ENERGY CONSUMPTION AND MITIGATION TECHNOLOGIES OF THE BUILDING SECTOR IN JAPAN

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ABSTRACT

Since the primary due period of 2008-2012 of the Kyoto Protocol Target Year is close at hand, specific measures for the prevention of global warming should be implemented in all areas. This paper outlines the energy consumption and greenhouse gas emission trends in the residential and commercial sectors in Japan. The paper presents the projections of CO_2 emissions until 2050. The projections indicated that if the various energy conservation measures were implemented, up to 59% of reduction in CO_2 emissions against the 1990 level can be achieved. The paper also describes political measures in energy conservation, including the building energy conservation standard, Comprehensive Assessment System for Building Environmental Efficiency (CASBEE), top-runner programs, financial incentives, and the dissemination of Cool Biz concept.

KEYWORDS

PCC, GHG, Building, Energy, Japan

INTRODUCTION

In May 2007, the Fourth Assessment Report (AR4) of The Intergovernmental Panel on Climate Change (IPCC) /WG3 was approved in Bangkok, Thailand. One of the authors has participated in the working group for Chapter 6 Residential and Commercial Buildings of AR4, IPCC/WG3. In relation to this work, the Building Alleviation Policy Review Committee (Chairperson: Shuzo Murakami) was established in November 2004 with the cooperation of the Institute for Building Environment and Energy Conservation (IBEC), and the Global Industrial and Social Progress Research Institute (GISPRI) under the sponsorship of the Land, Infrastructure and Transportation Ministry and the Ministry of Economy, Trade and Industry, Japan. A report with up-to-date information of energy consumption and mitigation technologies in Japan was prepared and submitted to the IPCC/WG4. The report was later published by Lawrence Berkeley National Laboratory in association with Mark Levine in December 2006. This paper summarizes the contents of the said report entitled “Energy Consumption, Efficiency, Conservation, and Greenhouse Gas Mitigation in Japan’s Building Sector” (Murakami et al., 2006).

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OVERVIEW OF ENERGY CONSUMPTION AND GREEN HOUSE GAS (GHG) EMISSION TRENDS IN JAPANESE BUILDINGS

Total Energy Consumption by Residential and Commercial Sectors

In Japan, energy consumption by building sector constituted 28% of the total energy consumption (2005). Of this, the shares of commercial and residential sectors were 13.2 and 14.8%, respectively. Since the oil crisis in 1973, energy consumption by industrial sector remains at almost constant level, while consumption by transportation sector was increasing until few year ago, on the other hand, energy consumption by commercial/residential sector is still increasing.

Energy Consumption by End Uses in Japan's Residential Buildings

Comparison with End-Use Energy Consumption in Other Developed Nations

Figure 1 shows that energy consumption and end uses in Japanese households differ significantly from other developed nations. One of the main differences is that energy consumption for space heating is much lower in Japan than in western countries. It is mainly due to differences in space-heating methods and practices because of different lifestyle and climate.

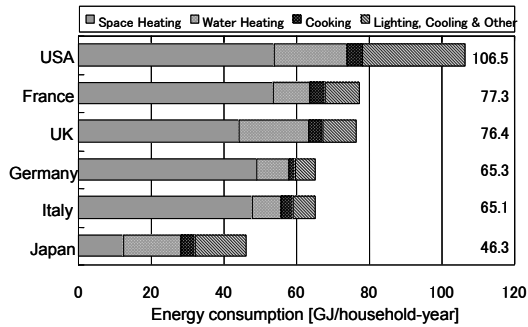

Figure 1. Energy consumption of developed countries.

Trends in Residential Energy Consumption in Japan

In Japan, the average annual residential energy consumption is about 45 GJ/household per year in the last decade, and the figure is increasing almost every year. The most recent data show that 25 to 30 percent of the total residential energy consumed in Japan is used for space heating/cooling, 35 to 40 for hot water supply (e.g., baths and showers), and 35 to 40 percent for lighting/other (e.g., refrigerators, TVs). Growth in energy use for hot water supply and lighting/other uses is more significant than space heating/cooling. Thus, in order to reduce the residential energy consumption, it is necessary to reduce the energy consumption for hot water supply and lighting/other uses.

Regional Differences in Japan

Figure 2 shows the geographical pattern of energy consumption in Japan. In Hokkaido, energy consumption for space heating is comparable to that in the western countries. However, energy consumption for space heating in the southern regions (south of Tokyo) is less than 25 percent of the consumption of Hokkaido. The overall energy consumption in the southern regions of Japan is about two-thirds of the total in Hokkaido.

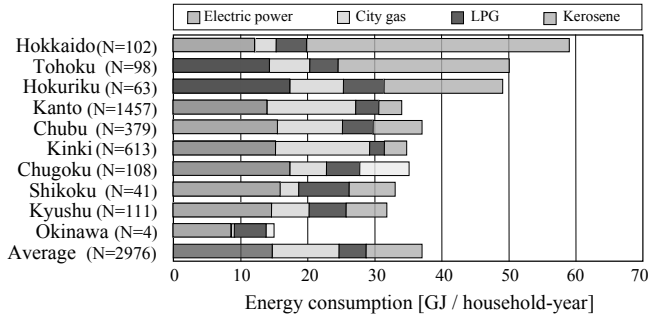

Figure 2. Geographical pattern of energy consumption in Japan.

Energy Consumption in Japanese Non-residential Buildings

The energy consumption trend for the Japanese commercial building sector is shown in Figure 3. Although energy consumption intensity is relatively stable, the total amount of energy consumed is increasing at a rapid rate, particularly in the commercial sector. The increase in commercial sector energy consumption is mainly caused by the increase in the total floor area of commercial buildings.

The energy consumption intensity for offices, which accounts for the largest floor area in commercial sector, is about 1,900 MJ/m^2 per year, of which about 50 percent is for air conditioning, 30 percent for lighting and office equipment, and 20 percent for elevators, hot-water supply, and other uses. In hotels and hospitals, by contrast, hot-water supply accounts for the majority of total energy consumed. Total energy consumption by hotels and hospitals is about 1.5 to 2 times greater than that of offices.

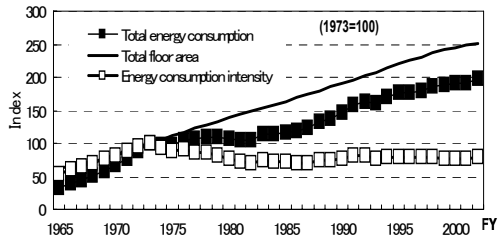

Figure 3. Energy consumption trend for Japanese commercial building sector.

Projection of CO_2 Emissions from the Japanese Building Sector through 2050

For projecting CO_2 emissions from construction, renovation, and operation of buildings in Japan through the year 2050, several scenarios were modeled based on different assumptions about future emissions-reduction and energy-conservation measures.

Figure 4 shows the projections under Scenario 1-a, which assumes that no emissions-reduction / energy-conservation measure to be adopted. Under this scenario, annual CO_2 emissions from construction, renovation and operation of buildings will emit 470 million tons of CO_2 in 2010, a 15 percent increase from 1990 level. The total floor area of buildings is expected to decline gradually due to decreasing population. As such, building-related CO_2 emissions under Scenario 1-a in 2050 are projected to decrease by 10 percent from 1990 level.

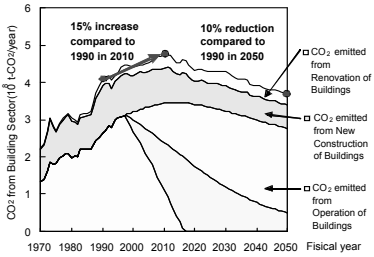

Figure 4. Projection results of Scenario 1-a.

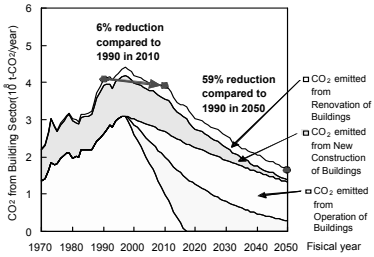

Figure 5. Projection results of Scenario 5-c-X.

Figure 5 shows Scenario 5-c-X, which assumes that CO_2 emissions from electricity use are reduced in accordance with the targets set for emissions-reduction/energy-conservation measures. Annual CO_2 emissions in 2010 will be 390 million tons, a decrease of 20 million tons or 6 percent from 1990 level. Annual CO_2 emissions in 2050 will be reduced to 40 percent of 1990 levels.

CURRENT TECHNOLOGIES AND ENERGY-CONSERVATIOIN/GHG MITIGATION STRATEGIES FOR JAPANESE BUILDINGS

Technologies for Residential Buildings in Japan

Building Envelop and Space Heating & Cooling

Japanese houses are traditionally constructed of wood; half of all new houses today are wooden (post and beam construction). Prefabricated houses account for 20% or 30% of the total residential buildings in Japan. Construction methods include RC (Reinforced Concrete) system, S (Steel) system, and wooden system. Insulation/air tightness technologies have been employed in all of these construction methods. In order to allow for both thermal insulation and air tightness in winter and cross ventilation in other seasons, large windows with significant insulation properties are installed. Double glazing is becoming more and more common in recent years (installed in more than 80 percent of all newly built detached houses in 2004). At the same time, other types of glazing are also being used, including low-emissivity (low-E), vacuum sealing, and combinations. With regard to solar shading performance, the prevalence of rainfall and strong winds (including typhoons) in Japan means that outdoor shading and awnings are not popular. Instead, large eaves/canopies or solar shading glass are generally used.

A number of heating technologies are used in Japan: passive solar, total heat exchanger, traditional Japanese Kotatsu, heat pump, gas/kerosene fan, and biomass-fueled stove.

Room air-conditioners are installed in 87% of the houses in Japan and the 2.3 units were possessed in average, but the energy consumption used for space cooling is only 3%. In the near future, the number of the units installed in houses will increase and it is expected that the peak load of electrical consumption will rise remarkably.

Water Heating

Energy consumption for hot water supply, which shares about 30% of the total residential energy consumption, is one of the main subjects for energy saving. For saving energy in hot water supply, the reuse of water in bathtub for washing machine, change of lifestyle from bathing in bathtub to taking a shower, thermal insulation of bathtub, change to water saving shower head, etc.

Strategies for supply side energy conservation of hot water include the use of solar water heaters heat

pump, hot water heater with CO2 refrigerant, condensing water heaters, etc. In recent year, solar water heater usage decreased by half because of the difficulty of maintenance and the spread of PV. CO2-refrigerant heat-pump water heater has a COP of approximately 4.9.

Residential Power Generation

At the end of March 2004, PV power accounted for approximately 860 MW in Japan. An average household consumes approximately 3,600 kWh, which can be supplied by a 3- to 4- kW rated-output PV system. PV system owners have the ability to sell power back to utilities, which helps reduce power consumption during the hot summer when the demand for power is greatest.

Consumer Appliances

In Japan, consumer appliances whose energy consumption can be reduced to help reduce GHG emissions include: refrigerators, washing machines, dishwashers, televisions and videocassette recorders, and cooking devices.

Energy Savings from Lifestyle Changes in Japan

Energy-conservation strategies involve not only technical measures, such as adding thermal insulation to buildings and improving the efficiency of equipment, but also non-technical, lifestyle changes such as moderating temperature settings for space heating and cooling and reducing the duration and frequency of use of appliances.

In the previous investigation by the current authors, energy savings resulting from lifestyle changes by using the 74-item “Save-energy Menu” in summer, autumn and winter were 21.5%, 17.3% and 26.5% respectively in average, and 47% at the maximum in case of single apartments in Tokyo. Also, in the case of Tohoku District, energy consumption was found to decrease by up to 17.4%, with average decrease of 5.5% in spring and 5.1% in summer. On the other hand, dynamic simulation of energy consumption by a well-insulated house indicated that the energy consumption in the energy-saving case was reduced by 38% compared to the base case. Lifestyle changes were more effective than increasing the thickness of thermal insulation as a means to save energy as shown in Figure 6.

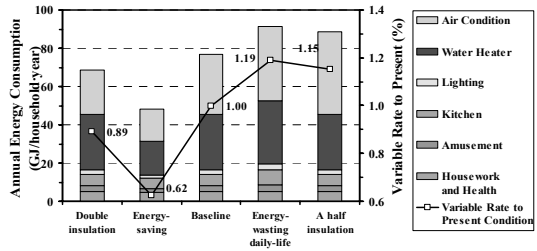

Figure 6. Calculated energy consumption results for different energy consumption behavior cases.

Technologies for Non-residential Buildings in Japan

Building Envelop

The Japanese standard for building envelope thermal performance is based on Perimeter Annual Load (PAL), which represents annual heat load per unit of perimeter floor space, according to the type of the building. To meet this standard, designers must carefully choose the building shape and orientation, window specifications, air-conditioning zoning, and many other elements, as well as paying careful attention to thermal insulation of the envelope and use of energy-efficient window glass, solar shading, etc. In most regions of Japan energy consumption for cooling in office buildings is greater than for

heating; as a result, solar shading, thermal insulation, and building tightness are extremely important in efficient office building designs. Windows' perform significantly less well than other building components (e.g., roofs, walls) in the area of solar shading and have significant impacts on cooling and heating loads. Various measures, such as double glazing, airflow windows (ventilation window) and window shading are employed to address the thermal impacts of windows. Some examples have been reported in which airflow windows equipped with built-in, automatic, slat-angle-control blinds provided excellent solar shading, daylight utilization, visibility, and energy savings

Shading performance of non-transparent envelope elements such as exterior walls and roofs can be enhanced by increasing solar-reflective properties as well as by thermal insulation. Roof-top planting is beginning to be implemented in Tokyo with hopes to offset temperature increases associated with urban heat-island effects through the thermal insulating properties of soil and the evaporative cooling effect of both soil and plants.

HVAC systems

Cooling and heating rooms by using air conditioners in small-size and medium-size non-residential buildings is as common as in homes. These devices are mainly for variable refrigerant volume (VRV) systems, which have one or more outdoor and indoor units connected by piping. The COP rating of package air-conditioners for commercial use is 2.93 - 4.28 for cooling, and 3.45 - 4.71 for heating.

In recent years, it has become popular to attach an inverter (variable speed control) to the pump or the fan of VAV and VWV systems, which reduces annual energy consumption. Installing a building energy management system (BEMS) allows for real-time display of energy usage and analysis of operations data to enable effective management of lighting and air conditioning, detection of problems, and appropriate maintenance.

Power Generation/District Heating and Cooling

As of 2004, Japanese district heating and cooling systems served 151 districts, which comprising 44,949 houses, 1,515 commercial buildings, 45M m^2 of service area, and a gross floor area of 47M m^2. The residential portion was 1,316 TJ (mainly for heating and hot water supply), and the non-residential portion was 23,586 TJ, of which cooling was 15,108 TJ, heating was 8,477 TJ District cooling and heating systems mainly rely on one of three types of energy sources: absorption/boiler (combined absorption chiller and boiler with cogeneration use of exhaust heat); electric-drive chiller/heat pump; or electric drive/absorption, which combines the previous two methods.

Office Equipment

During the past 30 years, office automation has increased rapidly, causing a significant increase in power consumption and cooling loads in office buildings. Energy savings have been achieved in computers, disk drives and copiers, based on the Japanese Top Runner Standard. A target energy-efficiency ratio improvement has been established for computers at 83 percent of the 1997 energy use level by 2005 and for copiers at 30 percent of 1997 levels by 2006.

POLICIES TO PROMOTE ENERGY CONSERVATION ANDGHG EMISSIONS MITIGATION IN JAPANESE BUILDINGS

Energy Conservation Standards for Residential and Non-residential Buildings

In Japan, the Energy Conservation Law was passed in 1979. Based on this law, energy conservation standards for residential and non-residential buildings were formulated in 1980.

The standards for residential buildings were revised in 1992 and 1999. The 1999 revision added a

number of measures including efficiency-based standards for annual air-conditioning load, and introduced a formula for passive solar systems.

For the non-residential buildings, efficiency standards using PAL (Perimeter Annual Load) and CEC (Coefficient of Energy Consumption) indices have been suggested as energy conservation standards. PAL refers to the estimated annual space heating load in the indoor perimeter area within five meters of exterior walls, per total floor area. CEC is the ratio of estimated annual energy consumption for building systems such as the air-conditioning system to the virtual total heat load over one year. When the standards were revised in 1993, new CECs were added for elevators, mechanical ventilation, lighting and hot-water supply systems. Specification standards were added in 2003.

A revised Energy Conservation Law was enacted in 2003 requiring owners of new non-residential buildings with a total floor area of 2,000 m^2 or more to report the energy conservation measures included in the design to the relevant authorities when buildings are constructed or renovated. As a result, the percentage of non-residential buildings complying with the Energy Conservation Standards has increased from approximately 35 percent in 2001 to approximately 74 percent in 2004.

A revised Energy Conservation Law enacted in 2006 requires the owners of new residential buildings with a total floor area of 2,000 m^2 or more to report to the relevant authorities the energy conservation measures included in the design when buildings are constructed or renovated.

Housing Efficiency Assessment and Labeling Systems

The “Japanese Housing Efficiency Labeling System” based on the “Law Concerning Promotion of Housing Quality Assurance” (a.k.a. the “Quality Assurance Law”) commenced full-scale operation from October 2000, the idea being to help consumers choose houses with high energy conservation efficiency. In FY 2004, approximately 160,000 new housing units were rated based on the housing design efficiency assessment standards and approximately 110,000 based on the housing construction efficiency assessment standards, with compliance increasing each year.

Comprehensive Assessment System for Building Environmental Efficiency

In order to promote sustainable buildings through the mechanism of the marketplace, a consortium consisting of experts from industry, government and academia was established in 2001, and the Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) is under development. Since then, “CASBEE – new buildings” (2003), “CASBEE – existing buildings” (2004) and “CASBEE – renovated buildings” (2005) have been developed. The Building Environmental Efficiency (BEE) index is expressed by the ratio of the building environmental quality and efficiency to the external building environmental impact. The building environmental quality and efficiency include the indoor environment, quality of services and outdoor environment of the site. The external building environmental impact includes energy, resources and material, and the external environment of the site. Approximately ninety items are used as input data for the assessment.

Recently some local building administration authorities have been requiring builders to introduce CASBEE, in a system that makes it obligatory to submit assessment results and indications based on the CASBEE at the construction of specific buildings. The “CASBEE-Home” for detached houses was developed and a trial version has been published.

Top Runner Program

When the Japanese government revised its Energy Conservation Law in 1998, the Top Runner Standards system was introduced. The Top Runner system sets target energy efficiency standards including scope, target values and target years for appliances, based on the idea that manufacturers are to produce products better than those products with the highest energy conservation efficiency of all products in the same group currently in the market. Top Runner standards have been established for 18 items. Energy Efficiency Labels are displayed voluntarily.

Low-interest Loans for Residential Buildings

The Government Housing Loan Corporation is a government financial institution and has offered loans with long-term fixed interest rates to finance the construction and purchase of buildings since its establishment in 1950. To improve energy conservation efficiency, all houses built or purchased with loans from the Corporation must comply with the 1980 Energy Conservation Standards. Houses which comply with the 1992 Energy Conservation Standards qualify for premium loans as well as favorable interest rates.

Low-interest Loans for Non-residential Buildings

To promote environmentally friendly non-residential buildings, the Development Bank of Japan, a government financial institution, offers lower interest loans to projects with a floor area of 2000 m^2 or more with a commitment to energy conservation efficiency 20 percent or more higher than the Energy Conservation Standards, utilization of water resources and retention of rain water, or other options.

Japanese Dress Code

In 2005, the Japanese Ministry of the Environment (MOE) promoted office-building air-conditioning settings of 28º C during summer. As a part of this campaign, MOE has been promoting "Cool Biz," to encourage business people to wear cool and comfortable clothes to work in summer. Due to a web-based survey on the Cool Biz campaign in September, 2005, it was shown that 95.8 percent of the 562 respondents knew about Cool Biz. Based on these results, it was estimated that the equivalent of the CO_2 emissions from approximately one million households during one month.

CONCLUSIONS

This report clarifies the current status of energy consumption and CO_2 emissions, and shows their future projections. Various technologies to mitigate global warming and their effects, and the current status of political measures are also described. Substantial reduction of CO_2 emissions is expected if all measures/technologies available at present are implemented. Aggressive promotion of political measures and awareness-raising activities is also important.

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