8

The Status and Direction of Energy Conservation Technologies in the Consumer Sector

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8.1 Introduction

Based primarily on the experience of having survived the two oil crises, Japan has been striving to simultaneously achieve 3E (energy supply, environment conservation, and economic development), placing these objectives at the center of its energy policy. Energy consumption in Japan, however, is ever increasing, with the society becoming more and more energy-intensive.

Energy conservation is usually considered in a broad sense – i.e., an overall reduction in final energy consumption, which refers to primary energy (oil, etc.) consumption minus power generation losses and other losses involved in the production/conversion process of secondary energy. Specifically, energy conservation can be achieved through two initiatives: one that reduces the input of primary energy itself by streamlining various industrial production processes and improving the efficiency in energy conversion (e.g., power generation), and the other one that reduces final energy consumption in the consumer and transportation sectors. In Japan, energy consumption in the industry sector (centered on the manufacturing industry) has been relatively stable since the first oil crisis, while that in the consumer (household and business) and the transportation sectors has increased dramatically. In particular, energy demand by the consumer sector is expected to surge in the future. There is thus a pressing need to take energy conservation measures, placing particular emphasis on the consumer sector. As part of its Energy Sector Promotion Strategy (2001), the Council for Science and Technology Policy is pushing ahead with R&D to improve the efficiency of energy-consuming equipment, and research on incentives designed to promote energy conservation measures.

In view of these developments, this report addresses energy conservation technologies with particular emphasis on the consumer sector, which may require drastic energy conservation measures because of its increasing energy consumption, and discusses viewpoints for energy conservation technologies in this sector.

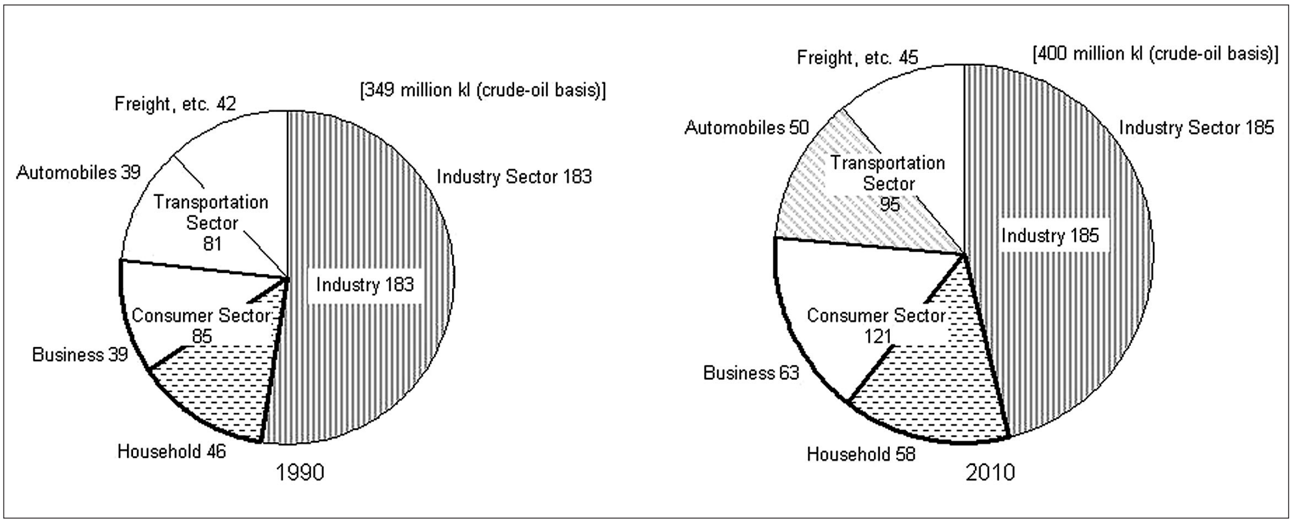
8.2 The status and prospects of energy consumption

To meet Japan's CO_2 emission reduction target under the Kyoto Protocol, according to the Guideline of Measures to Prevent Global Warming (2002), final energy consumption in 2010 must be maintained below 400 million kl on a crude-oil basis through measures such as the promotion of energy conservation measures, new energy sources and nuclear power generation.

Figure 1 shows the breakdown of actual energy consumption by the industry, consumer and transportation sectors in 1990, and the prospects of energy consumption in 2010, with measures to achieve the Kyoto Protocol's target taken into account. As shown in the chart, energy consumption in the consumer sector is expected to account for some 30% of the total consumption in 2010.

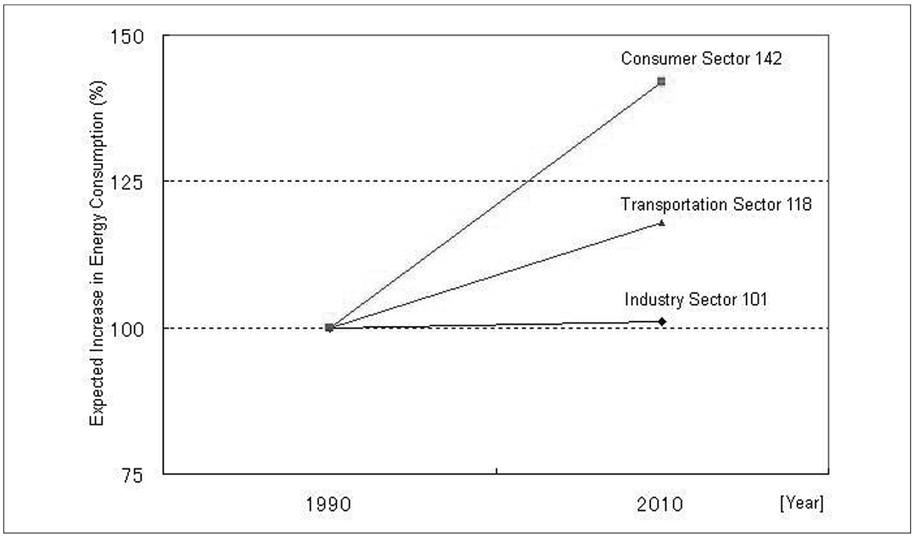
Figure 2 shows prospective increases in energy consumption by sector in 2010, with 1990 as a base year (see Figure 1); energy consumption in the consumer sector is expected to increase by some 40%. Thus, of all the energy conservation measures, those for the consumer sector are particularly important.

Figure 1: Status and prospects of energy consumption



Source: Author's compilation based on reference [1].

Figure 2: Prospects of energy consumption by sector

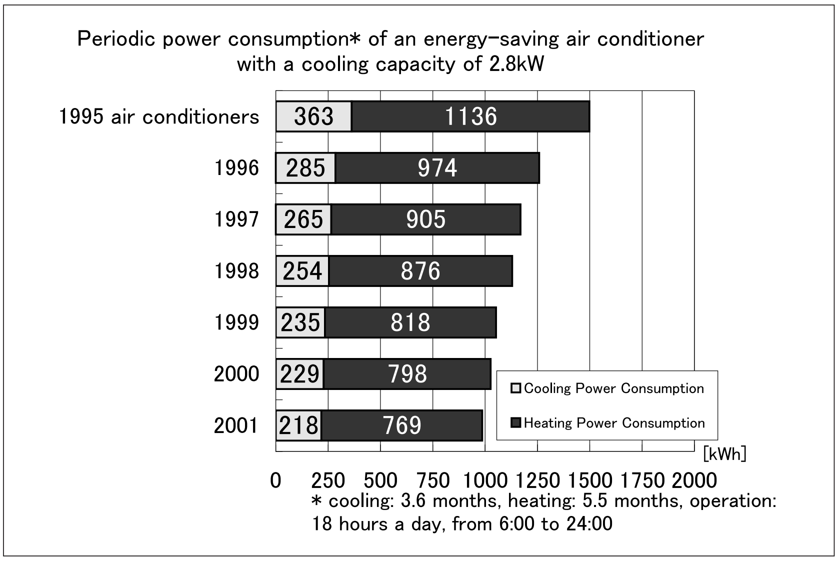


Source: Author's compilation based on reference [1].

Energy consumption in the consumer sector (household and business) currently accounts for some 25% of Japan's total energy consumption; it is expected to increase in the future. Specifically, a large part of energy consumption in the business sector can be attributed to air conditioning (50%) and lighting (30%) [2]. While energy consumption in the business sector is on the rise because of extending business hours and around-the-clock services, always-on devices are also increasing as we move into the information age - these devices not only consume energy but also raise room temperatures, which in turn may boost the demand for air conditioning. Another problem involves a relatively low awareness of energy management among the business sector, compared to the industry sector - energy costs in which could have a direct impact on production costs. Energy consumption in the household sector is also expected to increase.

Figure 3 shows the recent trend in energy consumption by air conditioning, which has decreased by about one third in the last six years. Energy consumption in the consumer sector, however, is increasing despite the improved efficiency of energy-consuming equipment. The possible reasons: an increase in the number of air conditioners with longer operating hours, and the rapid and widespread proliferation of personal computers and other electronic devices.

Figure 3: Progress in energy saving in air conditioners



Source: Author's compilation based on statistical data provided by the Japan Refrigeration and Air Conditioning Industry Association (JRAIA).

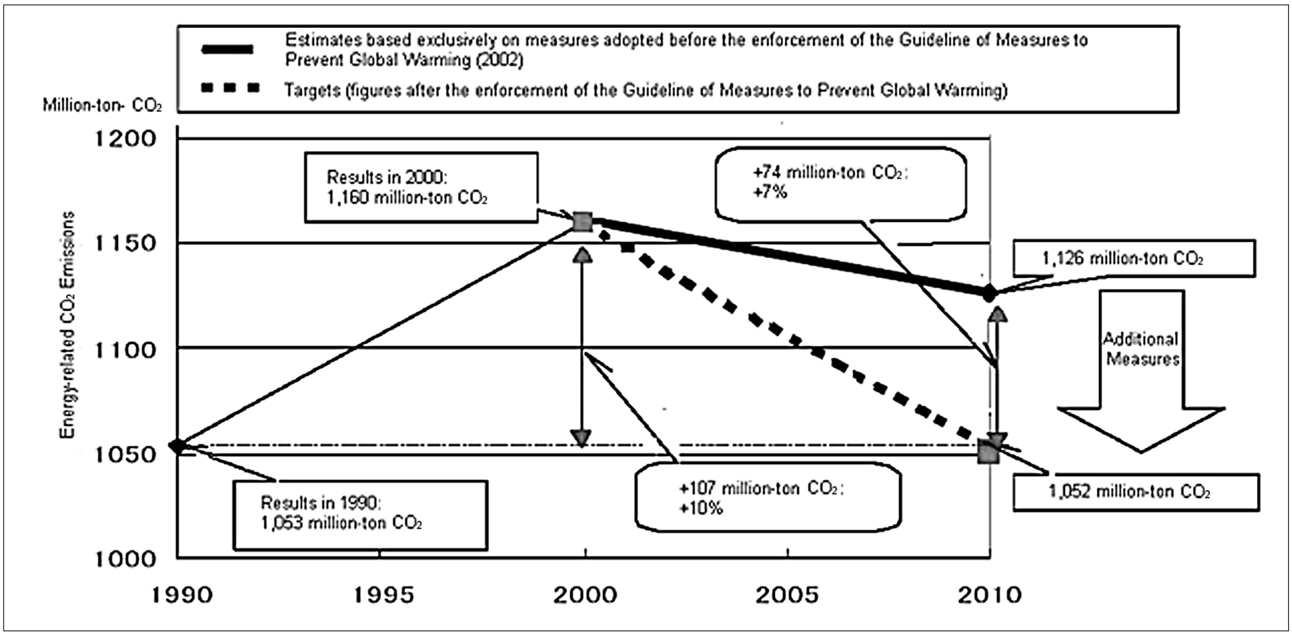
8.3 Energy conservation and anti-global warming measures

With the Kyoto Protocol ratified, Japan aims to reduce greenhouse gas emissions by 6% below the 1990 levels between 2008 and 2012. The Guideline of Measures to Prevent Global Warming (2002) specifies reductions in methane and nitrous oxide emissions, development of innovative technology, forest sink, a shift to CFC's substitutes and reductions in energy-related CO_2 emissions as measures to achieve this target. In particular, it is expected that energy-related CO_2 emissions in 2010 be maintained at 1990 levels.

Japan's energy-related CO_2 emissions, however, increased by some 10% from 1990 to 2000 (see Figure 4). The Guideline of Measures to Prevent Global Warming, therefore, adopted the following three measures (expected reductions in CO_2 emissions: 74 million tons) to maintain energy-related CO_2 emissions at 1990 levels.

1. Energy conservation measures (expected reductions in CO_2 emissions: 22 million tons)

Figure 4: Results and prospects of energy-related CO_2 emissions (Base year: 1990)



Source: Author's compilation based on the Guideline of Measures to Prevent Global Warming (2002).

2. New energy measures (expected reductions in CO_2 emissions: 38 million tons)
3. Fuel shift in power sources, etc. (expected reductions in CO_2 emissions: 18 million tons)

Energy conservation measures contribute to about 30% of the total reductions expected for these three measures, which suggests their significance in curbing global warming.

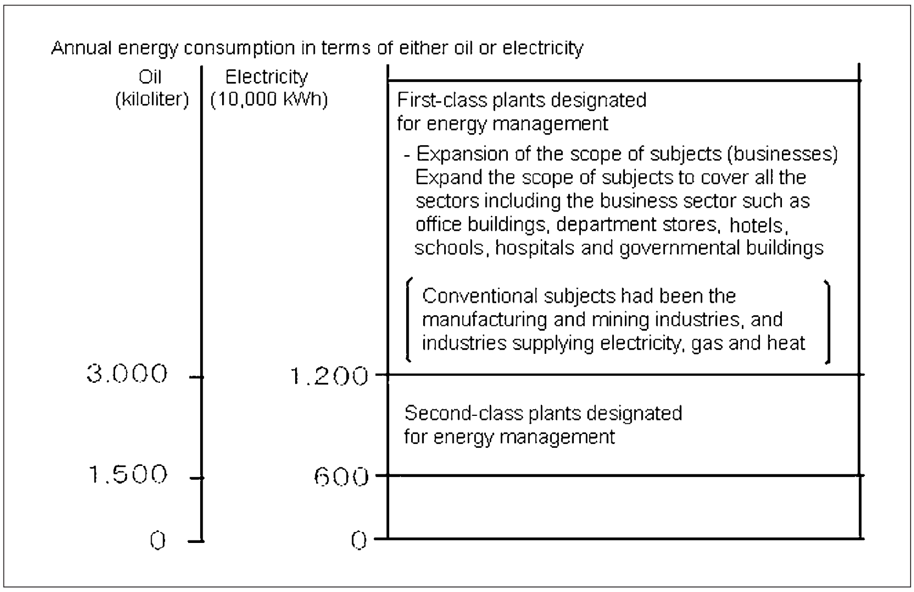
To meet Japan's CO_2 emission reduction target under the Kyoto Protocol, final energy consumption in 2010 must be maintained below 400 million kl on a crude-oil basis, as mentioned in Chapter 8.2. This target is based on the premise that 10 to 13 nuclear power plants be constructed by 2010, in addition to measures such as those for energy conservation and new energy. The present situation, however, is such that the expansion of nuclear power generation is not feasible due to site selections and other related problems. Without the expansion of nuclear power generation, energy-related CO_2 emissions will increase by some 40 million tons between 1990 and 2010, according to some estimates[1]. Moreover, energy-related CO_2 emissions are increasing gradually, in part because of shutdowns of nuclear power plants. In view of these circumstances, energy conservation measures are becoming increasingly important for achieving the target under the Kyoto Protocol.

8.4 Development of laws and regulations

The law concerning the rationalization of energy use (hereinafter referred to as "The Energy Conservation Law") was instituted in 1979 in response to the two oil crises, and has been revised six times up to 2002. As mentioned in Chapter 8.2, awareness of energy management among the consumer sector (particularly the business sector), energy consumption of which is increasing dramatically, is not relatively sufficient when compared to the industry sector. In a bid to raise the general awareness of energy management, therefore, the 6th version of the Energy Conservation Law (revised in June 2002 and enforced in April 2003) expanded the scope of energy conservation measures (originally designed for first-class plants designated for energy management) to cover all the sectors, and tightened regulations for the business sector (see Figure 5). First-class plants designated for energy management refer to those whose annual energy consumption exceeds 3,000 kl on a crude-oil basis or 12 million kWh.

First-class plants designated for energy management set energy standards for each of their facilities (air conditioners, light fittings, elevators, etc.), and are obliged to appoint energy managers,

Figure 5: Subjects of energy-saving measures (at Plants designated for energy management)



Source: Author's compilation based on the Energy Conservation Law (2002).

Table 1: Additional conservation measures in the consumer sector

Measures		Expected Reductions (million kl/crude oil)
Reductions in standby power consumption		0.4
Promotion of high-efficiency water heaters		0.5
Promotion of high-efficiency light fittings (cross-sectorial)		0.5
Improvement of energy management systems	Household demand	0.9
	Business demand	1.6
promotion of equipment conforming to top-runner standards		1.2
Total		5.1

Source: Author's compilation based on reference [3].

prepare and submit energy conservation plans and report on energy consumption on a regular basis. Incidentally, second-class plants designated for energy management refer to those whose annual energy consumption exceeds 1,500 kl on a crude-oil basis or 6 million kWh; they are also obliged to report on energy consumption and its related issues regularly.

On-the-spot inspections are conducted for these first-class and second-class plants as the need arises, and procedures such as recommendations and announcements are taken when energy conservation measures fall far short of the standards.

8.5 Trends in energy conservation measures and technologies

As mentioned in Chapter 8.3, energy conservation is considered an effective means to help reduce energy-related CO_2 emissions in the framework of the Guideline of Measures to Prevent Global Warming (2002). This chapter addresses additional energy conservation measures that the guideline adopted in order to maintain energy-related CO_2 emissions at 1990 levels.

The additional energy conservation measures (an equivalent to 7 million-kl reductions in crude oil, or 22 million-ton reductions in CO_2 emissions) are expected to cut back 0.9 million kl in the industry sector, 1.0 million kl in the transportation sector and 5.1 million kl in the consumer sector, all on a crude-oil basis. Energy conservation measures in the consumer sector account for some 70% of the total reductions, which indicates their significance.

Table 1 shows the energy conservation measures in the consumer sector.

The "Top Runner Standard," which was introduced when the Energy Conservation Law was revised in 1998, aims to "raise the energy conservation standards of electric appliances (home appliances, office automation equipment, etc.) so that they match or outpace the energy conservation standards of the best products (in each category) currently on the market." This standard applies to mass-produced and energy-intensive appliances such as refrigerators, TVs and air conditioners. Manufacturers that continue to produce substandard products are made known to the public, along with their products in question, and are penalized accordingly.

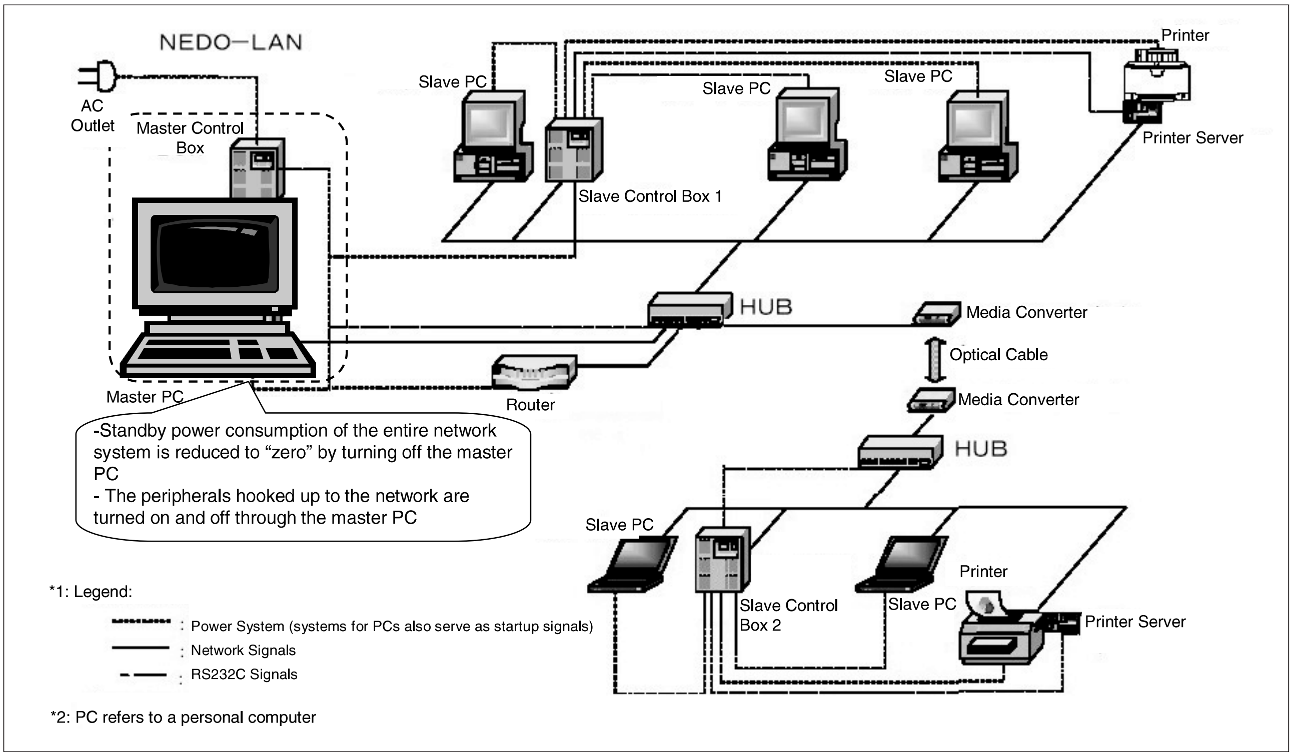
The New Energy and Industrial Technology Development Organization (NEDO), through its project researches, is playing a leading role in conducting R&D in Japan for the measures mentioned above. The following are the recent trends in related R&D activities:

8.5.1 Development of technologies for reducing standby power consumption

Standby power consumption refers to power consumption during the standby mode of electrical equipment. Most office equipment are connected to and controlled through networks, and like home appliances, they are always plugged into outlets. Battery chargers and adaptors that convert alternating current into low-voltage direct current also consume power as long as they are plugged into outlets. Standby power consumption is said to account for some 10% of operational power consumption.

R&D is now underway to minimize standby power consumption by controlling the power

Figure 6: Example of technology for reducing standby power consumption



Source: Author’s compilation based on reference [4].

on/off of electrical equipment through networks (see Figure 6).

8.5.2 Development of high-efficiency equipment

(1) Development of technologies for high-efficiency lighting

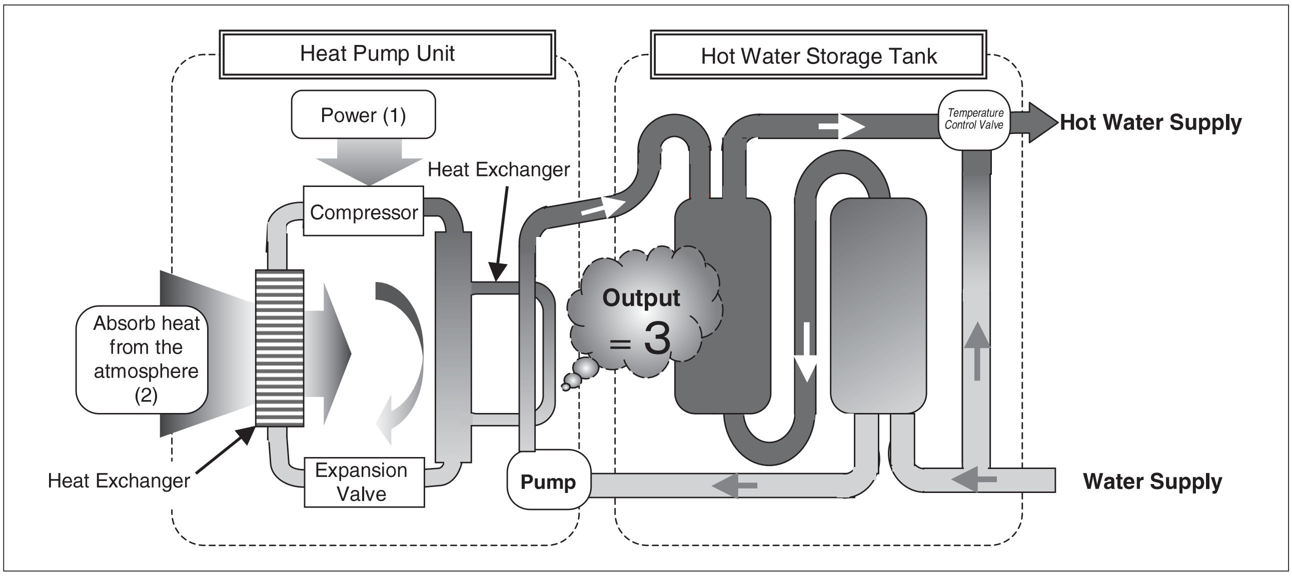
Lighting accounts for 20–40% of the total power consumption in the consumer sector. Reducing power consumption by lighting, therefore, contributes to energy conservation and lowers the air-conditioning load. For this reason, R&D is underway on high-efficiency lighting and displays (e.g., long-life white LED lighting systems, which reduce energy consumption by 50% compared to conventional fluorescent lights). NEDO’s recent project succeeded in developing a high-efficiency LED, which converts electric energy into effective light energy at a record high rate of 43%[5]. According to some estimates, white LED lighting systems would save 0.83 million kl of crude oil a year at an adoption rate of 13% [6] – a reduction that far outpaces the numerical targets shown in Table 1.

(2) Development of technologies for high-efficiency water heaters

Energy demand in the household sector, which is decentralized, fluctuates daily and seasonally; its heat utilization is limited to low-temperature heat such as for heating and hot-water supply. This is why cascade utilization of heat (i.e., effective energy use from higher temperatures to lower temperatures) is not feasible in the household sector.

The latest technologies for improving the heat utilization efficiency in air conditioning and hot-water supply include waste-heat utilization that makes use of low-temperature heat sources, functional materials such as heat storage materials, and heat pumps. For example, systems such as a hybrid cycle consisting of absorption/compression refrigerating cycles are being developed to use low-temperature waste heat for air-conditioning purposes[7]. On the other hand, regulations against the use of CFCs are tightening because of their ozone depletion properties, which in turn accelerate the development of heat pumps using CO_2 as a refrigerant (CO_2 does not deplete the ozone layer, and its global warming potential is relatively low). A heat pump is a system that utilizes the heat pumped up from low-temperature heat sources, and generates more energy than it consumes. In fact, recently-developed heat pumps

Figure 7: Mechanism of a CO_2 heat pump water heater



can produce more than three times the energy they consume; water heaters incorporating these heat pumps have been developed recently (see Figure 7).

R&D efforts are also underway on geothermal heat pumps that use groundwater, river water, etc., as heat sources[8].

8.5.3 Development of energy management systems

Energy demand in the consumer sector has been on the rise, and is expected to increase further in the future. But the consumer sector has yet to raise its awareness of energy management. With this situation as a backdrop, there has been growing attention to IT-based energy management as a means to use equipment efficiently, while expectations are running high for its contribution to energy conservation. This system, however, is still in the demonstration phase with its cost issues pending. A user-friendly system should thus be developed for its promotion - a means to pursue cost reductions.

(1) Home energy management system (HEMS)

The Home Energy Management System (HEMS) controls the energy conservation operation of home appliances in a given household. With the network of home appliances (using gateways installed on voltmeters and switchboards, and communication facilities such as lamp cords, wireless/infrared devices, etc.), it detects the movement of residents, the information on which is shared and controlled by each electric appliance. Specifically, this system, which is designed to promote energy conservation in households, controls the energy-efficient operation of appliances (air conditioners, etc.) and the switching on/off of light fittings, while displaying the electricity bill on a real-time basis in order to raise the awareness of energy management.

A typical example of adopting HEMS shows that power consumption can be reduced by some 23% (for home appliances such as air conditioners, TVs and light fittings) [9].

(2) Building Energy Management System (BEMS)

The Building Energy Management System (BEMS) monitors and controls energy consumption, thereby saving as much energy as possible. Like HEMS, it communicates with the electric equipment in a building to detect their operating conditions as well as utilizing environmental information such as temperatures and luminous intensity.

Systems that can control a group of buildings are being developed to promote the adoption by medium-scale buildings that are becoming widespread (see Figure 8).

A simulation of controlling the heat source and air conditioners in a building[10], based on BEMS, shows that power consumption can be reduced by some 14%.

8.6 Viewpoint of promising energy conservation measures

The technologies discussed in Chapter 8.5 should be addressed proactively since they hold great promise of contributing to energy conservation. Conventional energy conservation measures, meanwhile, are designed to address individual targets such as buildings, facilities and equipment.

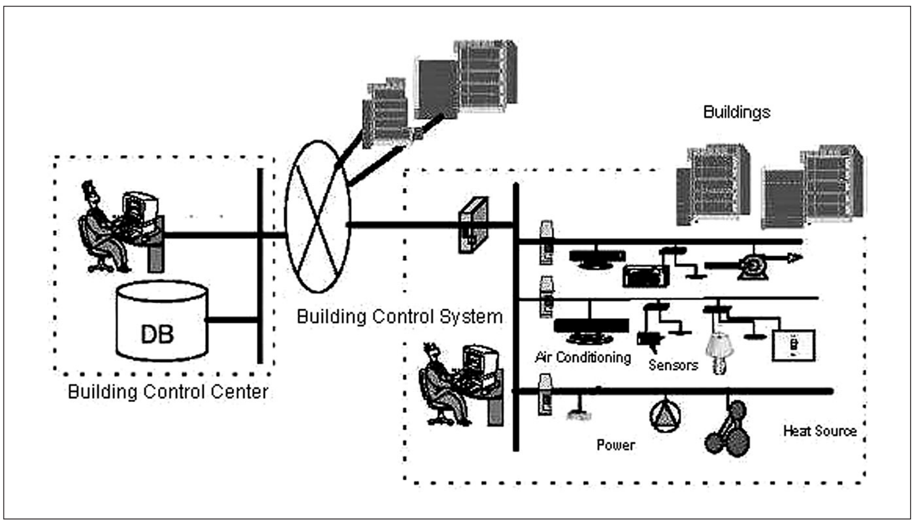
In Japan, specific research is underway on measures to save energy by appropriately combining existing energy sources (power, gas, etc.) with decentralized power sources (fuel cells, etc.) in accordance with users' energy demand. Introduction of decentralized power sources, however, is not necessarily beneficial to society even if it has localized advantages (to specific users) in terms of energy consumption, environmental loads and costs (the introduction of low-cost but environment-unfriendly equipment is one such example). There is thus a growing need to develop technologies for pursuing energy conservation based on combinations of various measures such as energy-efficient air conditioners and light fittings, energy management systems and decentralized power sources. Hand-in-hand with the development of these technologies, there will also be a need to discuss what kind of energy conservation equipment and decentralized power sources should be adopted, and to what extent they should be introduced. Whatever the case may be, all these relevant factors should be taken into account in developing energy conservation technologies that are rational from a social point of view.

In the meantime, there has been a move in the academic society to establish ad hoc groups on energy conservation, based on a cross-sectional framework, in a bid to promote collaboration between energy conservation experts and researchers in industry, academia and government[10]. This initiative is expected to contribute to addressing the issues mentioned above.

Conventional approaches to energy conservation include dissemination of information about energy conservation practices, and public relations activities primarily through seminars, both of which should be promoted in the future. Public awareness of acting on behalf of the environment, however, is hardly sustainable only with the argument that the environment must be protected and we should be responsible for future generations. In this context, more practical measures should be adopted and introduced - e.g., systems whose very energy conservation measures would benefit those who implement them. It is also important to raise public awareness of energy conservation through day-to-day educational activities.

A system implemented in California in the summer of 2001 and 2002 provides a good example of power-saving programs; the state government, through this system (The 20/20

Figure 8: System for controlling heat sources and air conditioning in buildings



Source: Author's compilation based on reference [5].

Program), shouldered 20% of the electric bills of users who had reduced electricity consumption by more than 20% from their 2000 levels (about 34% of the users benefited from the program in 2001[11], while only household users were entitled to the program in 2002). This kind of economic incentive for the mindset and activities to proactively change lifestyles and implement energy conservation measures is expected to serve as a tool to curb energy consumption because it works directly in favor of those who implement effective measures. The introduction of such a system, moreover, would have an impact on the behavior of the public as well as on their awareness of energy conservation activities.

8.7 Conclusion

Japan has been striving to save energy, promoting technological development through a variety of measures such as the application of the Top Runner System to energy-consuming equipment. It is essential to further develop energy-efficient equipment, and for the application of the Top Runner System to be expanded. Energy management systems (HEMS, BEMS, etc.) being developed are certainly part of the key technologies that should be promoted further because they contribute to achieving energy conservation through the rational use of equipment, and without detriment to our day-to-day amenities.

In the future, technologies for achieving further energy conservation should be developed, based on combinations of a variety of relevant technologies being developed independently. In addition to developing these energy conservation technologies, systems to offer economic incentives for energy conservation activities should be discussed as one of the key measures.

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