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Energy Situation and Related Technology Development in Japan

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ABSTRACT

Recently especially after 1990, we have experienced so many natural disasters or abnormal climate changes which might have been caused by global warming. Now it became common understanding that the green house gas or CO_2 emitted by the combustion of fossil fuel is the main cause of the global warming. Reflecting the economic growth and increase in population, the consumption of fossil fuel is expected to increase largely during this century especially by remarkable energy requirement in developing countries. Japan has committed to decrease GHG (green house gas) emission level by 6% compared with 1990 emission level at the 1st Commitment Period (2008-2012) given by the requirement under Kyoto-Protocol. On the other hand, Japan also has to meet the energy requirement needed during its term, even though the increasing ratio is so mild compared with the past or developing countries. However recent forecast expects GHG emission level at that time will exceed about 13 % over the 1990 level, which forces Japan to take further energy saving technologies such as adopting higher efficient gas turbine cycle. This paper explains the Japanese energy situation, future energy and demand prospect, and finally the outline how to meet the above mentioned CO_2 emission target, focusing the importance of energy saving technologies.

INTRODUCTION

Energy and environmental issues are serious concern of Japan because Japan is a densely populated, highly industrialized, and small country with little energy resource. Japan has been tackling these issues vigorously with international coordination. Above all, recognizing the significance of Kyoto Protocol, an international commitment to reduce greenhouse gases emission, Japan's government and industry have been actively addressed the issue with great efforts. Reflecting the above circumstances, this paper presents the status of Japanese energy situation, and some activities on energy and environment technology development.

STATUS OF ENERGY DEMAND AND SUUPLY

Economic growth & energy consumption trend

After World War II, Japanese energy consumption had risen remarkably almost in proportion to the economic growth or GDP increase. However after the two oil crises of 1970s, the increasing rate of the energy consumption per GDP and oil dependency had declined reflecting nationwide movement of the energy saving, and fuel conversion from oil to other fuel. Then after the latter half of 1980s, reflecting the falling oil prices at that time, life style changes and concern for achieving comfort among Japanese citizens, the demand for energy had gradually began to increase. But when we see the detail of the consumption tendency, there appear different faces according to the difference of sector or section. As shown in Fig. 1, which is derived from Ministry of Economy, Trade and Industry (METI) “Energy in Japan” (2006), the energy

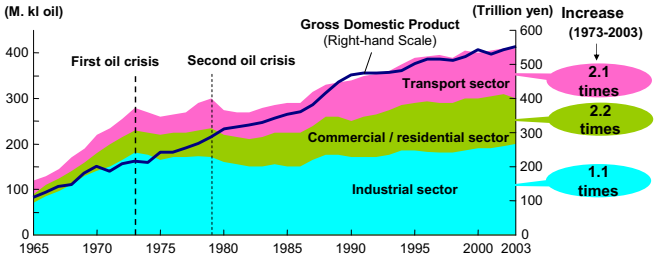

Fig.1 Trend of energy consumption and GDP in Japan.

consumption in industrial sector has stayed almost same level in spite of GDP increase for that period by sharing still the big portion of about half of the total primary energy consumption, which means they have achieved the production increase with very low energy elasticity (ratio of energy supply expansion rate per GDP growth rate) for that period. On the contrary the energy consumption in transport sector and commercial / residential sector has increased steadily by sharing one quarter each in recent figures. This situation has been continued up to present as a whole in spite of facing so high priced oil in these years. Today Japan is facing big problems such as to meet the requirement of reducing GHG emission under the Kyoto Protocol, which means to reduce the energy consumption and to meet the necessary energy acquisition for keeping the national and economic activities. In order to meet the above requirement, it is needed to adopt the further energy saving technology than before such as the adoption of more high efficient gas turbine.

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Energy consumption in each sector

Energy consumption in industrial sector. At present, steel or chemical industries consume almost one third each of total industrial consumption. Other industries like ceramics, paper and pulp, machines, foods, textile, and others share the rest of one third as shown in Fig. 2 which was drawn from "the Energy Data and Modeling Center (EDMC)" of Energy Conservation Center, Japan(2006). As shown there, most industries have continued to

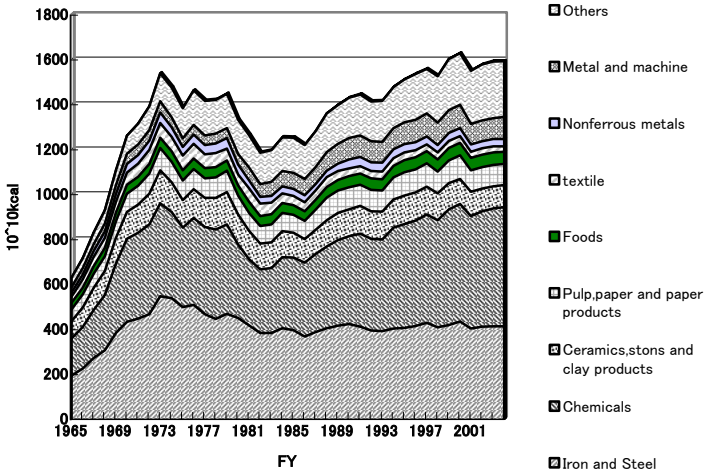

Fig. 2 Energy consumption of industrial sector in Japan

keep the same level of energy consumption after the oil crises except that in chemical industries which has shown gradual increase for that period reflecting possibly the increase of global economic increase.

Energy consumption in transportation sector. In the past 40 years, energy for transportation in Japan expanded almost five times, with less obvious hamper by two oil crises in 1970s. The increase was mostly driven by motorization both for passengers and freights. Especially, the energy consumption by private cars has shown remarkable increase. More energy efficient vehicles such as hybrid cars and fuel cell vehicle (FCV) in the future are expected to penetrate the market. If so, energy consumption volume might not inflate so much or decrease rather. Fig. 3, which was drawn from "EDMC" of Energy Conservation Center, Japan (2006), shows the energy consumption of transportation in Japan.

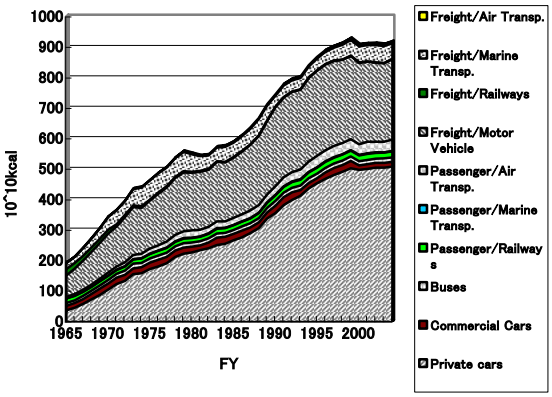

Fig. 3 Energy consumption of transportation sector in Japan

Energy consumption in residential and commercial sector. Energy consumption in residential and commercial sectors have shown the largest increase in the past 40 years. It increased about five times along with the rise of living standards. Fig. 4, which was drawn from "EDMC" of Energy Conservation Center, Japan (2006), shows energy consumption in residential and commercial sectors in Japan. As shown in the figure, the consumption of power for both business and household such as by power consumption for air conditioner using heat pump has increased most sharing big portion in this sector.

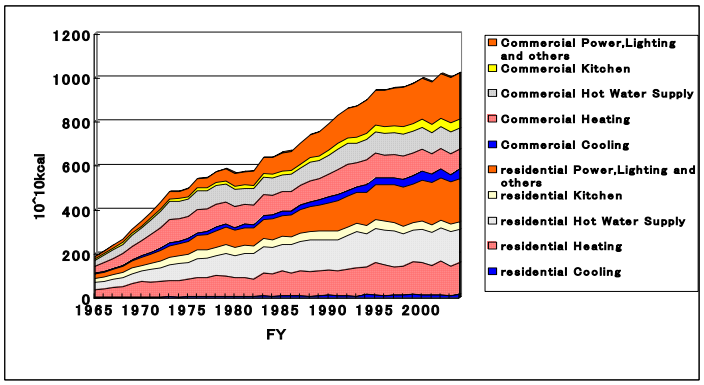

Fig.4 Energy consumption in residential and commercial sectors in Japan

Trend of energy supply in general

Fig. 5, which was drawn from "EDMC" of Energy Conservation Center, Japan (2006), shows the trend of energy supply in Japan. As to the oil, its share in primary energy supply expanded from about 20% before 1960 to about 77% in 1973. However thanks to the efforts to develop alternative energies for oil such as developing nuclear power and natural gas, the share of oil today in total energy supply became about 50%. Coal was once called as "Black

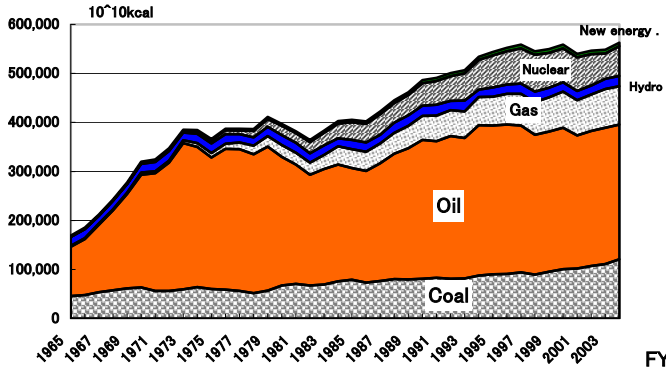

Fig. 5 Trend of Energy Supply in Japan

Diamond" used as main energy source, of which about half of supply came from domestic mines. But all of them have depleted and lost international competitiveness. Today share of coal is about 17% but all of them are imported. As to the natural gas, which we have invented liquefied natural gas chain in the world, it has become one of the main fuel sharing about 13%. Now fossil energy as a total in total energy supply shares about 82%, almost of which are imported. There are some very tiny oil and gas production in Japan, but their contributions are just negligible. Nuclear as indigenous energy source shares about 13% in the total energy supply. Electric power is safe, clean, and easy to use, and demand therefore continues to increase. The ratio of electricity consumption to the total primary energy supply grew from about 26% in 1970 to

about 46% in 2003. This trend is expected to grow even more in future. The transition from the use of oil to nuclear power or natural gas in the electricity generation has made significant progress, and in 2004 these were the major power sources, with nuclear power supplying about 29% and natural gas 26% of the nation's electricity by kWh base.

JAPANESE ACTIVITES TOWARDS THE LONG TERM ENERGY AND SUPPLY FORECAST

Overview of Japanese governmental activities

Cabinet has functions to control science and technology development, energy and nuclear development and environmental issues, by means of various councils, commissions and committees. Concerning to national energy policy, Energy Basic Law (EBL) was established in 2002 and Energy Basic Plan (EBP) was established in 2003. EBP established by the requirement by EBL describe the basic plan to conduct the energy policy in general. In order to compensate the lack of the quantitative expression in EBL and EBP, the Long-term Energy Supply and Demand Plan (LESD) was established by the Special Committee under METI (Ministry of Economy, Trade and Industry) publishing in March 2005, by which the new energy supply and demand plan toward 2030 including 2010 was established. According to the report, energy demand will slightly increase by the year of 2020, but it will start to decline afterward, basically due to the low birth rate and industry structural change from heavy to service industry in Japan.

Countermeasure for the Kyoto protocol.

Today the energy issue can not be discussed without referring the global worming issue. It is now the common understanding that the global warming is one of the most critical problems for the world. If GHG emission continues to increase, rise of temperature and ocean will cause the overwhelmingly grave effects in such field of food supplies, water supplies and living environments in future. In an attempt to prevent this, numerous nations around the world have committed themselves to control emissions of GHG by signing the Kyoto Protocol in 1997 which became in effective February 2005. Japan has made a commitment to reduce its total average GHG

Fig. 6 The concept of obtaining the energy oriented CO_2 target level at 2010

emissions by 6% as mentioned before. In order to attain the target, the following methods are planned. At first it is to be noted that the key items of decreasing the GHG is how to decrease the emission from the energy originated CO_2 to the same level as 1990 level because of its dominating share in GHG. In 2002, it exceeded +12 % over 1990 level and it is expected to exceed about +13% at 2010 if not any proper approach be adopted, and about +6% if only existing approach be adopted. So, it is required to adopt additional approach in addition to the above mentioned approaches. Fig. 6, which was drawn from METI "Energy Supply & Demand Outlook in 2030"(2005), shows the concept of the way of obtaining the energy oriented CO_2 target level. Incidentally to attain the - 6% emission, it is needed to adopt further methods such as decreasing the non-energy oriented GHG by about -1.2%, forest absorption by about -3.9%, and adoption of Kyoto mechanism by about -1.6%.

ROLE OF TECHNOLOGY DEVELOPMENT

Energy conservation field

Energy conservation is one of the most effective measures in energy and environment policies. This measure is more easily to be performed than other measures such as new energy development, because, as is generally said, the economical advantage is also gained by adopting energy conservation. Related devices and systems in various sectors and application are listed in the Table 1 which was derived from the web-site of Energy Conservation Center, Japan. As shown there the high efficient gas turbine technology is listed as the main candidate in the industrial sector. As to the method of performing energy conservation for the goods of mass production, the "Top Runner" Program was introduced.

Table 1 Energy saving technology development in Japan.

System Technologies		■ Pinch Technology (Technology for analysis of optimal heat utilization)	■Demand Management System using IT (HEMS、BEMS) ■Cogeneration System ・**Gas Turbines**, Gas Engines and Heat Pumps ・Fuel Cells, etc.	■ITS (Intelligent Transport System)
Specific Technologies	Energy Production	■**High efficient Gas Turbines Technology** ■Power technology using superconductivity		
	Eenergy Utilization	■Power Electronics (SIC, etc.) ■Technology for High Efficienty Combustion for Industrial Furnaces, etc. ■Technology for Efficient Production, Processing and Recycling Processes	■Power Electronics (SIC, etc.) ■Technology for Efficient Lighting (LED) ■Efficiency Improvement for buildings ■Development of New Materials, ・Nano-materials ・Organic EL	■Power Electronics (SIC, etc.) ■Technology for High Efficient Combustion for Diesel Engines ■Technology for Automobiles Material
	Energy Storage	■Power Storage with Flywheels ■Technology for Heat Storage	■Development of Batteries ■Technology for Heat Storage	■Batteries and Capacitors
	Energy Recovery	■Technology for Waste Heat Management, such as Efficient Heat Exchangers	■Technology for Unutilized Energy, such as Waste Power Generation	

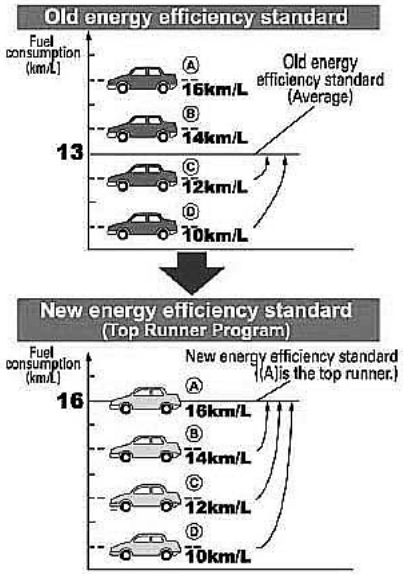

Fig. 7 Concept of Top Runner Program

This program requires manufacturers to meet the target value which is the highest availabe performance (top runner) among the manufacures. Fig. 7, which was derived from the web-site of Energy Conservation Center, Japan, shows the concept of the program.

New energy source field

New energy sources are domestic energy and produce little or no CO_2, which are desirable energy by ensuring a renewable supply of energy and escaping environmental problems. However, there are a number of drawbacks. Their cost is high in comparison with other forms of energy, due to the high capital cost and the low load factor. In addition, solar and wind power are affected by environmental conditions, making output unstable, and facilities can only be established in a limited number of areas. For instance solar PV case, although the cost of this energy has dropped, it is still high as two to three times as the cost of the electricity currently supplied to households. As to wind power, it has been installed in remarkable increasing ratio in these years. Technological advances and increases in the scale of wind power generation facilities have reduced costs and contributed to greater recognition of the viability of wind power generation. However, there are concerns that the instability of the output of wind power could adversely affect the power grid (by disrupting frequencies, etc.), and research and discussion therefore have been performed to stabilize power output and preventing any negative impact on the existing power supply by special committee in METI. Fuel cell application has been also expected to be developed. However its cost is still so high compared with existing energy. One reason is that hydrogen as the fuel for the fuel cell is a secondary energy like electricity, and have to be produced through electrolysis or thermal decomposition from various sources such as natural gas, coal, renewable, or nuclear energy. "Hydrogen society" has been a dream for long time, and fuel cell technology could be a breakthrough technology in economic competition. There are two main fields of possible application under development with enormous effort for stationary and automobile application. Table 2 which was drawn by METI "Energy Supply & Demand Outlook in 2030" (2005), shows the new energy development plan established by LESD.

Table 2 New energy development plan.

	2002FY	2010FY Existing Approach	2010FY Additional Approach	2030FY Outlook
Photovoltaic	15.6×10^4kl	118×10^4kl	118×10^4kl	2024×10^4kl
	63.7×10^4kW	482×10^4kW	482×10^4kW	–
Wind Power	18.9×10^4kl	134×10^4kl	134×10^4kl	269×10^4kl
	46.3×10^4kW	300×10^4kW	300×10^4kW	–
Waste to Energy & Biomass Power	174.6×10^4kl	586×10^4kl	586×10^4kl	494×10^4kl
	161.8×10^4kW	450×10^4kW	450×10^4kW	–
Solar Heat	74×10^4kl	74×10^4kl	90×10^4kl	112×10^4kl
Waste to Heat	164×10^4kl	186×10^4kl	186×10^4kl	–
Biomass Heat	–	67×10^4kl	308×10^4kl*1	423×10^4kl
Un-used Energy*2	4.6×10^4kl	5×10^4kl	5×10^4kl	87×10^4kl
Black-Liquor & Wood Wast	471×10^4kl	483×10^4kl	483×10^4kl	537×10^4kl
Total (Raito to Primary Energy)	923×10^4kl (1.6%)	$1,653\times10^4$kl (2.7%)	$1,910\times10^4$kl (Approx.3%)	$3,946\times10^4$kl (Approx.10%)

Note The dimension of kl corresponds to oil equivalent.
*1 Included Biomass Derived Fuel (50×104kl).
*2 Low Temperature Energy of Snow and Ice are Included.

Nuclear field

Nuclear energy is one of the important energy in Japan. Nuclear power plant in Japan have supplied about one-third of electricity demand at present and it is expected to play as the base load power generation. Uranium is widely available in politically stable countries, making it a highly stable energy source. Also, nuclear power does not produce CO_2 in the generation process. However like other resources, reserves of uranium are limited, and if it is disposed of after being used once, reserve-production ratio is similar to other fossil fuel. On the other hand, more than 90% of spent fuel from nuclear power plants is composed of uranium and plutonium that can be recovered and reused as fuel. The burning of recovered plutonium and uranium at existing nuclear power plants is called "Pluthermal" generation and the (plutonium and uranium) combined fuel is called as MOX fuel. Fig. 8 shows the concept of the "Pluthermal" power generation. After performing test plants (including demonstration plant using existing plant), it is expected to apply to the other nuclear plants widely.

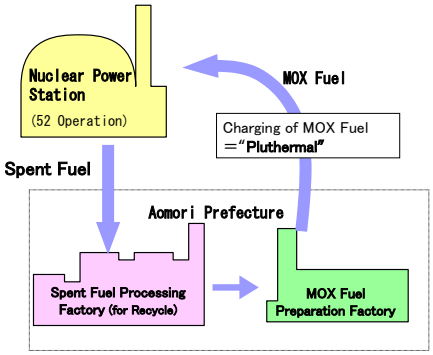

Fig. 8 Concept of "Pluthermal" Power Station

THE LONGER FUTURE ENERGY PLAN

As described before, the future energy plan for the year 2010 and 2030 was established in 2005 as the Long-term Energy Supply and Demand Plan by the committee under METI. However it lacks the argument to progress it in strategic way especially for 2030. So, METI established the report focusing the strategy with the target for main items titled the "New National Energy Strategy" in May 2006. In the report, some numerical targets for the development items are described. On the other hand, there exist an anxiety for more longer time such as around 2100. To study such a longer period, there have been established in some reports such as the SRES (Special Reports on Emission Scenarios) prepared in the 3rd report by IPCC (Intergovernmental Panel on Climate Change). However they lack the combination between energy requirement and technical advancement. METI therefore conducted study to see a possibility of approach to make up the gap between the energy requirement and technology requirement and established report titled the "Strategic Technology Roadmap in Energy Field (Energy Technology Vision 2100)" in 2005. In the paper three idealized cases are selected, namely Case A (Maximum utilization of fossil resources), Case B (Maximum utilization of nuclear energy), and Case C (Maximum utilization of renewable energy with energy-saving), as shown in the Fig. 9 which was derived from

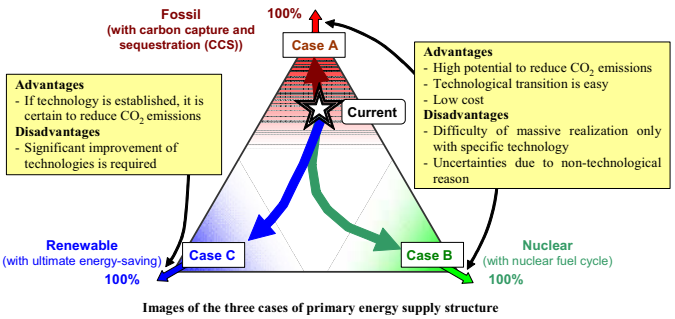

Fig. 9 Strategic Technology Road Map in Energy Field

Agency for Resource and Energy, Ministry of Economy Trade and Industry (2005). Then backwardly from that year (2100) to the present, they have listed up the necessary development items or corresponding technologies for each case to realize the idealized case, which they call “back-cast approach”.

CONCLUSION

I have introduced the Japanese energy situation together with political and technical countermeasures. As mentioned before, Japan on one hand has so little energy resources, and, on the other hand, has committed the Kyoto Protocol, so that Japan has to consider both requirement from energy acquisition and GHG emission abatement at the same time. The most important strategy to be adopted at first is to perform the further energy conservation as far as possible. Then energy conversion and development of the new energy will be followed. Adoption or development of higher efficient gas turbine cycle will play very important role as the main candidate for the further energy conservation.

I hope our approach as described in the paper will be of any help to our sustainable future and to other countries who are going to tackle with similar problems as Japan.

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