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Overview of energy consumption and GHG mitigation technologies in the building sector of Japan

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Abstract This paper outlines the energy consumption and greenhouse gas emission trends in the residential and commercial sectors in Japan. The results showed that the increase in residential energy consumption in Japan is mainly caused by the widespread use of heating equipment, hot water supply apparatus, and other household electrical appliances. On the other hand, it was indicated that the increase in commercial energy use is mainly due to the increase of the floor area of buildings, particularly hotels, hospitals, and department stores. The paper also describes political measures to promote energy conservation, including the building energy conservation standard, Comprehensive Assessment System for Building Environmental Efficiency, top runner programs, financial incentives, and the dissemination of the Cool Biz concept. Finally, the projections of CO_2 emissions until 2050 are presented.

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Introduction

There are enormous variations in the amount of energy use from country to country. Carbon dioxide emissions, the principal cause of global warming, are an inevitable consequence of energy use. Annual CO_2 emissions per capita of major countries are given in Fig. 1 (The Institute of Energy Economics 2006). The value of Japan is nearly similar to Germany, France, and UK, but it is half in contrast to that of the USA. In Japan, energy consumption by the building sector constituted 28% of the total energy consumption in 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 the industrial sector remains at this almost constant level, while consumption by the transportation sector was increasing until a few years ago. On the other hand, energy consumption by the commercial/residential sector is still increasing as shown in Fig. 2 (The Institute of Energy Economics 2006).

The energy consumption of various sectors is governed by different specific energy laws in Japan, and these laws are revised regularly and new laws are being proposed as well. Besides, the Japanese government has proposed stepping up energy conservation efforts in all sectors, including renewable energy sources, in order to minimize nationwide energy consumption and CO_2 emissions. Thus, many new technologies in terms of energy saving and reducing CO_2 emissions have been developed. In addition, policies and programmes aimed at building construction, retrofits, and equipment/systems installations are addressed.

This paper, which is based on the report by Murakami et al. (2006)[1], gives information on energy consumption and mitigation instruments of greenhouse gas (GHG) emission in Japan. In the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC)/WG4, there is little description for the situation in Japan due to the limited page space of the report. The paper will cover in detail the information which was briefly described in the IPCC report for the case of Japan.

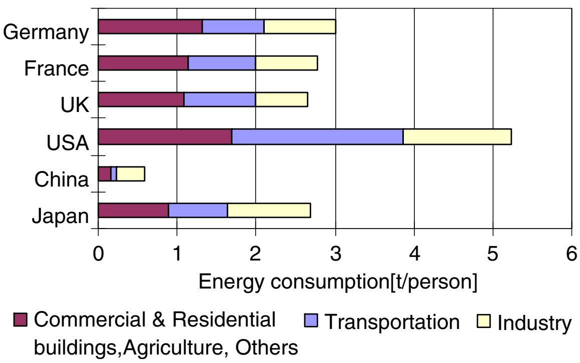


Fig. 1 Annual CO_2 emissions per capita of major countries (The Institute of Energy Economics 2006)

Overview of energy consumption emission trends in Japanese buildings

Energy consumption by end-uses in Japan's residential buildings

Trends in residential energy consumption in Japan

In Japan, the average annual residential energy consumption remained about 45 GJ/household per year in the last decade, while the value had been increasing every year until 1995, as shown in Fig. 3 (Jyukankyo Research Institute 2004). The most recent

[1] In May 2007, the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC)/WG3 was approved in Bangkok, Thailand. Two of the current authors have 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: Prof. Shuzo Murakami, Building Research Institute of Japan) 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 Ministry of Land, Infrastructure, Transport and Tourism of Japan and the Ministry of Economy, Trade and Industry of Japan. In this meeting, up-to-date information of energy consumption and mitigation technologies in Japan was prepared and compiled. This report, entitled "Energy Consumption, Efficiency, Conservation, and Greenhouse Gas Mitigation in Japan's Building Sector," was later published by Lawrence Berkeley National Laboratory in association with Dr. Mark Levine in December 2006 (Murakami et al. 2006).

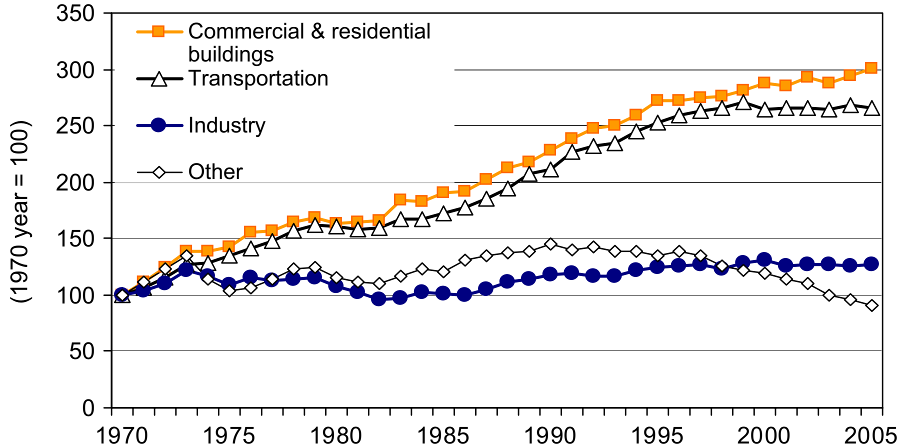


Fig. 2 Trends of energy consumption for sectors based on 1970 level in Japan (The Institute of Energy Economics 2006)

data (cf. Fig. 3) in 2004 show that 27.0% of the total residential energy consumed in Japan is used for space heating, 29.5% for hot water supply (e.g., baths and showers), and 41.2% for lighting/other (e.g., refrigerators, TVs). The energy consumed for cooling is only 2.4%. Growth in energy use for hot water supply and lighting/other uses is more significant than space heating. Thus, in order to decrease residential energy consumption, it is necessary to reduce the energy consumption for hot water supply and lighting/other uses.

The relationship between the number of households and CO_2 emission for the past 15 years is given in Fig. 4 (Ministry of Environment 2008). Although CO_2 emissions increase in line with the number of households, CO_2 emissions per household does not vary so much.

Comparison with end-use energy consumption in other developed nations

Figure 5 shows that energy consumption and end-uses in Japanese households in 2001 differ significantly from other developed nations (Iwafune et al. 2006). 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

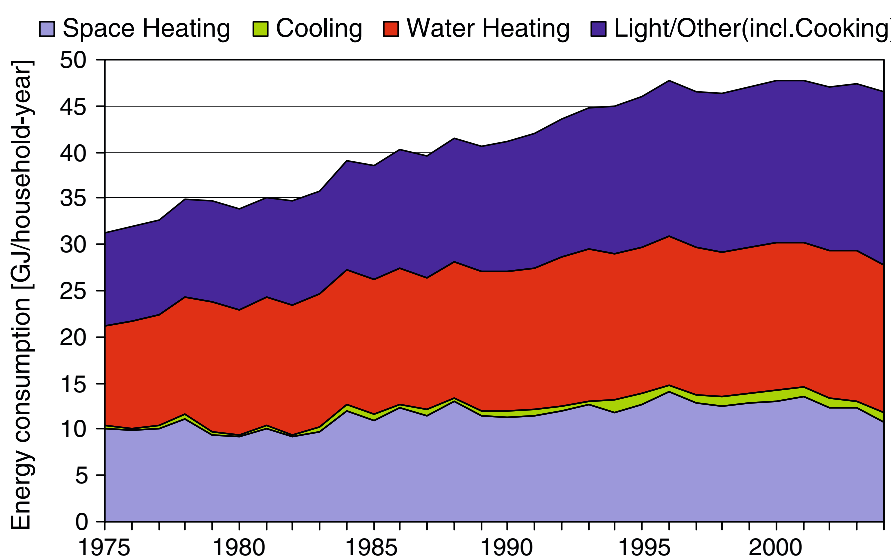


Fig. 3 Change of final energy consumption by end-use in Japan in 2004 (Jyukankyo Research Institute 2004)

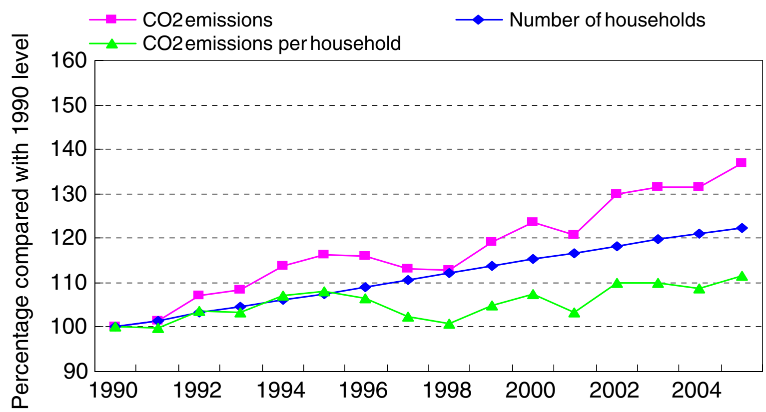


Fig. 4 Relationship between number of household and CO_2 emissions (Ministry of Environment 2008)

different lifestyle and climate. In Japanese houses, the use of space heating is mainly limited to living room during occupancy time. The indoor temperature is less than 10°C in non-heated rooms in many houses (Yoshino 1997).

Regional differences in Japan

Figure 6 shows the geographical pattern of energy consumption in the year 2004 in Japan which was drawn from data collected using Internet questionnaire survey (Hasegawa and Inoue 2004). In Hokkaido, energy consumption for space heating is comparable to that in European countries. However, energy consumption for space heating in the southern regions (south of Tokyo) is less than 25% of the consumption of Hokkaido. The overall energy consumption in the southern regions of Japan is about two thirds of the total in Hokkaido. This is due to limited use of space heating and mild climate in the southern region of Japan.

Energy consumption in Japanese non-residential buildings

The energy consumption trend for the Japanese commercial building sector is shown in Fig. 7 (Building-Energy Manager's Association of Japan 2002). Although energy consumption intensity is relatively stable, the total amount of energy consumed is increasing at a rapid rate. The increase in commercial sector energy consumption is mainly

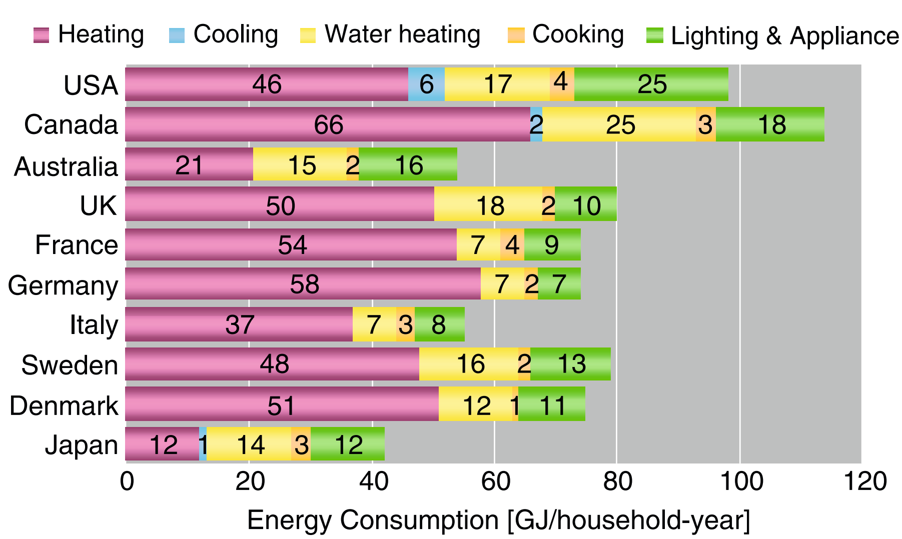


Fig. 5 Annual national average of residential energy consumption of main countries in 2001 (Iwafune et al. 2006)

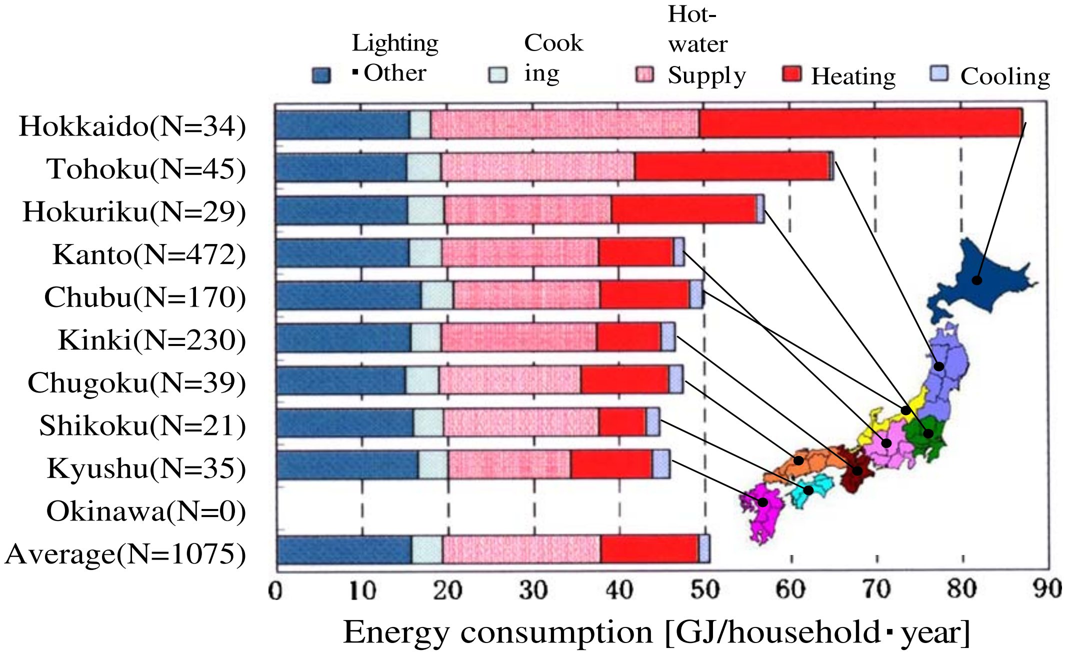


Fig. 6 Annual energy consumption of houses in different regions in 2004 (Hasegawa and Inoue 2004)

caused by the increase in the total floor area of commercial buildings. Figure 8 shows the energy consumption intensity and end-uses in 2004 within Japanese commercial buildings (IBEC 2004). 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% is for air conditioning, 30% for lighting and office equipment, and 20% 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 two times greater than that of offices.

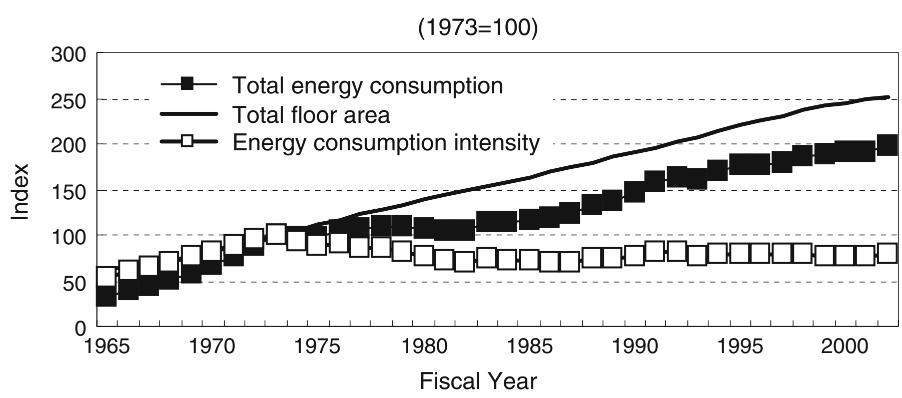
Current technologies and energy conservation/GHG mitigation strategies for Japanese buildings

Technologies for residential buildings in Japan

Building envelop and space heating and cooling

Japanese houses are traditionally constructed of wood; half of all new houses today are wooden (post and beam construction). Prefabricated houses, constructed in 2007, account for 13.7% of the total residential buildings in Japan (MLIT 2008a). Construction methods include reinforced concrete systems, steel systems, and wooden systems. Insulation/air tightness technologies

Fig. 7 Energy consumption trend for Japanese commercial building sector (Building-Energy Manager's Association of Japan 2002)



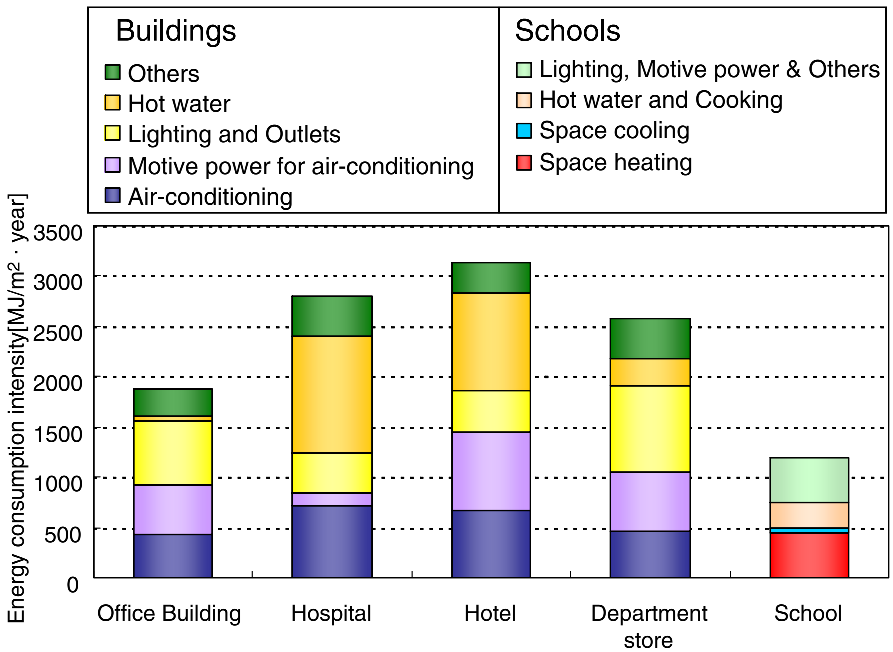


Fig. 8 Energy Consumption Intensity and End-Uses in Japanese Commercial Buildings in 2004 (Institute of Building Environment and Energy Conservation 2004)

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 90% of all newly built detached houses in 2007 (Flat Glass Manufactures Association of Japan)). 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.

For space heating, many kinds of apparatus are used in Japan. Portable unvented fan heaters (kerosene or gas) and portable kerosene heater are used in 67% and 54% of the houses, respectively (Cabinet Office 2004). Also, a traditional Japanese heater, Kotatsu, which is a low table with an electric heater under the table covered with a kilt, is still popular with saturation level of 75.9% in 2004 (MIC 2005). As described before, in many houses in the northern district of Japan, e.g., Hokkaido, the whole house is heated by the central heating system or vented-type kerosene heater. Room air conditioners are installed in 87% of the houses in Japan and the 2.3 units were possessed on average.

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, various strategies, reuse of warm water from bath in laundry, use shower with water-saving shower head instead of bath, thermal insulation of bathtub, for instance, are suggested.

Strategies for supply side energy conservation of hot water include the use of solar water heaters, heat pump hot water heater with CO_2 refrigerant, condensing water heaters, etc. In recent years, solar water heater usage decreased by half because of the difficulty of maintenance and the spread of photovoltaic (PV). CO_2 refrigerant heat pump water heater has a coefficient of performance (COP) of approximately 4.9 based on recent catalogues. The gas co-generation system for detached houses started to be in the market with subsidy by the City Gas Promotion Center.

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. Japanese government has intention to give subsidy to families which will install PV from FY 2009.

Consumer appliances

Consumer appliances include refrigerators, washing machines, dishwashers, televisions and videocassette recorders, computers, cooking devices, and so on. These daily commodities are common and widely used nowadays. These appliances play an important role in the increase of residential energy consumption and GHG emissions. For pursuing energy conservation and GHG emission reduction of these appliances, many strategies have been adopted in Japan. For instance, non-CFC refrigerants and high-efficiency refrigerators using a variable speed compressor and a vacuum-heat insulating material are promoted. Energy savings of 55.2% have been achieved in comparison with the refrigerators used in 1998 (The Institute of Energy Economics 2006). This is an effect of the Top Runner Standard, which will be described in a later section.

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.

The investigations of energy savings by lifestyle changes, in the case of single apartment in Tokyo, using the 74-item "Save-energy menu" shows 21.5%, 17.3%, and 26.5% in summer, autumn and winter, respectively, on average and 47% at maximum (Yuasa et al. 2005). The "Save-energy menu" included moderating temperature setting for space heating and cooling as well as reducing use of home appliances. Also, in the case of Tohoku District, energy consumption was found to decrease by up to 17.4%, with an average decrease of 5.5% in spring and 5.1% in summer (Yoshino et al. 2005).

In another study, energy savings were estimated for a detached house where the actual energy consumption of each household appliance was measured throughout a year (Chiba et al. 2004). The heat loss coefficient per floor area of this house was 1.8 kW/m^2 K. Space heating and cooling loads were estimated by dynamic simulation, and household energy consumption was calculated hourly throughout the year. It was also confirmed that the calculated estimates for energy consumption were nearly equal to the actual measured values for the whole year. Next, changes in daily life behavioral/operational parameters (e.g., temperature settings for space heating and cooling, hot water supply temperature, time and frequency of household appliance use) were defined for three different cases: the "energy-saving," "baseline," and "energy-wasting daily life" cases. Table 1 describes the energy-saving behavioral/operational lifestyle changes. The calculated results are shown in Fig. 9, including two additional cases that varied thermal insulation levels for the baseline case; in one, the thermal insulation thickness was doubled, and in the other, it was halved. The results indicate that energy consumption in the energy-saving case was reduced by 38%, relative to the baseline case, and that lifestyle changes were more effective than increasing the thickness of thermal insulation as a means to save energy. On the other hand, in the case with doubled thermal insulation, the energy saving was only 11%.

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 pay 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

Table 1 Description of energy-saving behavioral/operational lifestyle changes (Chiba et al. 2004)

Item		Condition		Energy-saving	Baseline	Energy-wasting
Air conditioning	Heating	Operation time		Morning and night	At occupancy	All day
		Temperature		2°C down	Living room 20°C Eur. room A 19°C	2°C up
	Cooling	Operation time		12:00–16:00	At occupancy	All day
		Temperature		1°C up	Living room 27°C	1°C down
		Window		Open at no AC	Open at no AC	Closed
Hot water supply		Frequency of bathing		Bath and shower every other day	Bath everyday	Bath everyday
		For cooking and washing	Hot or cold (Win./ Mid./ Sum.)	hot-water/ water/ water	hot/hot/hot	hot/hot/hot
			Temp.	1°C down	present	1°C up
			Amount	1 L/time down	present	1 L/time up
		Hot water volume in bathing		350 L	400 L	450 L
Lighting		Using duration time		1 h. short(morning and night)	present	1 h. long (morning and night)
Kitchen	Refrigerator	Temperature setting		Middle	Dec.–Aug. strong Sep.–Nov. middle	Strong
		Inside stuff		Normal	Normal	Congested
		Space from wall		2 cm	2 cm	No space
		Door leakage		No leakage	No leakage	More leakage
	Electric water pot	Times of boiling		2 times	1 time	1 time
		Keeping warm		No	Keeping 98°C, pull when sleeping	Keeping 98°C all day
Audio-visual and information	TV set	Usage duration time		1 h short	Present	1 h long
		Not in use		Disconnected to outlet	Remote-OFF	Remote-OFF
	Stereo	Usage duration time		Present	Present	1 h long
		Not in use		Disconnected to outlet	Always connected	Always connected
	PC	Usage duration time		1 h short	Present	1 h long
		Not in use		Disconnected to outlet	Always connected	Always connected
	Video	Not in use		Disconnected to outlet	Always connected	Always connected
Healthcare	Washing	Frequency		1 time every 2 days	1 time every 2 days	everyday
		Remained water of a bath		Use for washing	No use	No use
	Vacuum	Operation mode		Depend on situation	Always high mode	Always high mode

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. Rooftop 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 using air conditioners in small-sized and medium-sized non-residential buildings is as common as in homes. These devices are mainly for variable refrigerant volume systems which have one or

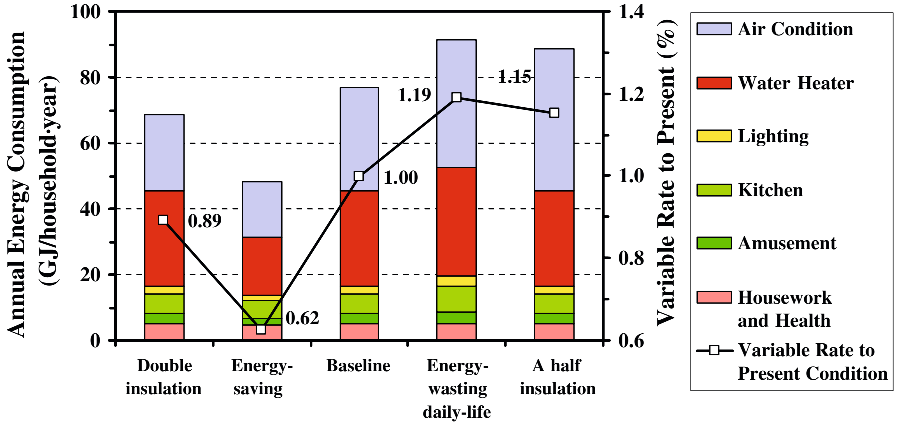


Fig. 9 Calculated Energy Consumption Results for Different Energy Consumption Behavior (Chiba et al. 2004)

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 (The Energy Conservation Center Japan 2006a).

In recent years, it has become popular to attach an inverter (variable speed control) to the pump or the fan of variable air volume and variable water volume 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 comprise 44,949 houses, 1,515 commercial buildings, 45 Mm^2 of service area, and a gross floor area of 47 M 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 and 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 (Japan Heat Service Utilities Association 2005).

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, which will be described in a later section. A target energy-efficiency ratio improvement has been established for computers at 83% of the 1997 energy use level by 2005 and for copiers at 30% of 1997 levels by 2006.

Policies to promote energy conservation and GHG emissions mitigation in Japanese buildings

The scope of Japanese policy instruments for the improvement of energy efficiency in buildings and equipment/appliances is given in Table 2. This table shows the Japanese policies and best practices to improve energy efficiency in buildings and appliances. The upper part shows the law concerning the rational use of energy involved in each life cycle stage. Energy conservation plan and top runner program are included in this part. The best practices for promoting energy conservation are given in the lower part of the table. These policy instruments will be described in the following sections. An improvement of energy efficiency index is shown in Fig. 10. It can be seen that the final energy consumption has substantially decreased about approximately 37% over the last 30 years, and Japan aimed to further improve its efficiency by at least 30% by 2030.

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

Table 2 Japanese policy instruments for the improvement of energy efficiency in buildings equipment/appliances (Murakami 2006)

	Life style stage			
	Design\construction		Operation	Renovation
Policy: The law concerning the rational use of energy	Energy conservation standard		Periodic reports	Energy conservation standard
	Residential	Commercial	Maintenance	
	Thermal insulation standards	Performance of building envelop	Energy consumption	
	Sunshine shielding equipment	Performance of equipment		
Best practices for promoting energy conservation	CASBEE		CASBEE	CASBEE
	Housing efficiency assessment system		BEMS/HEMS/ AEMS	ESCO Business
	Symbiotic housing project		Cool Biz	
	Energy-saving labeling system			
	Measures for standby power reduction			
	Low-interest loan by subsidy program			

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 and coefficient of energy consumption (CEC) indices have been suggested as energy conservation standards. PAL refers to the estimated annual space heating load in the indoor perimeter area within 5 m 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 1 year. The levels of these indices were more enhanced in the revisions of 1993 and 1999. 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.

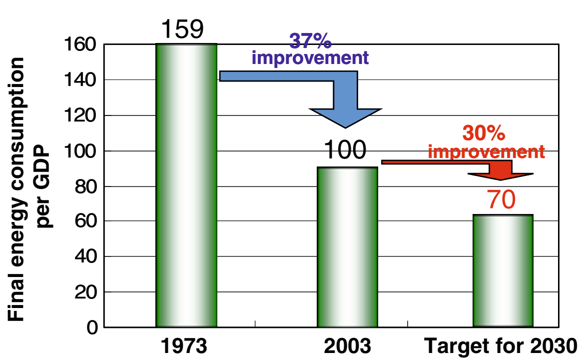
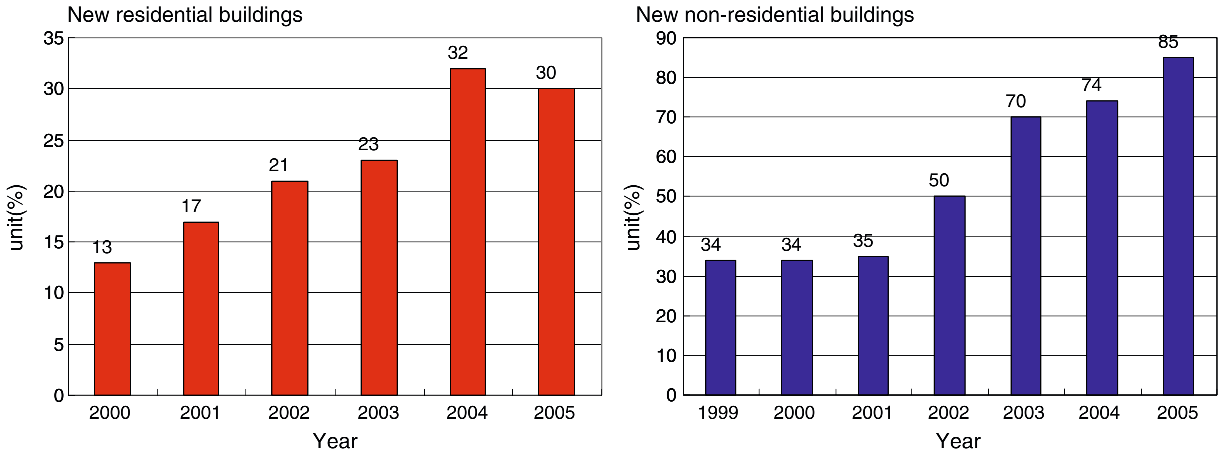


Fig. 10 Energy efficiency index for final energy consumption (METI 2006)

A revised Energy Conservation Law enacted in 2003 requires 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% in 2001 to approximately 85% in 2005.

Furthermore, the amended Energy Conservation Law enforced in 2006 stipulates that prior to major repairs, etc., as well as new construction, extension, or renovation, both non-residential and residential building owners shall report energy conservation measures used in the buildings to the relevant local authorities.

In 2008, the Energy Conservation Law was revised in which the total floor area will be expanded to 300 m^2–500 m^2. Figure 11 shows the trends in new residential and non-residential sectors in compliance with the latest 1999 Energy Conversation Standards (Fig. 11a), e.g., in 2005, the value of 30% is the ratio of houses which



(a) **New residential buildings** **(b)** **New non-residential buildings**

Fig. 11 Trends in compliance with 1999 Energy Conservation Standards (Murakami et al. 2006)

complied with the latest 1999 Energy Conservation Standard to the houses rated under labeling system. In addition, the ratio of the houses rated under the labeling system to the total constructed houses was 19%.

Housing efficiency assessment system

The "Japanese Housing Efficiency Labeling System" based on the "Law Concerning Promotion of Housing Quality Assurance" commenced full-scale operation from October 2000, the idea being to help consumers choose houses with high energy conservation efficiency. As aforementioned, the number of newly constructed houses in 2005 was 12 million; approximately 19% new housing units were rated based on the housing design efficiency assessment standards and approximately 12% based on the housing construction efficiency assessment standards, with compliance increasing each year (MLIT 2006b).

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) has been developed (IBEC 2008). Since then, "CASBEE—new buildings" (2003), "CASBEE—existing buildings" (2004), and "CASBEE—renovated buildings" (2005) have been developed. The building environmental efficiency 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 90 items are used as input data for the assessment.

Until 2007, 13 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 has been developed and the assessment has started in 2008.

Top runner program

When the Japanese government revised its Energy Conservation Law in 1998, the top runner standards system was introduced (The Energy Conservation Center Japan 2005). 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. To date, the top runner standards have been established for 21 items as shown in Table 3. Energy efficiency labels are displayed

Table 3 List of specific equipment for top runner program (The Energy Conservation Center Japan 2005)

Passenger vehicles	Space heaters
Freight vehicles	Gas cooking appliances
Air conditioners	Gas water heaters
TV sets	Oil water heaters
Videocassette recorders	Electric toilet seats
Fluorescent lights	Vending machines
Copying machines	Transformers
Computers	Rice cookers
Magnetic disk units	Microwaves
Electric refrigerators	DVD recorders
Electric freezers	

voluntarily. Table 4 shows the result of achieving standard values. Due to the efforts by manufacturers and others, each product category attained efficiency improvement that exceeds our initial expectations. Figure 12 gives an example of using the top runner approach. Due to the continuous effort to increase rated COP value of home air conditioner of manufacture, COP value has remarkably increased over the last 30 years. Top runner approach has played a key role in increasing appliance energy efficiency.

Low-interest loans for residential buildings

The Japan Housing Finance Agency, which has transformed from the Government Housing Corporation in 2007, is a financial institution which has offered loans with long-term fixed interest rates to finance the construction and purchase of buildings. The Government Housing Corporation was established in 1950. To improve energy conservation efficiency, all houses built or purchased with loans from the Japan Housing Finance Agency must comply with the 1980 Energy Conservation Standards. Houses which comply with the 1992 Energy Conservation Standards qualify for favourable interest rates.

Subsidy from symbiotic housing area model project

To encourage growth in symbiotic housing taking into account environmental issues including reduction in GHG emissions, subsidies have been offered as part of the "Symbiotic Housing Area Model Project" since 1993. These subsidies are provided for permeable pavements, rooftop gardening facilities, garbage disposal systems such as compost, etc. in area developments which, as ideal models, satisfy certain requirements including reduction in environmental impact. As of the end of FY 2005, such projects were underway in 85 areas.

NEDO subsidies

The New Energy and Industrial Technology Development Organization (NEDO) has promoted and

Table 4 Results of introducing the top runner program (Japan's "Top Runner" Standard 2008)

Equipment	Improvement of energy consumption efficiency (results, %)	Improvement of energy consumption efficiency (initial expectation, %)
TV sets (CRT-based television)	25.7 (FY1997→FY2003)	16.4
Videocassette recorders	73.6 (FY1997→FY2003)	58.7
Air conditioners[a]	67.8 (FY1997→FY2004)	66.1
Electric refrigerators	55.2 (FY1998→FY2004)	30.5
Electric freezers	29.6 (FY1998→FY2004)	22.9
Gasoline passenger vehicles[a]	22.8 (FY1995→FY2005)	22.8 (FY1995→FY2010)
Diesel freight vehicles[a]	21.7 (FY1995→FY2005)	6.5
Vending machines	37.3 (FY2000→FY2005)	33.9
Computers	99.1 (FY1997→FY2005)	83.0
Magnetic disk units	98.2 (FY1997→FY2005)	78.0
Fluorescent lights[a]	35.6 (FY1997→FY2005)	16.6

Energy saving standards are defined by energy consumption quantity (e.g., kWh/year). "Improvements of energy consumption efficiency" in the above table are judged by standards of each equipment (e.g., If 10 km/h changes to 15km/h, this is 50% improvement (it is not calculated by fuel quantity of 10 L/100 km and improved quantity of 6.7 L/100 km to say the improvement is 33%). If 10 kWh/year changed to 5 kWh/year, this is also 50% improvement)

[a] Energy saving standards are defined by energy consumption efficiency per unit (e.g., km/l)

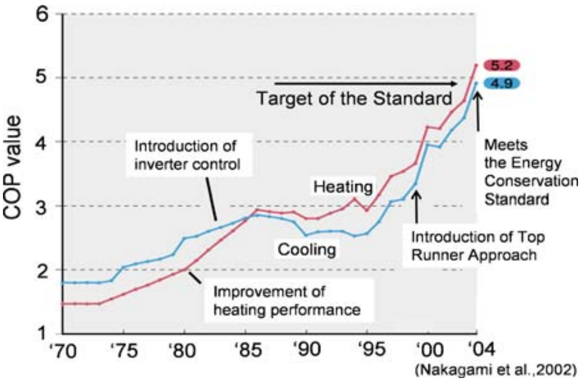


Fig. 12 Example of top runner approach: home air conditioners (Nakagami et al. 2002)

supported the research and development for saving energy. In FY2008, NEDO used 232.9 billion yen. From 1999 to 2005, for energy conservation in building sector, NEDO promotes introduction of highly energy-efficient systems in houses or other buildings with partial subsidies. NEDO also collects data to provide performance, cost–benefit analysis, and other related information on these systems. In 2002, NEDO introduced partial subsidies for installation of BEMSs in office buildings (NEDO 2006).

ESCO activities

Energy service companies (ESCOs) offer comprehensive energy services, including energy conservation solutions as a private business activity. ESCOs identify strategies to save energy in buildings, design/implement energy conservation technology, and assist with business capital planning and maintenance and operation management of new facilities. ESCOs were introduced in Japan in 1998, and the Japan Association of Energy Service Companies was established in 1999. Until 2005, ESCO energy efficiency services have been used in 163 buildings: 24 hotels, 48 shops, 20 hospitals, 64 offices, and seven other buildings. (The Energy Conservation Center Japan 2006b).

Japanese dress code

In 2005, the Japanese Ministry of the Environment (MOE) promoted office building air conditioning settings of 28°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% 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 1 month (Ministry of the Environment 2006).

Projection of CO_2 emissions from the Japanese building sector through 2050

Ikaga et al. (2000) studied the projection of CO_2 emissions of the building sector through to 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 emission reduction and energy conservation measures.

Figure 13 shows the projections under Scenario 1-a, which assumes that no emission 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% 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% from 1990 level.

Figure 14 shows Scenario 5-c-X, which assumes that CO_2 emissions from electricity use are reduced in accordance with the targets set for emission reduction/energy conservation measures. Annual CO_2 emissions in 2010 will be 390 million tons, a decrease of 20 million tons or 6% from 1990 level. Annual CO_2 emissions in 2050 will be reduced to 40% of 1990 levels.

Conclusions

This paper presents the current status of energy consumption and CO_2 emissions and shows their future projections in the building sector of Japan. 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

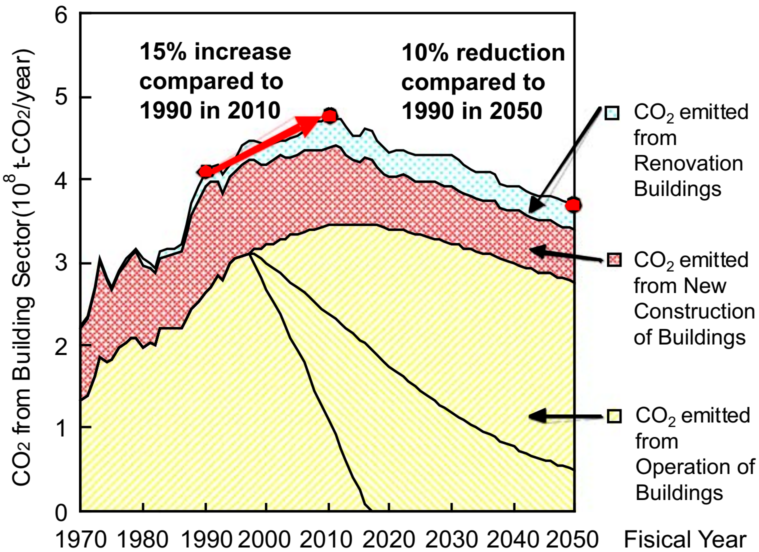


Fig. 13 Scenario 1-a: Projection of Japanese building sector CO_2 emissions with no emission reduction measures (Ikaga et al. 2000)

political measures and awareness-raising activities is also important. The concluding remarks of this paper are drawn as follows:

(1) Average annual energy consumption of Japanese houses is half that of the European countries due to the limited usage of space heating and mild climate conditions. It is desirable to persist this low energy consumption with increasing the quality of life.
(2) For energy conservation, houses have become well insulated nowadays. For example, double glazing is installed in 90% of all detached houses constructed in 2007. However, portable unvented heaters using kerosene or gas are still very popularly used.
(3) The energy consumption for water heating is more than 35% in Japan. The CO_2 refrigerant heat pump water heater with COP of 4.9 becomes popular.
(4) Lifestyle change is an effective way for energy conservation. Calculation results show that energy can be saved by 38% in corporation with lifestyle change such as appropriate thermostat adjustment, switching off electric lighting with-

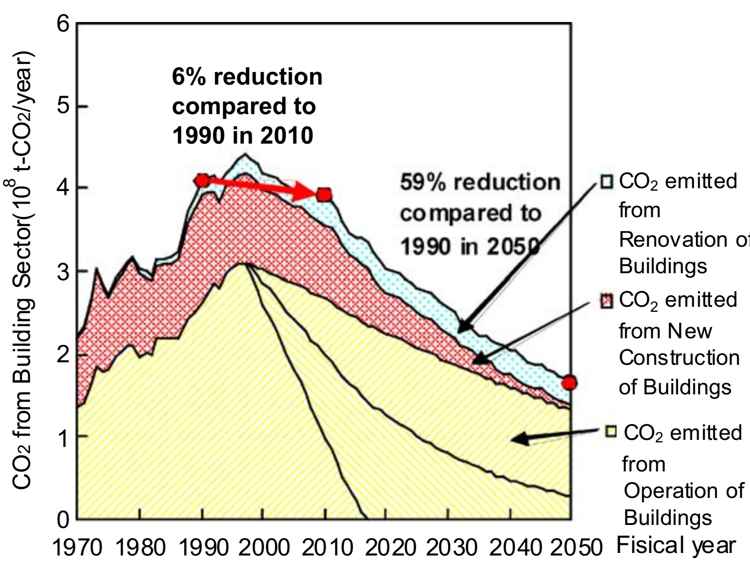


Fig. 14 Scenario 5-c-X: Projection of japanese building sector CO_2 emissions with emission reduction measures beginning in 1998 (Ikaga et al. 2000)

out occupancy, unplugging electrical appliances when not in use, and so on.

(5) Many strategies for energy conservation are installed in new commercial buildings in Japan, for example, thermal insulation, window airflow system, light shelves, valuable airflow volumes, etc.

(6) As for political instrument for energy conservation, described are the energy conservation standard, assessment system, and labeling system for energy conservation, top runner program, low interest loans, Japanese dress code, etc. These are effective strategies for energy conservation in the building sector of Japan.

(7) Projection of CO_2 emissions from the building sector through 2050 shows that the lowest emission scenario reduced to 40% of 1990 level.

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