Fuji Electric's Energy Conservation Activities and Techniques

Eiji Fukuda
Shinichi Kubota
Takeshi Uemura

1. Introduction

The setting of specific numerical targets for the reduction of CO_2 emission by the Kyoto Protocol (COP3), which was held in 1997 to prevent global warming, was a logical step toward protecting the environment. Subsequently in Japan, with the increasing number of enterprises that acquire self-imposed restraining ISO14001 certification, energy conservation has been promoted with the enactment of the Amended Energy Conservation Law.

Fuji Electric has been promoting the sale of products and systems for environment and energy conservation even prior to the first oil shock. Since 1998, we have expanded our energy conservation diagnostic activities, always keeping in mind "usefulness and economic feasibility for users" which is an especially "basic concept of energy conservation." Through these activities, we were fortunate to have had the opportunity to hold discussions with many users. From the discussions, we have uncovered many techniques of energy conservation and system concepts for energy conservation solutions.

Because energy conservation is a long-term ongoing activity, it is important to determine a practical plan each year, and to continue advancing the concepts one step at a time. As a result, the progress in each field will be clear.

This paper describes Fuji Electric's energy conservation measures and techniques, which have been planned and applied according to three important main themes of energy saving as shown in Fig. 1.

2. History of Energy Conservation

Table 1 lists the history of energy conservation. It is said that the concept of energy conservation was established after the 1st and 2nd oil shocks. Before that time, the only example of energy conservation was the regulation of heat management.

Most of Fuji Electric's energy saving products were developed, produced and introduced to the market after 1970. Especially in the 1970's, new and alternative energy caused a flurry of development. Energy saving equipment was introduced to the market in the 1980's and heat storage systems and power electronics products were sold in the 1990's. Following COP3, Fuji Electric also has developed a product line of eco-monitoring system products, and is compiling a database to reduce the increasing energy consumption.

3. Business Factors Relating to Energy Conservation

Figure 2 shows the business factors relating to energy conservation. User confidence has been cultivated by providing an energy saving diagnostic service free of charge to users during the early stages of energy saving activity. Unfortunately Fuji Electric was unable to offer sufficient benefits to the users. The reason for the above failure was because use of highly efficient equipment such as electric inverters or lighting was proposed without an underlying plan to compile a database to understand the present state.

Recently we have been working on applications of new alternative energy sources, energy saving solutions, etc. and have proposed a "comprehensive energy solution."

When this systemization becomes established, we believe that the Energy Service Company (ESCO) will grow even more.

Fig.1 Important themes in the promotion of the Amended Energy Conservation Law

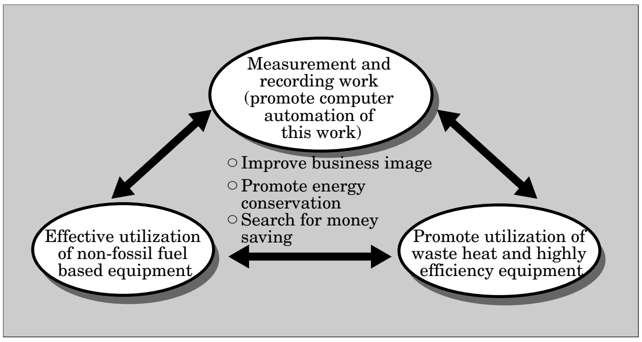
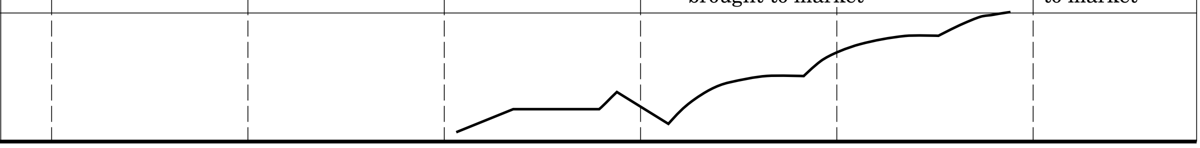


Table 1 History of energy conservation

Item \ Year (1950, 1960, 1970, 1980, 1990, 2000)	
Domestic and foreign events	○Launch of satellite; ○Switch to floating yen exchange rate system; ○First flight of space shuttle; ○Start of CS broadcasting service; ○Start of the Tokaido Shinkansen Line; ○Inauguration of the New Tokyo International Airport; ○Opening of the Seikan underground tunnel; ○Commencement of operating of the Tokai nuclear power plant; ○Apollo's landing on the moon; ○Windows95 was brought to market; ○Completion of the Kasumigaseki building; ○Start of PHS service; ○Opening of the Kanmon underground tunnel; ○Speed of manned linear motor car exceeds 400km/h; ○Start of the Tokyo Olympics; ○Start of the Tokyo Summit
Changes affecting the circumstances of energy conservation	○First IPCC meeting (Geneva); ○Enactment of Heat Management Regulation (Japan); ○First oil crisis; ○Second oil crisis; ○Global summit (Brazil); ○Enforcement of Heat Management Law (Japan); ○COP1 (Berlin); ○Enactment of Energy Conservation Law (Japan); ○COP2 (Geneva); ○COP3 (Kyoto); ○COP4 (Argentina); ○Enactment of Amended Energy Conservation Law (Japan); ○Enforcement of Amended Energy Conservation Law (Japan)
Fuji Electrics energy saving products and systems	○Initiation of photovoltaic power generation study; ○First result of ice heat storage system; ○Inverter; ○Start of investigation for small scale hydro power; ○Ecomonitoring system was brought to market (EcoPASSION) (EcoHIESSENCE); ○Start of fuel cell study; ○First result of wind power generation; ○First result of active filte; ○First result of geothermal power generation; ○Start of wave power generation study; ○Preparation for construction of the Tokai nuclear power plant; ○First result of mold transformer; ○First result of S-former; ○First result of cogeneration; ○First result of power saving equipment; ○Automatic power factor regulator brought to market; ○Comprehensive eco monitoring system brought to market; ○Demand control equipment brought to market
Changing trends of energy consumption	

4. Measures for Energy Conservation

Since enterprises typically have a tendency to move slowly when considering cost reduction strategies for energy, a "DSM (Demand Side Management)" system has been introduced so that the enterprise can by itself manage and control the energy demands. The description "within the enterprise" usually means that DSM is energy management on user side, in contrast to that of an electric power company. DSM is a type of energy management technique for the user.

Fuji Electric is already producing a highly regarded, flexible wireless network type, energy saving monitoring system, and has further plans to apply the system to create a network of energy saving data.

5. Engineering Activities at Fuji Electric

Engineering for energy saving is aligned with the interests of users, and through cooperation with the user, Fuji Electric resolves problems and satisfies user needs. Thus, it is important to recognize and understand the "actual conditions and problems of users." It is relatively easy to determine the targeted field of energy conservation by understanding when, where and how much energy is being consumed in each field segment as shown in Fig.3.

Fig.2 Business factors of energy conservation

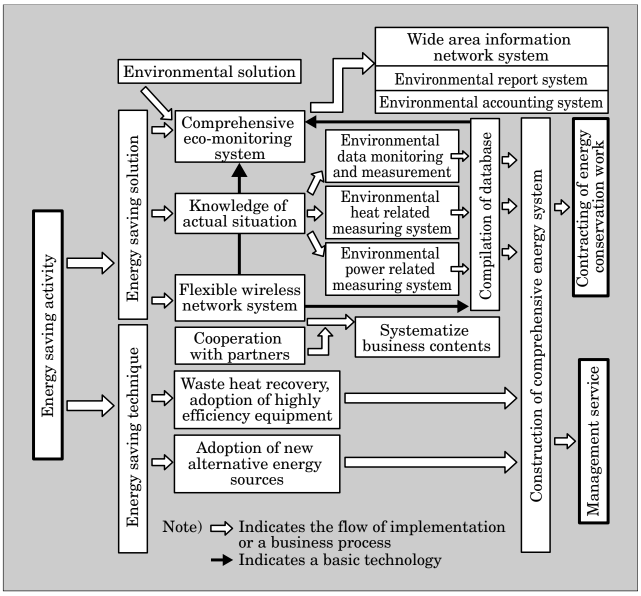
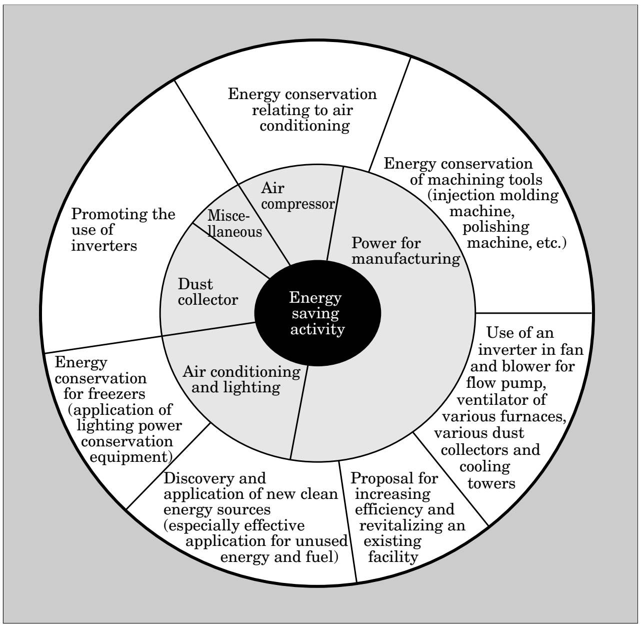


Fig.3 Energy consumption distribution and energy saving items in factory



Fuji Electric has performed assessments of manufacturing factories both internal and external to our company, as the central activities of the "diagnostic service for energy saving." As a part of these activities, we suggest measures to increase energy efficiency, and then implement those measures for the user. We will describe the energy saving items and measures implemented in the following sections.

6. Measures and Controls of Energy Saving Items

Energy conservation is based on the aggregation of data (compilation of a database) that is collected by using measuring and recording equipment as described in Fig. 1. It is important to tie specific measures to the extracted energy saving item through analysis and processing of the database.

Table 2 Flow of diagnostic service for energy saving

Step \ Class	Description of activity	Main items to check or activities to implement
1st step	Completion of user requirement list and feasibility consultation	① User's address and name of person in charge ② Received voltage and contracted power ③ Power usage ④ Electric power rates ⑤ Status of ISO certification acquisition ⑥ Equipment description and capacity ⑦ Desired measures to implement for energy conservation ⑧ Existence of measurement and recording data ⑨ Energy consumption percentage, etc.
2nd step (1st diagnosis)	Check user's location (qualitative check by observation)	① Is the received power appropriate (load factor, power factor, etc.) for the equipment and substation? ② Are operating states of various machine tools appropriate? ③ Are the working states of air conditioning and lighting appropriate? ④ Is the utility's operating state appropriate? ⑤ Is the working state of the air compressor appropriate? ⑥ Is working state of the dust collector appropriate?
3rd step	Prepare and submit the 1st diagnostic report	① Are all user concerns covered? ② Is a more detailed check necessary? ③ Is there interest in new alternative energy sources?
4th step (2nd diagnosis)	Check based on measurement and recording at user's location (quantitative check)	① Visualization of each load characteristic by measuring ② Analysis and processing of data ③ Estimation of practicality and economics for extracted items ④ Verification of unchecked items, etc.
5th step	Prepare and submit the 2nd diagnostic report	① Verification of user and measure or time ② Check of environment where measures are to be implemented
6th step	Inquiry and submission of written estimate	① Determine cost of implementing the measures
7th step	Implementation and completion of measures	① Check user's satisfaction with the results of the measures

6.1 Diagnostic service for energy saving

As shown in Table 2, the "diagnostic service for energy saving" begins from the 1st step of surveying the user's conditions, and completes at the 7th step of implementation. It is important that steps 1 through 7 are processed repeatedly.

6.2 Extraction of energy saving items

After Fuji Electric has performed the diagnostic service and found and stored items for which energy conservation is to be implemented, in order to tie the items to actual measures, it is important to classify them as short-, middle-, or long-range measures as shown in Table 3.

As is clearly shown in Table 3, since most of the short-range measures are concerned with daily work and have a low cost of implementation, they can be easily employed; on the other hand, the cost of implementation is high for the middle- and long-range measures. However, it is important to consider middle- and long-range planning to continue the activities of energy conservation.

6.3 Examples of energy saving measures

(1) Promotion of inverters

Inverters can control adjustable speed motors with high efficiency. Energy saving has been enhanced by using inverters in the fans and pumps for air conditioners, feed and waste water ducts, dust collectors, exhaust fans, etc. with square-law reduced torque characteristics. Since the fan or pump capacity usually exceeds that of the facility by 20 to 30%, the flow is restricted by adjustable valves or dampers. By using an inverter and regulating the flow via adjustable speed operation to minimize the delivery head, the power consumption is drastically cut. Conventional inefficient adjustable speed machines such as the fluid coupler and eddy-current coupler can rapidly enhance their energy saving characteristics by incorporating inverters.

Figure 4 shows an example of the energy saving effect when an inverter is used in a fan motor. Since air volume of the fan is usually proportional to rotation speed, the rotation speed can be decreased to 70% when using a reduced air volume of 70%. Because shaft power is proportional to the cube of the number of rotations, the input power becomes 34%.

Although the use of inverter is problematic with regard to high frequency harmonics, power factor, switching surge over voltage, etc., improvement is seen in the characteristics of input/output circuit filters, reactance for power factor enhancement, PWM (pulse width modulation) converter, active filters, etc. When promoting the use of inverters, it is desirable to understand the precise energy saving effects and to implement middle- and long-range plans.

(2) Application of energy saving devices to lighting

In a typical power source for lighting apparatus, the allowable fluctuation in voltage is 101±6V (95 to 107V) for 100V rated lighting. Illuminance and useful lifetime of general lighting are guaranteed in this range. Accounting for voltage fluctuations, the voltage supplied to 100V lighting is usually 105V. Generally, voltages 5 to 10V greater than the minimum requirement of 95V are applied to lighting apparatus.

The device which reduces the electric consumption of lighting apparatus by regulating the supplied voltage to a constant 95V is known as an "Energy Saving Master", the brand name of Fuji Electric. This energy saving device is connected near the panel board terminal and controls the fluctuating 95 to 107V supply voltage to be a constant 95V. As the device is a non-step voltage regulator constructed with IGBT

Table 3 List of energy saving items

Class	Energy saving items	Common items
Short -range measures (reduce daily waste)	○ ON · OFF management of lighting, office automation machines (turn completely OFF when not in use) ○ Management of air conditioner temperature (adhere to optimum temperature settings) ○ Dispose of unnecessary equipment	Construction of a measurement and recording system (EcoPASSION, Eco HIESSENCE, comprehensive eco supervision system)
Middle -range measures (introduction of light equipment)	○ Add an inverter to fan and pump motors(optimization of rotation) ○ Introduce power saving equipment to the lighting source (optimization of voltage) ○ Refurbish and streamline transformer (higher efficiency and optimum capacity) ○ Manage number of compressors and use an inverter to control air compressors (optimum control of capacity)	
Long -range measures (large -scale measures)	○ Refurbish obsolete equipment ○ Reduce energy consumption of production system (convert from air driven to electronic machinery) ○ Introduce cogeneration ○ Introduce ice heat storage ○ Introduce new alternative energy sources (wind power, hydropower, photovoltaic, fuel cell, wave power)	

Fig.4 Variable speed fan characteristics

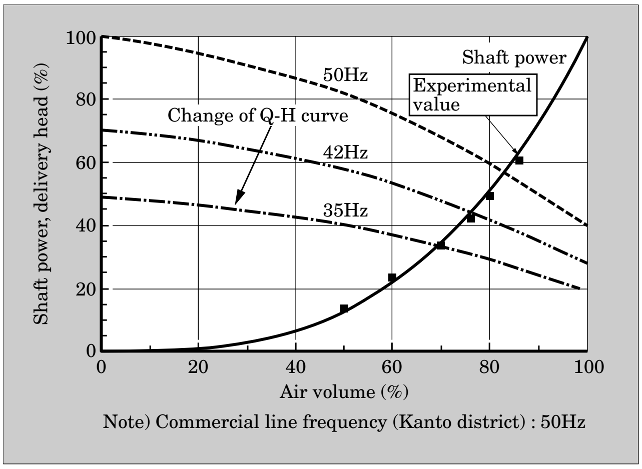


Fig.5 Principle of electricity conservation

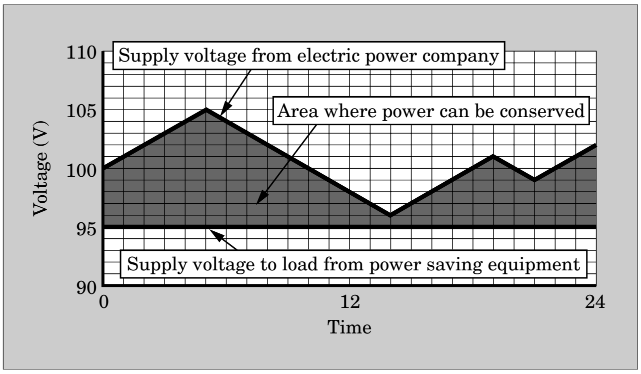
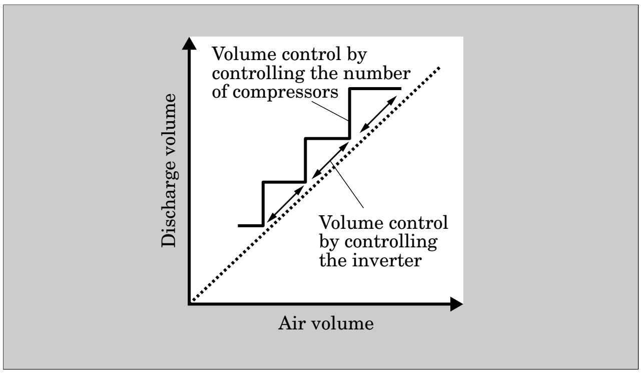


Fig.6 Air volume control of air compressor



technology, it controls the supply voltage more smoothly than a tap-changing controlled transformer. The electric saving principle of the "energy saving master" is shown in Fig. 5. When we reduce the supply voltage from 105V to 95V, power consumption is reduced by approximately 20% because the power consumption for lighting is proportional to the square of the applied voltage.

(3) Replacement of transformer

With a smaller load factor of the transformer, total transformer efficiency will decrease because the rate of non-load loss increases with lower load factor. Usually the maximum total efficiency is obtained by using an oil filled transformer with load factor of 40 to 60%, or a mold-type transformer with load factor of 50 to 70%. But surprisingly in actual operation there are many cases of light loads with 20 to 30% load factors. For example, if we replace an oil filled transformer having a load factor 20% with a high efficiency mold-type transformer of 1/3 the capacity, the load factor increases by a factor of 60% and an approximate 1.5% reduction in power can be obtained. Although the percentage of reduction is low, the annual amount of power reduction (kWh) is significant because the transformer operates throughout the year.

In the case of such a low load factor, it is important to increase the load factor through replacement with an optimum transformer or by streamlining the transformer group. Furthermore, we have considered the case of replacing an oil filled transformer with a high efficiency mold transformer. The mold transformer has additional merits of flame resistance, virtually maintenance-free operation and increased reliability with high efficiency.

(4) Energy conservation of the compressor

Many air compressors are used as power sources at machine factories or forging works. Sustaining high efficiency through optimum maintenance, adoption of looped piping, and the optimum design of piping have been considered as energy saving measures for compressors. Regulation of the number of compressors and control of the inverter are also considered as energy saving measures.

One of the mechanisms for compressor volume control is the "unload control" which reduces the fluctuation of a delivery head. However, the accompanying decrease in efficiency is a disadvantage of unload control. Regulation of the number of compressors is a means to achieve highly efficiency air volume control. When using multiple compressors, selection of the number of compressors to operate depends on the load air volume. This method is able to increase efficiency during partially loaded conditions. As shown in Fig. 6, by combining compressor number control with inverter utilization, we can use continuous air volume control.

However, due to the compressing mechanism of the compressor, it is necessary to consider the suitability of variable speed compressors on a case-by-case basis. In an example where an oil feeding type compressor was remanufactured into an inverter driven type and variable speed control was used to control the speed within a range of 30 to 100%, power consumption was reduced by 15%.

(5) ESCO business

ESCO collects discounted electric power and fuel bills by insuring a reduced quantity of consumed energy, assembling project financing for profitability, and implementing measures to realizing the guaranteed characteristics. Fuji Electric has implemented the first ESCO effort at a health and environmental facility in Ishikawa Prefecture. The insured power reduction rate of 10% was determined by implementing the following three measures: use of inverters in the fans and pumps for air conditioners, use of electricity saving devices in lighting apparatuses, and lowering the capacity of transformers and using molded type transformers. An approximate power reduction of 12% has been achieved after implementing these measures for electric saving. The funds for investment are scheduled to be collected over a 6-year period.

7. Application of New Alternative Energy Sources

7.1 Necessity of new alternative energy sources

New aternative energy will become a potentially large market in the long run, and is a pillar of Japan's energy policy for the purpose of simultaneous achievement of the 3Es: Energy security, Economic growth and Environmental protection for energy.

To achieve the 3E goals, it is necessary to promote energy conservation to reduce energy consumption. It is also important to introduce new alternative energies such as “non-fossil fuel energies” to supply energy.

7.2 Amendment concerning the rational use of energy and new alternative energy

The Amendment Concerning the Rational Use of Energy stipulates that “electric power generated by photovoltaic, wind power, etc. is exempt from efforts to rationalize the consumption of energy.”

In other words, non-fossil fuel energy sources (photovoltaic, wind power, hydropower, geothermal power, wave power, nuclear power, etc.) are very important as they are not subject to energy management.

Power from fuel cells is also exempt from energy management as it is classified as a non-fossil fuel energy source. However, the facilities that supply the fuel to the fuel cells are subject to energy management.

Table 4 shows the relations between the Amendment Concerning the Rational Use of Energy and new alternative energy sources.

7.3 Application of various assistance systems

In Japan, as the field of new alternative energy is a growing market that is receiving governmental guidance, it is important to reduce the investment cost to users by applying various systems of assistance.

Assistance, financing and tax related support are provided by governmental organizations such as the New Energy Development Organization (NEDO) and the New Energy Foundation (NEF).

7.4 New alternative energy solution

New alternative energy, which is necessitated by the present socio-economic conditions, is widely used to “liberalize the market for electrical power” and “promote regional power distribution” in addition to its stated purpose to “prevent global warming through energy conservation.”

Fuji Electric has proposed to its users optimum solutions which include some merits of “understanding the present state of energy usage”, “adoption of new alternative energy sources” and “evaluation after the introduction of new alternative energy sources”, and are based on the current socio-economic conditions.

Table 5 lists the new alternative energy sources promoted by Fuji Electric and the general trends of each field.

8. Systemization of Energy Conservation

Important points for energy conservation are the extraction of the energy conservation item and the

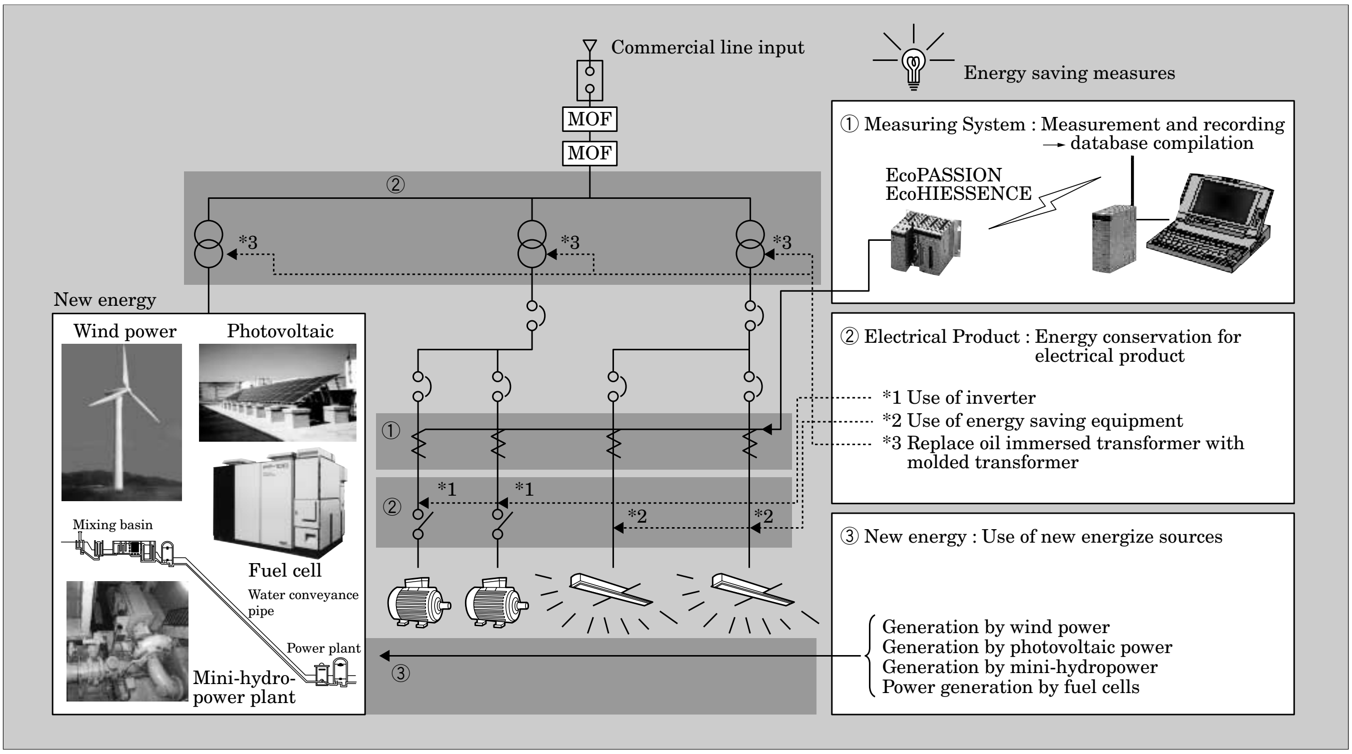
Table 4 Relation to Amended Energy Conservation Law

New alternative energy source	Relation to Amended Energy Conservation Law		Remarks
○ Photovoltaic generation ○ Wind power generation ○ Geothermal power generation ○ Wave power generation ○ Nuclear power generation	Not applicable	Exempt from energy management due to classification as a non-fossil fuel energy source	The energy source may be subject to regulation depending on its system construction. As such, permits must be obtained from the relevant authorities for each new alternative energy source.
○ Fuel cell generation	Not applicable	Exempt from energy management due to classification as a chemical reaction based energy source	
	Applicable	Fuel supply is subject to energy management	
○ Cogeneration	Applicable	However, recommended from the standpoint of equipment introduction with high energy efficiency	

Table 5 Major new alternative energy sources and their general trends in Japan

New alternative energy field	Estimated supply	Market trend
Wind power generation	14 MW (in 1996) 300 MW (in 2010)	○ Recently rapidly growing field ○ Market scale will grow to approx. 12 billion yen/year ○ Approaching price level that is competitive with commercial power rates
	Current status (in 1999) : Aggregate output approx. 70 MW	
Photovoltaic generation	57 MW (in 1996) 5,000 MW (in 2010)	○ Practical application of crystal solar cell ○ Developing thin film solar cell ○ Trending toward lower cost but still expensive
	Current status (in 1998) : Aggregate output approx. 130 MW	
Fuel cell	16 MW (in 1996) 2,200 MW (in 2010)	○ Practical application of phosphoric acid type fuel cell ○ Trending toward lower cost but still expensive ○ Accelerated development of power for car and home (solid polymer fuel cell)
	Current status (in 1999) : Aggregate output approx. 120 MW	
Cogeneration	3,850 MW (in 1996) 10,020 MW (in 2010)	○ Convention energy is used in a new format (most economical) ○ Remarkable micro gas turbine for distributed power
	Current status (in 1998) : Aggregate output approx. 4,630 MW	
Mini-hydro-power generation Wave power generation	——	○ Can effectively use a small water fall ○ Can use rich natural energy

Fig.7 Systemization of energy conservation



implementation of countermeasures based on analysis of the database compiled from the data of measurement and recording equipment. Utilization of additional non-fossil fuel energy sources is also important. Due to its widespread use, long-term measures and promotion, this system of energy conservation appears at first glance to be merely a business that supplies equipment and facilities; however, if scrutinized closely, it is actually an excellent energy conservation system as shown in Fig. 7.

For this reason, it is important to plan and implement energy conservation comprised of the following three basic components: a Measuring system, Electrical products and New alternative energy sources. As shown in Fig. 8, Fuji Electric has been promoting this concept as "MEN", an acronym based on the first letter of each component.

9. Conclusion

Although we are experienced in energy saving techniques and have learned much, our knowledge increases with each energy conservation problem we tackle.

In response to the need for energy savings, we can always find new themes and offer new solutions. Fuji Electric will continue to learn from its experiences and provide satisfying solutions to its customers.

Fig.8 Three basic components "MEN" of energy conservation