solder modules for the first time in the industry.
1996	Provided the domestic residential application market with multicrystalline modules.	2005	Reached a production capacity of 135 MW.
1998	Started commercial mass production of Mitsubishi Electric's original cells and modules at Nakatsugawa Works Iida Plant.	2006	Started selling power conditioners with the highest conversion efficiency in the industry in Europe. Started the set sales of Mitsubishi Electric's original modules and power conditioners for the first time in the industry.
1999	Received Good Design Award for BIPV roofing modules for the domestic residential market.		
		2007	Achieved the highest cell conversion efficiency of 18% (laboratory figure) in the industry. Started overseas sales of 190-W modules (max. capacity). Started domestic sales of power conditioners having a conversion efficiency of 97.5%, the highest in the industry. Reached a production capacity of 150 MW.
		2008	Reached a production capacity of 220 MW.

- Installability, etc.: For accelerated diffusion, the operability and weight reduction will have to be improved. We also plan to consider BIPV (Building Integrated Photovoltaic) applications.
- Mitsubishi Electric will consider developing thin film cells in accordance with the market trend as they have been increasingly receiving attention.

4.2 Production capacity

The Nakatsugawa Works in Gifu prefecture is the headquarters of Mitsubishi Electric's photovoltaic power business, which now has a production capacity of 150 MW. Mitsubishi Electric plans to expand the capacity to 220 MW in October 2008. As demand grows, Mitsubishi Electric aims to increase the capacity to 500 MW per year by fiscal 2013.

4.3 Sales

Mitsubishi Electric started doing business overseas in 2001 with Germany, which was actively introducing photovoltaic power systems. Since then, operations have expanded from Europe to the U.S. and Asia; today we deliver our products to many clients including power generation plants.

Future challenges for our business include the following: In Europe, we will sell module & power conditioner sets especially for residential homes, and will expand sales in southern European markets which are expected to grow rapidly. As for operations in the U.S., which have focused on California in the past, we will expand into other states. In Asian and Oceania countries, we will promote power plant facilities in their unelectrified regions. Furthermore, Mitsubishi Electric plans to enter the fields of large commercial complexes and power generation plants, including system technologies, from the current operations centering on residential home applications.

5. Conclusion

To spread photovoltaic power systems, long-term cooperation among national governments and the private sector is indispensable, such as to reduce the power generation cost. However, the key to increasing photovoltaic power systems is worldwide public awareness of environmental conservation. We hope the day will come in the near future when photovoltaic power systems play an important role in energy supply for the world.

Fig. 1 190-W module

Fig. 2 Power conditioner

Fig. 3 Installation sample of residential use

Fig. 4 Installation sample of small-scale power generation

MITSUBISHI ELECTRIC CORPORATION