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Nuclear Power Development in Japan

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1. Energy Situation in Japan

(1) Japan is in a fragile energy supply structure in which 83% of its energy depends on import. Because of its location where the ocean plate meets the Eurasian Continent and rather active geological movement has been noticed since the beginning of this small island, Japan is not abundant in mineral resources.

Out of total primary energy supply which amounts to 531 million kl crude oil equivalent, 56.7% was supplied in the form of oil. This dependence on oil is even more noteworthy considering that 99.7% of the oil supply comes from imports and that approximately 73% of crude oil is imported from the Middle East in FY 1991, resulting in a vulnerable economic base for Japan. It is still fresh memory that our economy was disturbed severely by first oil crisis in 1973. In Jan.1974, oil price was jumped up four times as much as that in Oct. 1973. This crisis was supposed to be an epoch which marked the end of the period when Japanese economy had enjoyed miracle growth. One of factor which allowed the Japanese high economic growth rate was easy access to stable and low cost oil supply. Missing the favourable condition, Japanese industry had embarked upon its structual change which enables energy saving and high value-added production.

(2) International comparison of energy supply

Vulnerability in energy structure of Japan is more evident when it is compared with those of Western countries. Figure shows that regarding to primary energy supply patterns of major developed countries, dependence on imported energy of Japan is the highest among them. USA and UK who have indigenous oil, Germany whose land is rich in coal are much less dependent on imported energy. (See Figure-1)

(3) Nevertheless, Japanese dependence on oil for its primary energy supply, which was at a high 77% level prior to the oil crisis in 1973, has declined gradually thereafter to 58% in 1992. This decline can be attributed mainly to industry's efforts for energy conservation and conversion to alternative energy.

2. Japan's Strategy for Stable Supply of Energy

Taking such consideration into account that :

a. Energy is fundamental factor for sustainable economic growth.
b. Japan still depends heavily on imported energy, especially on oil.
c. For energy security, it is indispensable to diversify energy source and to create indigenous energy.
d. Global environmental problems should be given utmost consideration.

Japan's energy policy consists of three basic concepts, those are
to reduce dependence on oil,
to promote efficient use of energy, and
to increase use of non-fossil fuels.

For providing policy target, the long-term energy supply and demand outlook was made periodically. According to the recent outlook announced in Oct. 1990, energy demand was anticipated to expand steadily, with annual rate of 1.4% until 2000 and 1.1% till 2010, reflecting people's growing needs for better living amenity and closer business network being

formed rapidly.

In order to ensure necessary supply of energy, Government has set energy supply target for each source. (See Figure–2) The long–term outlook will be revised in this year.

(New energy sources)

New energy sources should be introduced to the greatest extent as possible. However, their supply is limited before 2010 because of drawbacks including their low energy density, unstable supply affected by natural conditions and their high cost.

(Hydro and geothermal energy)

This energy should also be introduced as much as possible. However, some drawbacks including its concerns to natural environment and lack of suitable location limit its expansion.

(Natural gas)

It is appropriate to promote the use of natural gas because its supply is relatively stable, and its CO2 emissions are lower than other fossil fuels.

(Coal)

Although its supply is extremely stable and it is price competitive, it produces more CO2 than any other fossil fuels, so it is difficult to encourage greater use over medium and long term.

(Oil)

Continued endeavors to reduce Japan's dependency on oil is important in order to ensure energy security and stabilize international oil supply and demand. But it is expected that we will continue to depend on it to some extent in the future. Therefore, it is necessary to make greater efforts to secure stable supply.

(Nuclear energy)

Great stress is put on developing nuclear energy and its introduction to power generation. According to the target, 17% of energy or 43% of electricity (72 GW) will depend on nuclear power in 2010.

3. Benefits of Nuclear Power

Nuclear power is said as a core of alternative energy for petroleum because it has the following advantages over other energy sources.

(1) Stable supply of uranium resources

Uranium as fuel for the nuclear power generation relies on import from overseas because of lack of demestic natural resources similar to petroleum.

However, supply sources consist of the United States of America, Canada, Australia which are all developed countries, and stable supply is expected. Because uranium is capable of generating electric power with extremely small quantity as compared with petroleum, it has an advantage of easy transportation and storage.

In the nuclear power generation, if the fuel is once put in the nuclear reactor, it generates power at least for one year without replacing it. Therefore, it provides almost the same effect as stockpiling fuel for that period.

With the accomlishment of nuclear fuel cycle, in which uranium and plutonium retrieved by reprocessing of spent fuel, uranium can effectively be used and it will become a more stable source of energy, so to speak, as a semi–domestic energy source.

(2) Adaptation to global environmental problems

Recently, various environmental problems such as global warming and acid rain are highlighted. These problems are closely related to consumption of energies by humankind, and it has become a very important theme from the energy policy point of view to lower the dependence on fossil fuel which emits a lot of carbon dioxide, sulphur oxides, nitrogen

oxides, etc.. (See figure–3)

On the other hand, the nuclear power is non–fossil energy which does not emit such substances mentioned above similar to hydraulic power and solar energy, and it has been recognized in recent years that the nuclear power will fulfill an important role in solving the global environmental problems.

(3) Economics of nuclear power generation

One of big features of the economic performance of nuclear power is that it is less influenced by fuel cost. In the case of the petroleum thermal power, because of high ratio (approximately 60 %) of the fuel cost accounting for the generationg cost, if the fuel price is raised up, it immediately causes the generating cost to rise. As opposed to it, in the case of the nuclear power, because of lower ratio (approximately 20 %) of the fuel cost, the rise in the price of uranium, if any, will not so much affect the generating cost.

The price of petroleum is considered to be unstable in the future. Therefore, nuclear power has an advantage for stabilizing consumer price.

4. History of Development of Nuclear Power

(1) Beginning (since 1954)

a. Japan was obliged to stop research efforts on nuclear power for about ten years due to the World War II. In 1951, the Peace Treaty was concluded between Japan and the United States, and the academic world started to express a desire to re–start research efforts on nuclear power. On the other hand, however, some people expressed their opposition to the research efforts on nuclear development on the ground that it would lead to the development and production of nuclear arms.

b. The Atoms for Peace Proposal presented by President Eisenhower at the General Assembly of the United Nations in 1953 had a great impact on Japan to promote research on nuclear power for peaceful use only (Note 1). Under such circumstances, conditions to guarantee peaceful use of nuclear power were established (Note 2).

(Note 1) In 1954, the first government budget for nuclear research was appropriated.
In 1954, an organization which later became Japan Atomic Energy Research Institute was established.

(Note 2) In 1955, the Atomic Energy Fundamental Act was established.
The 2nd Article provides, " Nuclear research, development and use shall be restricted to the peaceful purposes only, and shall be effected under a democratic way of management. The results and achievement shall be made public, and shall be utilized for international cooperation.
In 1995, the Atomic Energy Commission Act was enacted.

c. In those days, there were two main streams with regard to the development of nuclear power, i.e. independent developmental efforts and introduction of foreign technologies. In order to establish basic technologies, R & D efforts were made for the time being on the development of research reactors of various types (Note 3).

(Note 3) JRR–1 : In 1957, the reactor reached criticality. Liquid homogeneous reactor having light water moderator and coolant, and using enriched uranium.
JRR–2 : In 1960, the reactor reached criticality. Heterogeneous reactor having heavy water moderator and coolant, and using enriched uranium.
JRR–3 : In 1962, the reactor reached criticality. Heterogeneous reactor having heavy water moderator and coolant, and using enriched and natural uranium This was the first reactor developed and constructed in Japan.
JRR–4 : In 1965, the reactor reached criticality. A domestic reactor for radiation shielding research purpose.

d. In 1956, the Atomic Energy Commission made the first long range program. At that time, it was determined to improve domestic technological level by introducing foreign technologies in order to realize domestic production of reactors as early as possible. As for nuclear fuel, a plan was made to develop a breeder reactor (Note 4), to fully utilize domestic resources.

(Note 4) Japan then thought that it could not be expected to secure a smooth import of nuclear fuel from abroad.
Japan aimed at development of breeder type reactor from the beginning, and has been continuing efforts to develop it. For Japan, in a condition of poor energy resources, it is a earnest desire to obtain a stable energy supply, and the same situations still remain at the present time.

(2) Introduction (since 1957)

a. In 1956, while the R&D program was continuing, a desire for early introduction of nuclear power station intensified (Note 5), and an investigating mission was sent to the U.K. as it started operation of a power station of Calder Hall type. The mission reported that the Calder Hall type reactor would be appropriate to be introduced to Japan as a working reactor, though some anti-earthquake measures to be considered, and that it would be also appropriate to introduce a light water reactor as an experimental power reactor (Note 6).

(Note 5) It was thought that nuclear power would be a major electric power source in future, and that a total amount of foreign currency needed to secure nuclear fuel would be less when compared with fossil fuel resources.

(Note 6) In 1963, JPDR (Japan Atomic Energy Research Institute, 12 MW) started its first power generation.

b. In 1957, a pioneering company was established with an objective of nuclear power generation, and a plan to introduce the of Calder Hall type reactor was promoted (Tokai Power Station, 166MW, started operation in 1966). Then, development of a light water reactor progressed in the United States brought a thought that a light water reactor would be more promising both in terms of economy and future prospect. In 1961, the Atomic Energy Commission showed its decision that a light water reactor should be introduced as the second nuclear power reactor. In 1963, the pioneering company announced the light water reactor power station program (Turuga Power Station Unit 1, 357MW, BWR, starting operation in 1970).

c. In 1958, in a tender for the U.S. Oyster Creek Power Station Project, a nuclear power station plan having a cost-wise better way of power station than coal power generation was proposed. This promoted private power companies to make plans to introduce nuclear power generation (Mihama Unit 1, 340MW, PWR, starting operation 1970; Fukushima No.1 Power Station Unit 1, 460MW, BWR, starting operation in 1971).

(3) Hardship (1970's)

a. In 1970's, general public became sensitive to environmental pollution and also critical of companies activities. Moreover, due to troubles (Note 7) occuured at nuclear power stations, plant availability factor hung with low level of 40 to 50% (See Figure-4). As a result, the public view toward nuclear power generation became more critical, and it became even more difficult to secure sites for new construction.

(Note 7) Stress corrosion cracking in BRWs (in the first half of 1970's)
Fuel troubles in PWRs (in the first half of 1970's)
Neutron leakage in the nuclear powered ship (1974)

(4) Measures

a. Following the oil crisis of 1973, an expectation for nuclear power generation rose as a major energy source to replace oil as nuclear power generation was thought less expensive, a clean energy source causing no air pollution and easy to transport and store.

b. Therefore, improvement of organization and system (Note 8), improvement of safety research, development of guidelines, and technology development (Note 9), etc. were vigorously carried out.

(Note 8) In 1973, a system of public hearing was established.
In 1979, laws were enacted with an objective of assisting local development (Assistance for the development of public facilities).
In 1978, regulating systems were adjusted, including establishment of the Nuclear Safety Commission.

(Note 9) From 1975 through 1985, the government, power companies and manufacturers jointly carried out the First, Second and Third Development and Standardization Plans to establish own technologies.

(5) Establishment

a. Through voluntary programs in the private sector and joint government and private programs, countermeasures against troubles were taken, inspection work was made more efficient, and generating capacity was expanded. In 1980's, a steady improvement was realized to raise the availability factor of nuclear power stations.

b. Currently, Japan is the third nuclear power generating country following the United States and France, with a total of 46 units and a total power generating capacity of 38,376 MW. Nuclear power generation today accounts for about 30% of total power generation.

c. With the domestically developed technologies, occurrence of troubles is currently at an extremely low level at 0.5 troubles per year per reactor. Unplanned shutdown of reactor due to trouble is almost none today, and the reactors are running well excluding duration of periodical inspection (See Figure–5). As for steam generators, too, considerable improvement has been effected through a number of countermeasures. Also, work has been continuing to replace older steam generators with newer ones.

(6) Evaluation of Past Development Efforts

a. As stated above, the nuclear power stations in Japan are currently operating almost trouble–free. This is a result of employment of high quality equipment and materials and thorough preventive maintenance (In Japan, the law requires a regular inspection each year, and power companies conduct additional inspection and maintenance) to improve reliability of individual equipment, because Japan had gone through " hardship" in lower availability factor.

b. In Japan, whenever failures occur, not only parts are replaced and plants are recovered from unusual condition but also a thorough investigation is made to find the causes to take necessary measures to prevent same failures. In addition, the similar countermeasures are taken at other power stations, too (horizontal evolution).

Japan may be said unique in this respect. Sometimes, people might wonder if it is really necessary to take measures as far as this extent as it is natural that equipment sometimes fails and a safety system is provided to prepare the entire system against failure. Nevertheless, Japan has been taking a way of thorough quality control.

Japanese way mentioned above is supported by a common sense among government, utilities, plant suppliers, and general peoples. It doesn't look like a rational manner. However, it might be a right mánner from following viewpoints.

Nuclear power generation involves a giant and comlicated system, and it is not always easy

to fully understand a possible results derived from the events. Especially, it is almost impossible to understand events derived from not a few coincidental failures and maloperation. Therefore, we try to keep plants perfect condition in order to allow single failures only. Endless efforts to realize zero deffect has necessarilly resulted in a higher cost, but it also resulted in less exposure of employees to radiation, a higher availability and also a higher safety and economy of nuclear power generation.

5. Future Issues

(1) Development of Entire System

a. Nuclear power generation involves not only power station itself but also establishment of nuclear fuel cycle, including treatment and disposal of radioactive waste materials. In view of limited supply of uranium resource, it is essential to establish technologies to reprocess used fuel and effective utilization of plutonium in order to enjoy the merits of nuclear power over a long range of time.

b. This has been a policy of Japan from the beginning of nuclear power development. As a result of step–by–step and steady R & D efforts, present situations are as follows:

Fuel processing facilities: 100% domestic.
Enriching facilities: In 1992, a plant of 150 tons/SWU per year started operation.
(The capacity will be expanded to 1500 tons/SWU per year by around 2000.)
Reprocessing facilities: A plant of 800 tons per year will start operation around 2000.
MOX processing facilities: No extra pultonium is to be stored except one for research purpose, and all pultonium is to be consumed on a pu–thermal basis.
Low level radioactiv waste disposing facilities: Started operation in 1992. Initial capacity is 1 million drum cans. Ultimate capasity is 3 million.
High level radioactiv waste controlling facilities: Under construction. To be started operation in Feb. 1995.
High level radioactiv waste disposal: Organization will be established until 2000.
Fast breeder reactor:
Experimental reactor: Critical in Apr. 1977, 100MWt
Prototype reactor: Critical in Apr. 1994, 280MWe
Demonstration reactor: Will be started construction late 1990's

c. As for reprocessing of spent fuel from light water reactors and utilization of resulting plutonium, there may be some problems in relation to non–proliferation of nuclear weapons. There is no question about the global importance of non–proliferation of nuclear weapons. However, it is doubtful whether any solution can be found in Japan, small and narrow country, from the standpoint of environmental load, to safely dispose plutonium coming out of the nuclear fuel cycle in the form of spent fuel. It may be more important not to dispose plutonium into the environment by reprocessing spent fuel, using the resulting plutonium and thus by confining plutonium within the system of utilization of nuclear power under required and proper security measures.

In order to make the system of nuclear power both permanent and complete, it is essential to efficiently utilize uranium resources and to establish measures to dispose waste.

d. At any rate, as a measure to secure a long range stable supply of energy which supports the global continuing growth, it is significant to develop a system of reprocessing and fast breeder reactor as one of future options, and Japan has a basic policy of continuing R & D efforts to establish technologies to reprocess spent fuel and utilize the resulting plutonium as a promissing future option.

(2) Social Acceptance

a. Securing sites has been a great problem in recent years. Currently there are 17 nuclear power station sites in Japan. The latest nuclear power station site was registered for national power development plan in 1986. Since then, there has been expansion of nuclear power generation facilities, but no new sites have been secured.

b. There are a number of reasons for this. According to a survey of people's awareness, while about 70% of people understand the necessity of nuclear power generation, people who accept the safety of nuclear plant still halt in a level of 40% (See Figure-6).

c. According to the recent analyses, people feel less uneasy if they get sufficient information and feel that their views are taken into consideration.

d. It is, therefore, necessary to make efforts to improve welfare of the people residing in the vicinity of nuclear facilities through development of local public facilities, and at the same time to conduct environmental radioactivity surveys, hot waste water effect surveys, and technical projects and research to confirm safety of facilities, and also to make public relations efforts and to disclose information.

e. Short term apart, it should not be possible to develop and use nuclear power without the support of the residents and people in general over a long range of time. It is therefore essential as a future task to improve social acceptance of nuclear power.

(3) Safety and Economy

a. As pointed out earlier, the essential characteritics of nuclear power is that its fuel cost in relation to the entire cost is low and thus it is less vulnerable to tight supply and resulting higher costs of energy resources. This means, on the other hand, that its economic advantage becomes less when the cost of energy sources is lower. This is,in addition to the safety issue, one of the reasons for global slow development of nuclear power.

b. One of the difficulties in developing nuclear power is that it is necessary to carry out development in the time range of several ten years.
When energy costs are at a high level as after the oil crisis, the necessity from the standpoint of long term stable supply of energy agree with the short term economic necessity. When they are at a lower level, on the other hand, they go apart. The market is an excellent mechanism for short term opitimization, but can not guarantee optimization from the standpoint of long term.

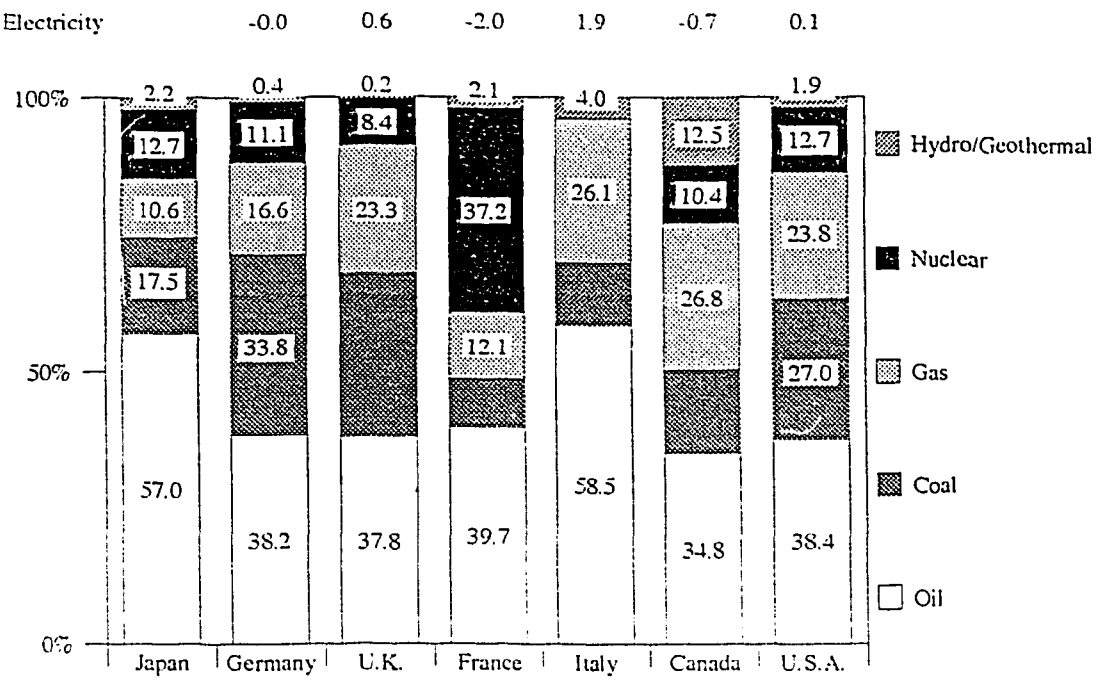
c. Forunately, the economic advantage of nuclear power is still maintained in Japan, though reduced. This does not mean, however, that the economic advantage of nuclear power will be maintained in the future, too. Technological development and energy cost changes may result in reversing economic advantage of various power sources.

d. Japan is not in a position to control the world energy market under such circumstances, and has to accept the changes in the energy market as given conditions. It is, therefore, necessary for Japan to continue development of nuclear power, placing emphasis on the diversification of energy sources so that the country could smoothly adapt itself to changes in energy costs.
To prepare itself when caught in a dilemma of incompatible short and long term requirements as mentioned above, Japan shoud continue its efforts to further improve the safety and economy of nuclear power generation.

(Note 10) energy costs in 1989:
Nuclear power – 9 yen/kwh
Oil thermal – 11 yen/kwh

Primary Energy Supply Patterns

(1991)
(Unit : %)

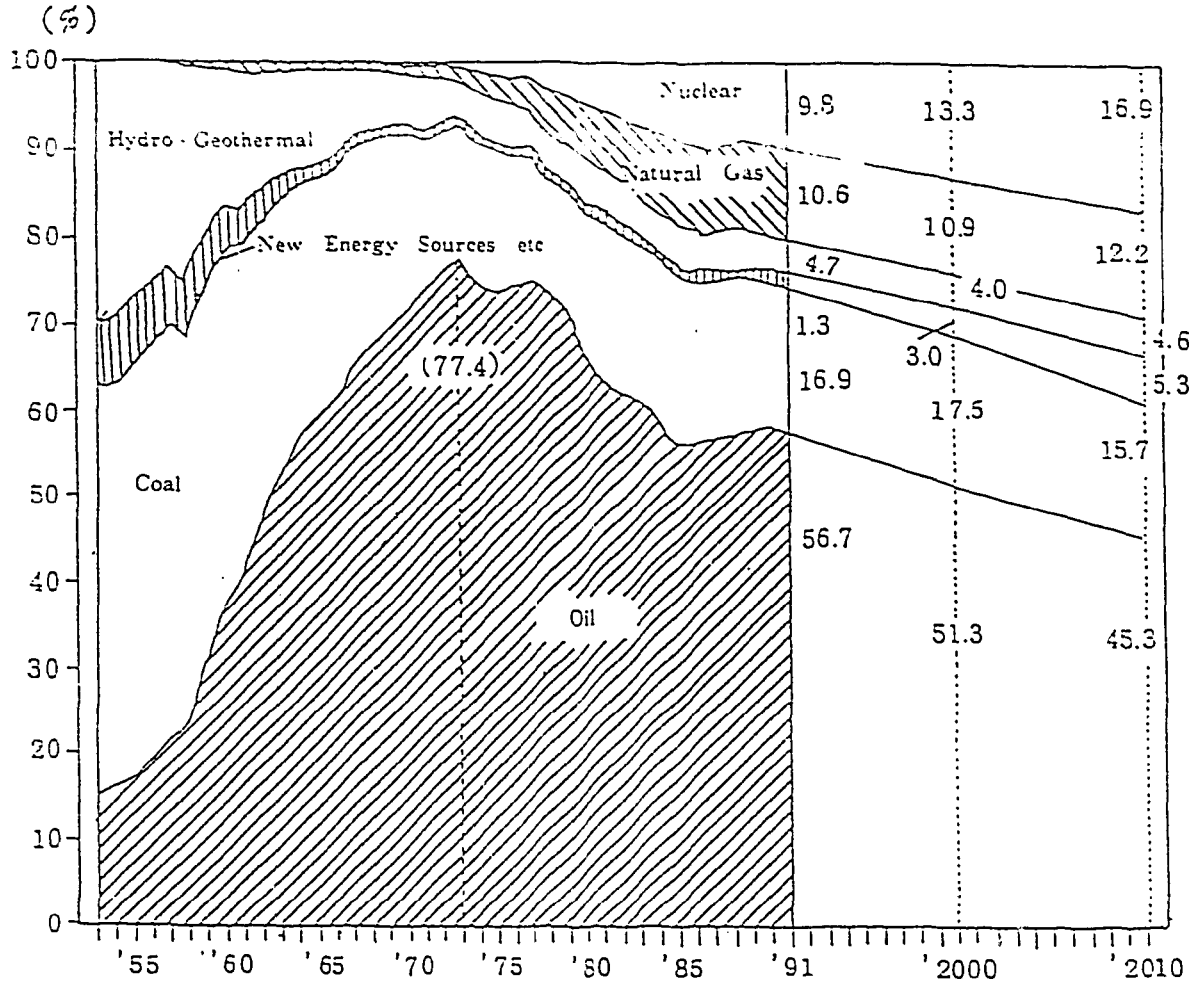


Total Primary Energy Supply (Mtoe)	438	347	218	232	159	212	1933
Dependence on Imported Energy (%)	83.4	52.1	2.0	52.9	83.4	-35.4	15.3
Dependence on Imported Oil (%)	99.7	96.8	-13.6	95.9	95.1	-28.8	43.0

(Source : OECD Energy Balances)

Fig. 2

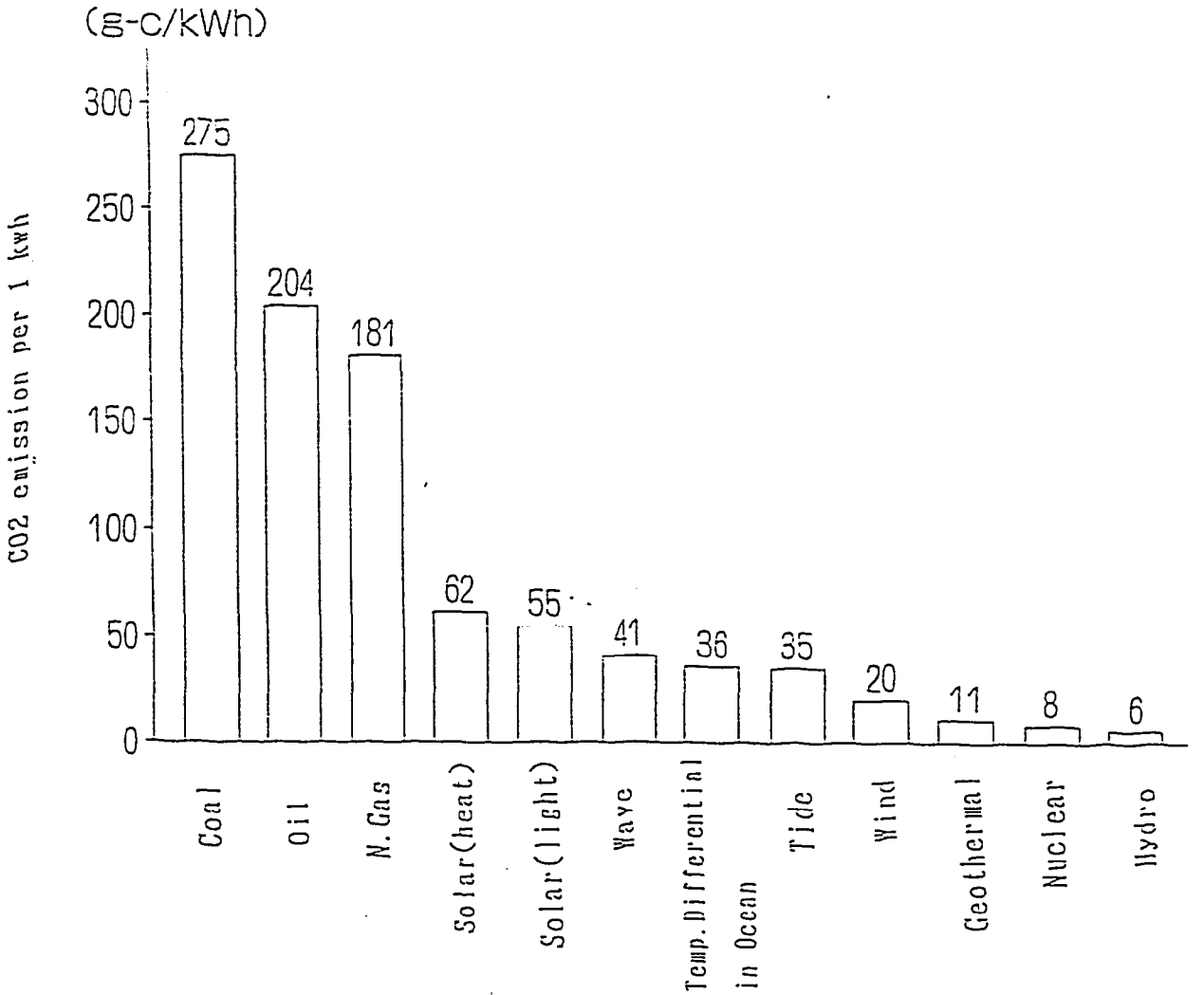
Share of EnergySources in Primary Energy Supply



(Note) Data of FY2000 and FY2010 are based on Energy Supply and Demand Outlook which contributed to decide the goal of alternative energy supply of oil.

Figure 3

Comparision of CO2 Emission on Various Kind of Electric Power Generation



(Note) CO2 emitted from all the process, including mining, construction, transportation, refining, operation, and maintenance, are taken into account for caluculation of value.

(example) Coal [mining & selection] → [transport] → [power generation]

→ [ash disposal]

Figure 4

Annual NPP Capasity Factor (Average)

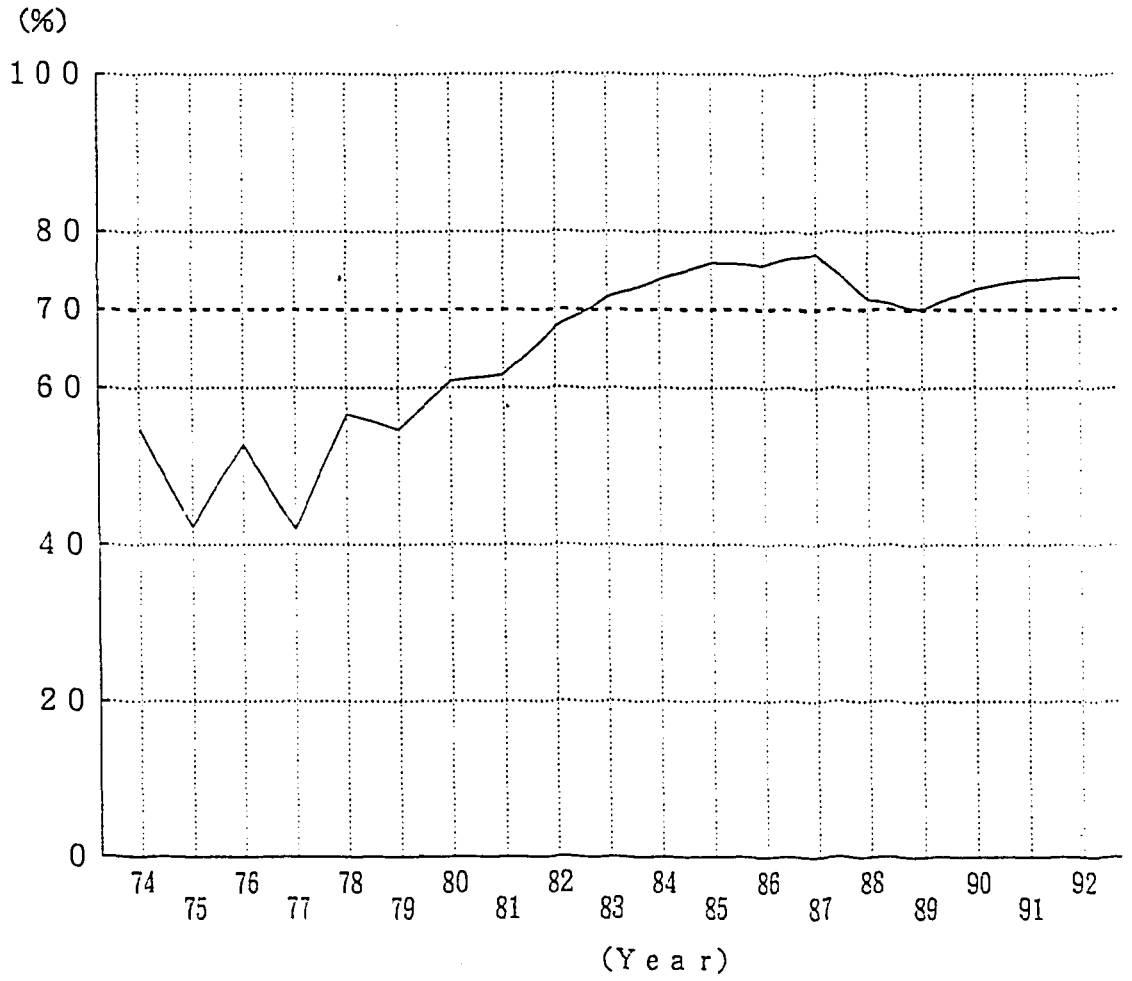
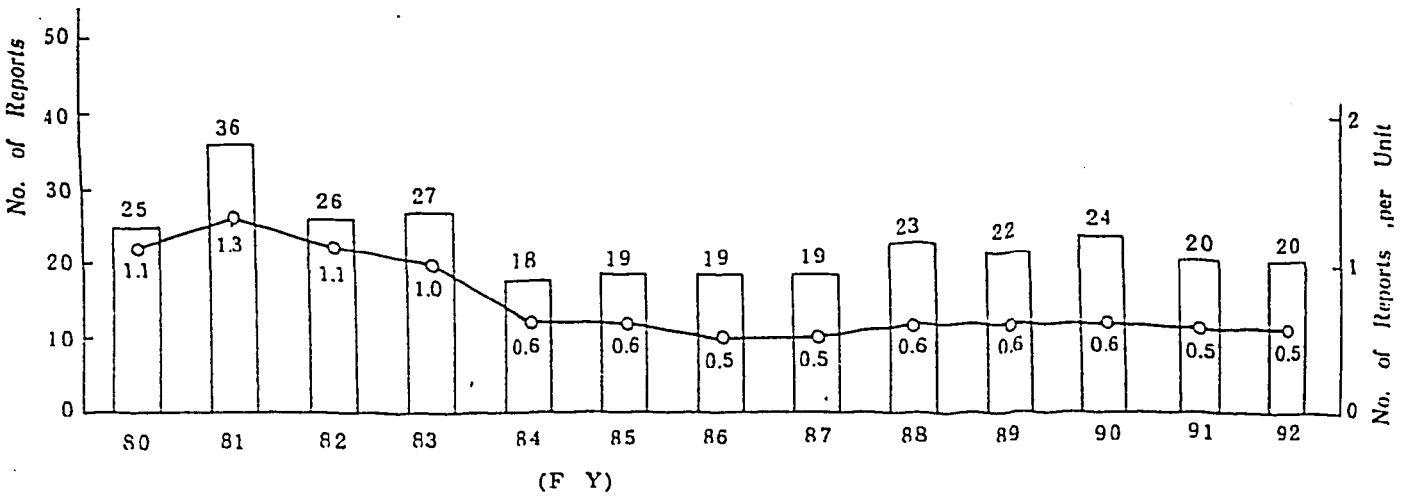


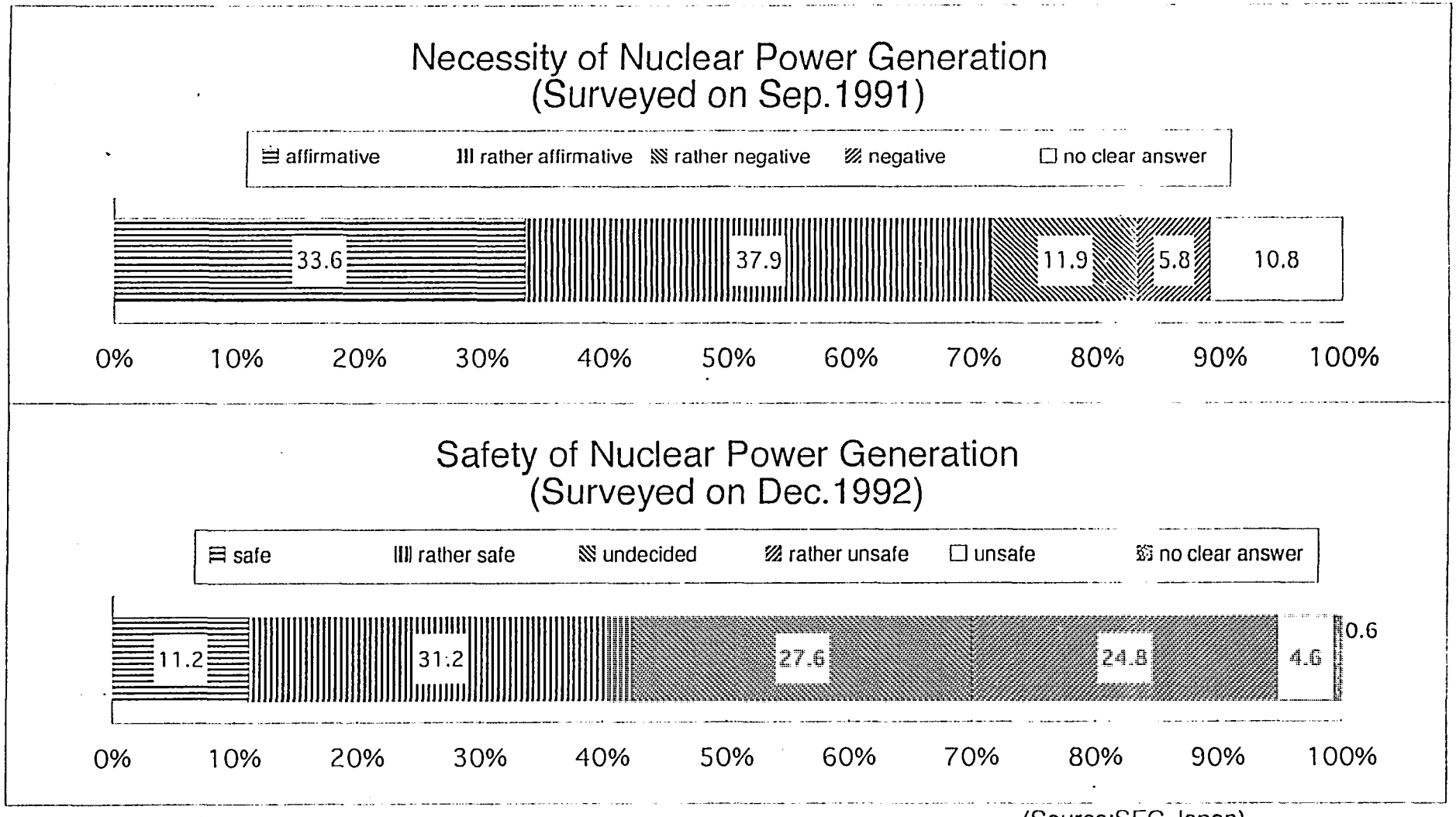
Figure 5

Number of Incident and Failure Repoets, and Average Number of Repoets per Unit



Public Opinion on Nuclear Power Plant

Figure.6



(Source:SEC Japan)