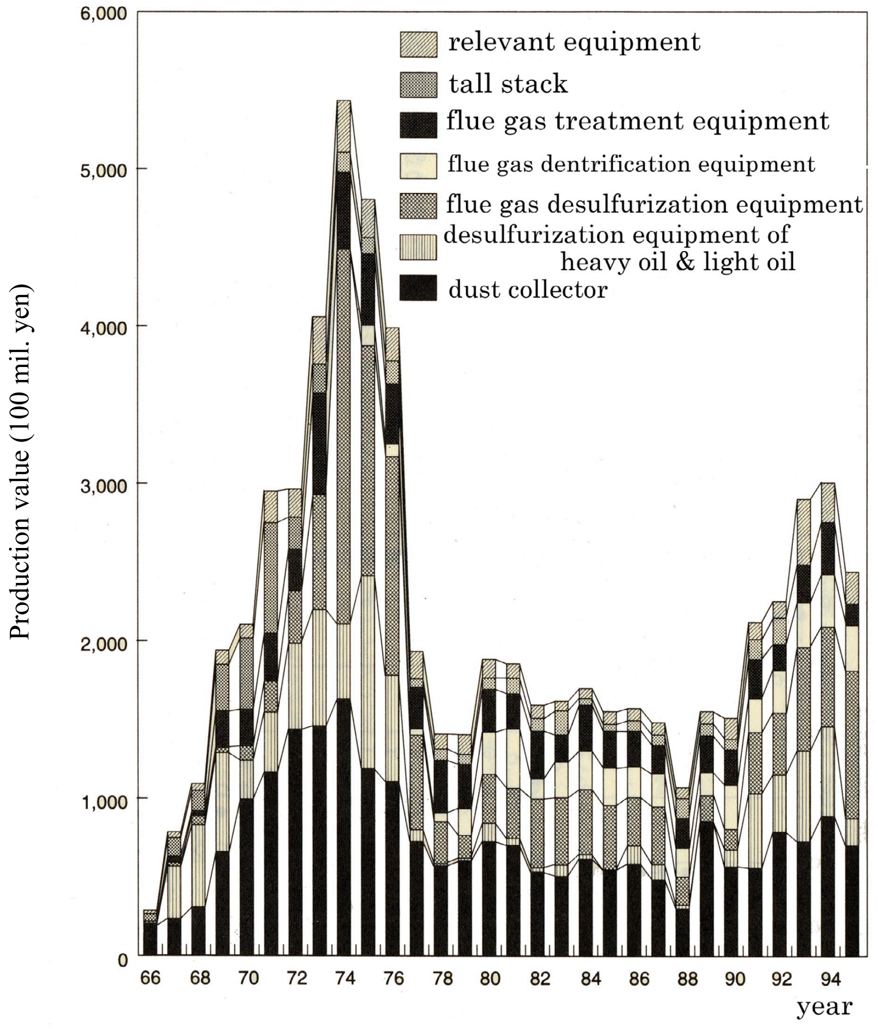
On the contrary, there were very few orders for heavy and light oil desulfurization equipment. That indicates that factories were not renewing their facilities, but looking into alternative measures. Details will be discussed later.



Source: Committee for Japan's Experience in the Battle against Air Pollution, *Japan's Experience in the Battle against Air Pollution*, Japan Times, 1997, p.81

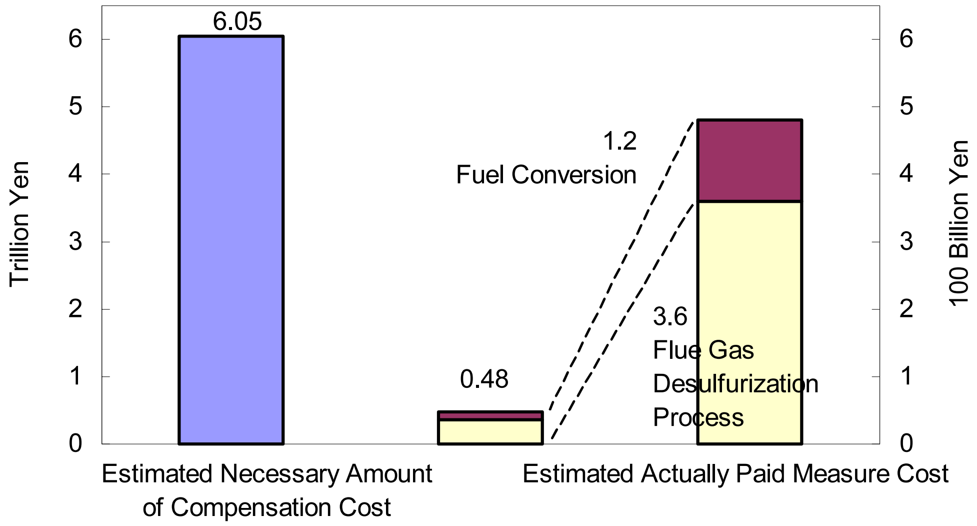
Figure 2.2.5 Changes in Production Value of Air Pollution Control Equipment (at 1990 price, 1966-1994)

2.2.2 Cases of Analysis of SOx Control Measures at National Level

This section reviews cases which macroscopically analyze the historical details of occurrence of air pollution, implementation of control measures, and overcoming pollution on SOx from the perspective of country's socioeconomic costs. Also, it describes how the SOx control measures implemented from the late 1960s to the 1980 are evaluated in these cases from a financial cost-performance viewpoint.

a. Comparison between Costs of SOx Control Measures at Sources and Damages Caused by Air Pollution

Youich Kaya submitted his monograph to the Club of Rome Symposium in Tokyo in 1982, in which he estimated costs of SOx control at source and costs of compensation in case no measure were taken, and made the comparison as shown in Figure 2.2.6.



Note from the original monograph

The calculations of the costs for pollution control were done by the following methods, based on published material from the Environmental Agency, etc. 1976 that was used as the point of calculation because the most data was available for that year.

1) The costs for fuel exchange was calculated by the following: the percentage of kerosene in primary energy supplies in 1965, when sulfur dioxide control measures were not taken seriously, was compared to the actual share of kerosene in 1976, then the increase amount was considered to be the increase in kerosene consumption that corresponded to fuel exchange for sulfur dioxide control. The difference in the prices of heavy oil and kerosene with the same amount of heat was considered to be the actual cost of energy exchange policy.
2) In estimated sums for the cost for installing flue gas desulfurization equipments, the actual number of desulfurization equipments was multiplied with both the yearly depreciation amount for an average sized equipment and the costs for operation.
3) The compensation amounts was calculated by the following: under the assumption that environmental concentration of sulfur dioxide will grow in proportion to the increase rate of primary energy supplies from 1965 to 1976, it was estimated that 15% of the population in the main industrial areas of Japan would be identified as pollution sufferers/patients under this surmised environment, and the compensation amount was the result of multiplying the assumed number of patients with the amount of compensation for each patient, at the time of 1976 .

Source: Chikyu Kankyo Keizai Kenkyukai (ed.), *Nihon no Kogai Keiken*, Godo Shuppan, 1991, p.21

Figure 2.2.6 Comparison between Annual Costs of SOx Control Measures and Those of Compensation if Measures Are Not Taken (at 1976 price)

Figure 2.2.6 shows comparison of the yearly pollution control costs spent by SOx source factories with the pollution damage costs that would have occurred if no measures had been taken as of 1976.

This graph is merely estimation, based on bold assumptions, but the calculated damage costs when no pollution control measures were taken (approximately 6 trillion JPY per annum, calculated with 1976 prices) exceeded by far the estimated real pollution control costs (approximately 480 billion JPY per annum, calculated with 1976 year prices).

The report prepared by Chikyu Kankyo Keizai Kenkyukai (Study Group on Global Environment and Economy)[4] points out that economic development with environmental conservation is on the whole better, from the economic point of view, than economic development without environmental protection, although there are grounds for criticism of the estimated recognition rate of victims of air pollution based on the Pollution-Related Health Damage Compensation Law and damage costs in the case of severe pollution. In addition, the report includes a comparative analysis of SOx control costs and damage costs, based on the assumptions adopted in Kaya's monograph, using the SOx pollution case of Yokkaichi. Details of this analysis will be described in the later section: Analysis of the Measures for Sulfur Dioxide Control on the Local/Industry Sector Level (Section 2.2.3).

b. Cost-Benefit of SOx Measures

Kawauchi, Matsuoka, Matsumoto and Murakami performed a cost-benefit analysis of SOx control measures from a social cost benefit approach, using the Cost of Illness Approach (COI) for benefit evaluation[6]. The social cost benefit ratio of the first period (1968-1973), the second period (1974-1983) and the third period (1984-1993) are shown in Table 2.2.2.

Table 2.2.2 Results of the Cost-Benefit Analysis of SOx Control Measures

Unit: billion JPY (at 1993 price)

	Case with 0% social discount rate			Case with 2.5% social discount rate			Case with 9% social discount rate		
	1st period	2nd period	3rd period	1st period	2nd period	3rd period	1st period	2nd period	3rd period
Cost	10,608	26,573	13,158	6,565	16,386	8,494	3,046	7,445	4,041
Benefit	81,403	82,819	28,840	50,071	50,936	18,104	21,772	22,154	8,204
Benefit/ Cost	7.67	3.12	2.19	7.63	3.11	2.13	7.15	2.98	2.03

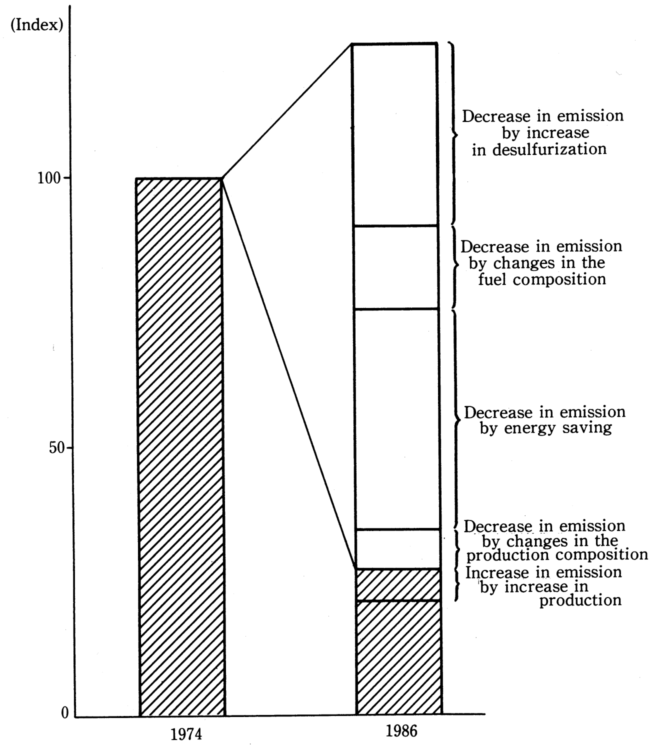
Note: Costs include: cost for converting to better quality fuel, investments in SOx control facilities (higher stack, flue gas desulfurization equipment, and heavy oil desulfurization facility), and maintenance costs of flue gas desulfurization facilities. Benefits include: SOx concentration lowered by control measures, first period (0.085 ppm --> 0.0300 ppm), 2nd period (0.0300 ppm --> 0.0130 ppm), 3rd period (0.0130 ppm --> 0.086 ppm); the changes in asthma morbidity according to the dose-response relationship divided into 3 periods based on survey results by the Environmental Agency, 1st period (6.358% --> 4.306%), 2nd period (4.306% --> 3.082%), 3rd period (3.082% --> 2.758%), and calculated as an assumed willingness-to-pay amount for the reduction of health damages by taking control measures, by multiplying the number of patients reduced in each period with the medical costs and the amount of money lost by the reduction of working time.

Source: KAWAUCHI Ikuho et al., "Taiki Osen Taisaku no Hiyo Beneki Bunseki: Nihon no SOx Kisei wo Jirei toshite", *Higashi Ajia heno Shiten*, Special Fall Edition, 2000

Regarding the efficiency of environmental measures, there is a possibility that allocation of resources for other environmental measures should have been emphasized because social efficiency of SOx control measures would decline with environmental improvement. However, considering the numerical value, the social cost-benefit ratio during the third phase of 2.03-2.19 still showed high efficiency.

c. Factors for SOx Emission Reduction

The Environment Agency analyzed factors contributing to SOx emission reduction during 1974-1986. As shown in Figure 2.2.7, the factor that contributed most was energy saving, followed by increase in desulfurization, changes in the fuel composition, and changes in the production composition.



Notes : 1. Prepared by the Environment Agency
2. For the index, the emission of 1974 is set at 100.

Source: Environment Agency, *1990 White Paper on the Environment*, p.128

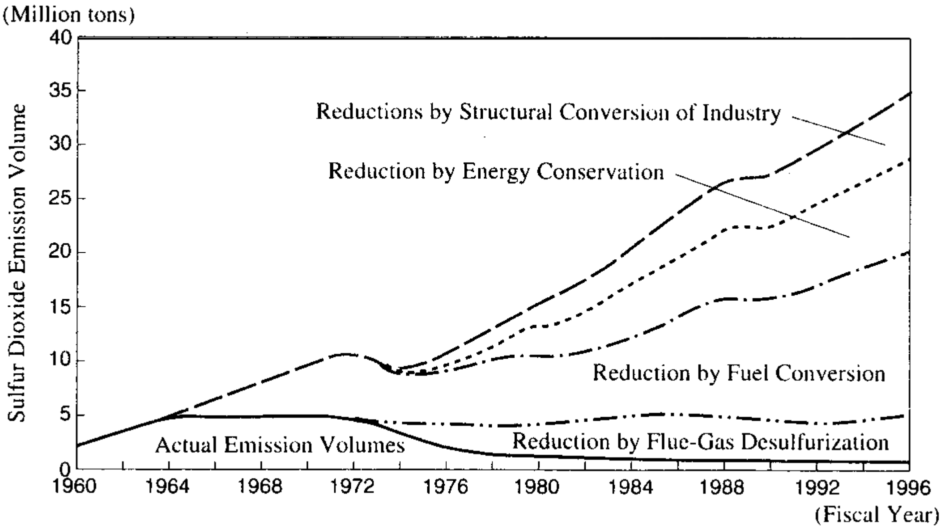
Figure 2.2.7 Analysis of Factors Contributing to Changes in SOx Emissions

Figure 2.2.8 indicates the results of the simulation of SO_2 emission reduction measures in Japan, conducted by the Committee for Japan's Experience in the Battle against Air Pollution.[7] The economic model was developed based on the MERGE model (a combination of ETA, an energy model which reproduces determining mechanisms for energy mixes, and MARCO, an economic model which reproduces the relationship between economic growth and energy consumption. The MERGE model was jointly developed by Alan Manne of Stanford University and Richard Richels of the United States Electric Power Research Institute). A pollution control investment module and a pollution damage function module were incorporated into the improved MERGE model, to simulate the following three mechanisms of reducing SOx emissions.

1. Reduction in sulfur dioxide emission through flue-gas desulfurization
2. Reduction in sulfur dioxide emission through reduction of sulfur content in fuel
3. Reduction in sulfur dioxide emission through energy conservation and the conversion of industrial structure

In addition, the details of this model can be found in *Japan's Experience in the Battle against Air Pollution* edited by the Committee for Japan's Experience in the Battle against Air Pollution. However, it should be noted that this simulation was applied based upon multiple hypotheses and limited data, and needs to be verified with scientific testing.

[7] Committee for Japan's Experience in the Battle against Air Pollution, *Japan's Experience in the Battle against Air Pollution,* Japan Times, 1997



Source: Committee for Japan's Experience in the Battle against Air Pollution, *Japan's Experience in the Battle against Air Pollution*, Japan Times, 1997, p.92

Figure 2.2.8 Factor Analysis of SO_2 Reduction in Japan (1960-1996)

As seen in Figure 2.2.8, if absolutely no SOx reduction measures had been taken in Japan, it is estimated that emission volumes would have increased rapidly to more than seven times as much as the actual peak around 1974.

This figure shows that main factor contributing to SO_2 reduction was fuel shift in the 1960s, while the significant effects of flue-gas desulfurization started to appear in the beginning of the 1970s. Energy conservation efforts also had a significant influence on the situation. The effectiveness of measures to reduce SO_2 emissions varied dramatically according to the level of policy progress, energy prices, and other external factors.

The above-mentioned report indicates two major factors explaining why SO_2 control has been successful up to a certain point.

1. Changes in International Fuel Price

Changes in low sulfur crude oil prices in the international market had a major impact on the progress of fuel shift for sulfur content reduction in the 1960s, also two oil crises had a profound effect on energy conservation in the 1970s and 1980s.

2. Maintenance of Appropriate Domestic Market Competition

The fact that fair market competition mechanism had been maintained in Japan greatly influenced the variation in SOx control measures resulting from fuel price changes and the spread of flue gas desulfurization technology in the beginning of the 1970s.

However, it should be noted that fair market competition is different from currently expanding mechanism of market competition in international markets with the WTO.

Market competition in Japan was supported by national industry policy aiming at developing domestic industry. The government implemented policies to minimize inequalities in the areas of pollution control between companies in terms of scale and financial strength through financial mechanisms and preferential tax treatment such as subsidies for pollution control measures, low interest loans, and tax exemption.

Moreover, efforts to maintain fair market competition by eliminating "free-riders" through air pollution monitoring and on-site inspections improved SOx control measures in the private sector.

d. Pollution Reduction Effect of Levy System by Pollution-Related Health Damage Compensation Law

The pollution reduction effect of the levy system under the Pollution-Related Health Damage Compensation Law will be considered in this section with quotations from Matsuno and Ueda[8].

The amount of the levy payment per unit of SOx emission is called the rate of levy (JPY/Nm^3) and the notional formula is as follows:

Rate of levy = anticipated amount of compensation payment in the fiscal year (t) /
nation-wide total SOx emission in the calendar year (t-1)

The first characteristic of this system is that its purpose is to raise revenues for compensation; the amount of revenue required would be decided first, then the rate of levy would be decided. Secondly, SOx generators did not know the levy rate at the time of generation. The third characteristic is that only SOx was charged for, although other air pollutants such as nitrogen oxides also induce health hazards. Finally, because assigned health hazards by the Pollution-Related Health Damage Compensation Law are cumulative and irreversible, health hazards in t-year were also due to pollutants generated before (t-1) year; however, only generators in (t-1) year were charged. By this system, the total amount of compensation would be decided independently from current SOx emissions, which leads to sharp increase in the levy rate according to the first characteristic. On the other hand, it was an inordinate burden for current SOx generators, which means that the mechanism encourage current SOx generators to reduce current SOx emissions.

At a thermal power plant in Osaka Prefecture, the main factor explaining SOx emissions reduction was a regulation based on the Pollution control agreement, not because of the levy system. However, incentives due to the levy system for emission reduction also partly existed and mainly influenced small and medium size factories and power plants where enforcement of the regulations was relatively lax. The incentives gradually increased as fuel price differences by sulfur content decreased and the levy rate sharply increased.

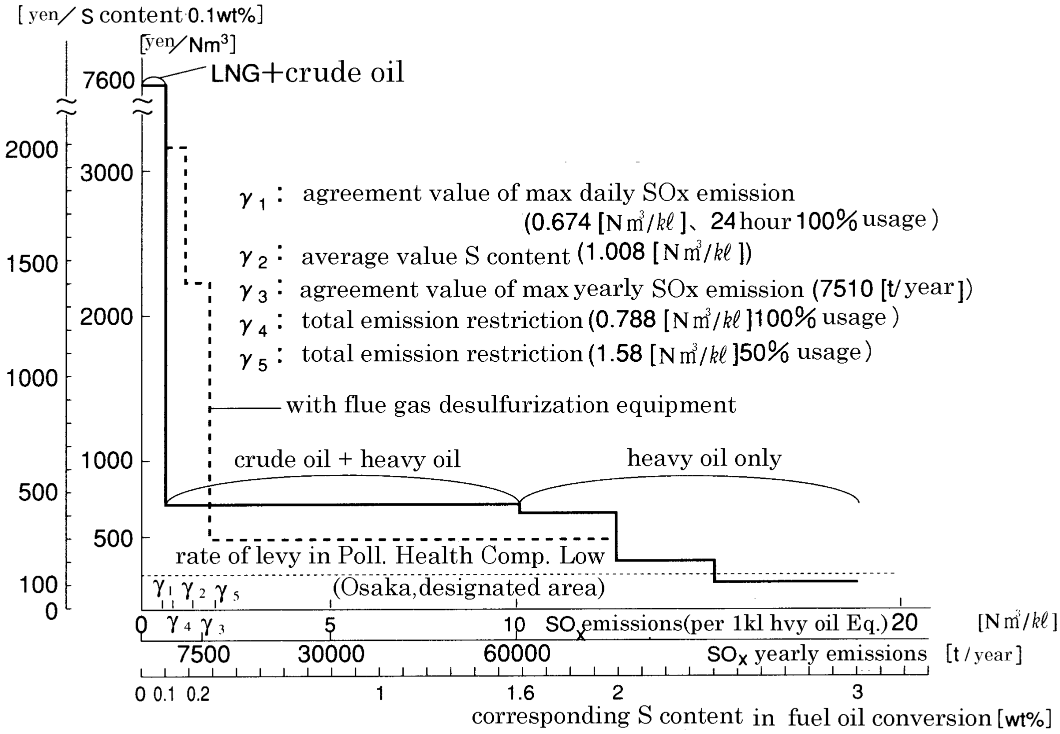
The levy rate in the designated areas by the Pollution-Related Health Damage Compensation Law in Osaka Prefecture is the highest in the country. However, there is little room for the levy to work as pollution reduction incentive because direct regulations such as the total amount control and the pollution control agreement are very strict. By contrast, it is estimated that areas where direct regulations are not so strict and the levy rate is relatively low have seen bigger pollution reduction effects than Osaka.

Figure 2.2.9 indicates how high the cost of implementing the measures in response to the Pollution control agreement was. Besides, Figure 2.2.10 shows the marginal costs of SOx control by small and medium enterprises. Matsuno and others have estimated the marginal reduction costs of SOx control measures by Sakai thermal power plant as of 1975. The cost of implementing the measures was extremely high under the emission volume regulated by the pollution control agreement shown as γ_2 in the figure, and it was far higher than the levy rate in Osaka City under the Pollution-Related Health Damage Compensation Law.

Furthermore, Fujii[9] has pointed out that 'regulatory measures effectively worked to reduce pollution at the first stage but remained as a factor distorting the cost structure because of

[8] MATSUNO Yu / UEDA Kazuhiro, "Kokenho Fukakin", UEDA Kazuhiro / OKA Toshihiro / NIIZAWA Hidenori (eds.), *Kankyo Seisaku no Keizaigaku - Riron to Genjitsu*, Nihon Hyoron Sya, 1997, pp.91-96

changes in energy and fuel prices, which may hinder companies from taking more effective and flexible response with their discretion.



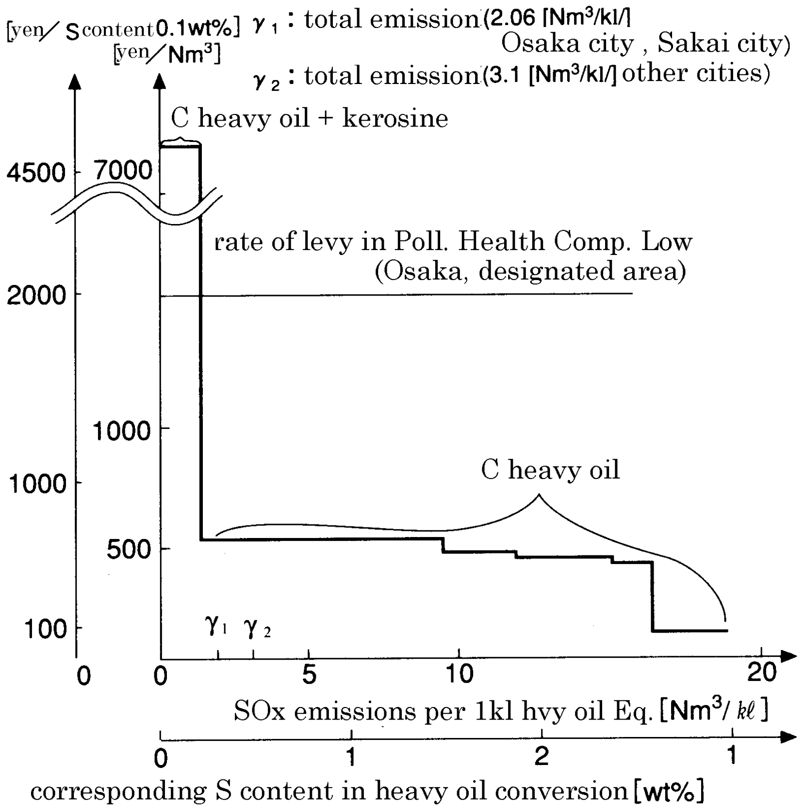
Source: MATSUNO Yu / UEDA Kazuhiro, "Kokenho Fukakin," in UEDA Kazuhiro / OKA Toshihiro / NIIZAWA Hidenori (eds.), *Kankyo Seisaku no Keizaigaku - Riron to Genjitsu*, Nihon Hyoron Sya, 1997, pp.79-95

Figure 2.2.9 Marginal Cost of SOx Reduction at Sakai Power Plant

It could be said that temporal success of environmental measures based on regulations and technical solutions in Japan weakened the society's capability to respond to new environmental problems that were changing in quality. As a result, the introduction of flexible measures, such as economic incentives, was delayed, which caused the distortion and rigidity of cost effective measures from the environmental aspect. It also hindered the emergence of a direct participatory decision-making system, which would make market solutions more effective, and the appearance of new actors such as NPOs and green consumers. When considering environmental measures in developing countries that are already located in the global environment regime, it may be necessary to seek a structure where new actors and the market are more utilized[10].

[9] FUJII Yoshihumi, "Kogai Boshi Gijyutsu Kaihatsu to Sangyo Soshiki - Nihon no Keiken ni Miru Kankyo Kisei to Sangyo Gijyutsu no Dynamic Process -", *Kaihatsu to Kankyo no Seisakukatei to Dynamism - Nihon no Keiken /Higashi Asia no Kadai*, 2002, p.84

[10] Ibid. p.103



Source: MATSUNO Yu / UEDA Kazuhiro, "Kokenho Fukakin," in UEDA Kazuhiro / OKA Toshihiro / NIIZAWA Hidenori (eds.), *Kankyo Seisaku no Keizaigaku - Riron to Genjitsu*, Nihon Hyoron Sya, 1997

Figure 2.2.10 Marginal Cost of SOx Reduction in Small and Medium Businesses

e. Promotion of Low-Sulfur Fuel by the Government and Responses from the Petroleum Refining Industry, the Petrochemical Industry and the Electric Utility Industry

Regulation of SOx started with the Smoke and Soot Control Law enacted in 1962, which was replaced by the Air Pollution Control Law in 1968. On the other hand, administrative guidance was provided for the industries, the fuel suppliers and consumers, and it is said that these measures have made a large impact on the development of SOx measures in Japan.

Terao[11]'s analysis regarding impacts on corporate behavior and SOx costs in the petroleum refining industry, the petrochemical industry, and electric utility industry will be introduced here.

e.1 Sulfur Content Reduction Measures in Energy Policies

The Advisory Committee for Energy, an advisory panel for the Minister for International Trade and Industry, filed a committee report titled "General Energy Policies and their Direction" in February 1967, mentioning the need for "a plan for lowering the sulfur content in fuel." The committee set up a task force to address this problem in May 1969, and prepared the plan in December. This plan indicated long-term guiding principles for lowering the sulfur content in fuel; it set targets for oil suppliers for the supply amount and the average sulfur content in heavy fuel oil by oil type and for oil consumers for the consumption and the average sulfur content in oil by location. Based on this plan,

[11] TERAO Tadayoshi, "Nihon no Sangyo Seisaku to Sangyo Kogai", KOJIMA Reiitsu / FUJISAKI Nariaki (eds.), *Kaihatsu to Kankyo – Asia Sin Seityoken no Kadai*, Institute of Developing Economics, 1994

administrative guidance was given to both the suppliers and the consumers. Later, there was a need to revise the baseline of the goals and methods for the lowering the sulfur content, due to the increase in fuel demand, so a revision was made in 1970[12].

The government encouraged the development of desulfurization technology for heavy oil and flue gas to implement this plan. It also lightened the financial burden of companies upon installation of these facilities by low-interest loans from governmental financial institutions such as the Japan Development Bank (now the Development Bank of Japan), accelerated depreciation as special tax treatment, reduction/exemption of property taxes, and reduction of import tariffs on low sulfur crude oil[13].

During the implementation of the measures for lowering the sulfur content in fuel, the Ministry of International Trade and Industry gave administrative guidance to coordinate the conflicting interests between the industries and asked for their cooperation. The industries involved were the petroleum refining industry as the fuel suppliers, and the power industry and the steel industry as major consumers of heavy oil. Besides fuel, the processing of petroleum oil produces a certain amount of naphtha, which is used as raw material in the petrochemical industry; therefore, the shift in demand for heavy oil was a matter of great concern to the petrochemical industry as well. All these industries are known as being under large influence of the Ministry of International Trade and Industry. The petrochemical industry, especially, was under heavy interventions by the Ministry concerning production volume, prices and facility investments, under the Petroleum Industry Law of 1962[14].

The actual responses of the power industry and the oil industry are described below. According to Terao, when a conflict arose over the lowering the sulfur content measures among the petroleum refining, petrochemical, and power industries, the Ministry of International Trade and Industry seemed not to succeed in developing the energy policy that rose over the conflict and was consistent with industrial pollution control measures. He also states that the administrative guidance implemented by the Ministry of International Trade and Industry did not consider the substitutable relationship between fuel and raw material, as seen in the connection between the direct burning of naphtha and low-sulfur heavy oil, which aggravated the conflict. However, he proceeds to say that the confirmation of direct burning of crude oil and naphtha burning at the power industry and the steel industry helped to control air pollution by these industries[15].

e.2 Responses of the Power Industry towards Measures for Lowering the Sulfur Content in Fuel

The power industry started the direct burning of crude oil in thermal power plants in 1962 for substituting heavy oil before the measures for lowering the sulfur content in fuel were put into effect. Since almost all the sulfur contained in crude oil remains in the heavy oil during the refining process, the sulfur content of heavy oil becomes higher than that of crude oil. However, the reason why the power industry had started the direct burning of crude oil in thermal plants was not because crude oil contained less sulfur than heavy oil, but because the price of heavy oil processed in Japan was high. The prices of oil products in Japan were in actuality controlled; naphtha was set at a low price for the growth of the emerging petrochemical industry, and the price of heavy oil was set relatively high[16].

In addition, for the power industry, it was advantageous to delay as long as possible the introduction of flue gas desulfurization equipment to thermal power plants, only implementing fuel-related measures for SOx control. In the latter half of the 1960s, the

12 Ibid. p.315
13 Ibid. pp.315-317
14 Ibid. p.317
15 Ibid. p.324
16 Ibid. p.317

technology for flue gas desulfurization was not yet established, and for the power industry, the standstill in SOx control by lowering the sulfur content in fuel meant that they had to pay for the costs of the unreliable flue gas desulfurization[17].

For the power industry, the development of pollution control regulations was a cost-increasing factor in general. However, at the same time, the social demand for lowering the sulfur content in fuel created an opportunity for them to escape from the restrictions that the administration and the fuel supplying industry in Japan set, to diversify fuel types used for thermal power plants, and to lower costs by reducing consumption of expensive heavy oils processed in Japan[18].

With a background of such conflict of interests between industries, the measures for lowering the sulfur content in fuel were implemented. An important turning-point was the pollution control agreement, a kind of pollution control regulation unique to local governments. The Tokyo Metropolitan Government and Tokyo Electric Power Co. Ltd. signed a pollution control agreement in September 1968, upon the construction of a thermal power plant on Ohi-Futo reclaimed land. In this agreement, Tokyo Electric Power Co. Ltd. promised to use only the extremely low-sulfur Minas crude oil as fuel at the Ohi thermal power plant from 1973. The burning of Minas oil only was a suggestion from the Tokyo Electric Power Co. Ltd. side. The sulfur content in Minas crude oil was 0.1%, far lower than 1.7%, the technological limit of the equipment for heavy oil desulfurization (indirect desulfurization) at that time. Furthermore, Tokyo Electric Power Co. Ltd. promised to continue the use of low-sulfur crude oils at the Ohi thermal power plant in the future. This agreement was a great shock to the petroleum refining industry and the petrochemical industry. Both industries rebelled against the direct burning of good quality low-sulfur crude oil that was limited in amount. In the negotiations between Tokyo Electric Power Co. Ltd. and the Tokyo Metropolitan Government, there was almost no evidence of intervention by the Ministry of International Trade and Industry[19].

The power industry managed to use the pressure from local citizens and local governments (as mentioned above) advantageously, in their negotiations with the petroleum refining industry, the petrochemical industry and the Ministry of International Trade and Industry for the direct burning of crude oil. After 1968, the year in which Tokyo Electric Power Co. Ltd. signed the pollution control agreement with the Tokyo Metropolitan Government, nine electric power companies signed pollution control agreements with the local government of the area in which they had power plants. In almost all of these agreements, there are specific regulations for lowering the sulfur content in fuel[20].

e.3 Impact of the Power Industry's Direct Burning of Crude Oil on the Oil Industry, and the Oil Industry's Response

Because the policy of the Ministry of International Trade and Industry had a principle to refine oil where consumed and an assumption to strictly safeguard traditional oil-processing patterns, a certain amount of heavy oil was produced from crude oil. To maintain the production levels of light-oil content such as naphtha, which was in desperate demand at the time, the petroleum refiners had to secure a sales route for heavy oil. In addition, because burning of crude oil does not bring a profit to the petroleum refiners, the petroleum refining industry was against the increase in direct burning of crude oil in the power industry. They protested that burning of low-sulfur crude oil would squeezed its supply for processing and not be good for lowering the sulfur content of fuels in Japan as a whole. The committee report of the Advisory Committee for Energy in February 1967 set the limit of the power industry's direct burning of crude oil to the planned import amount of C heavy oil, due to the

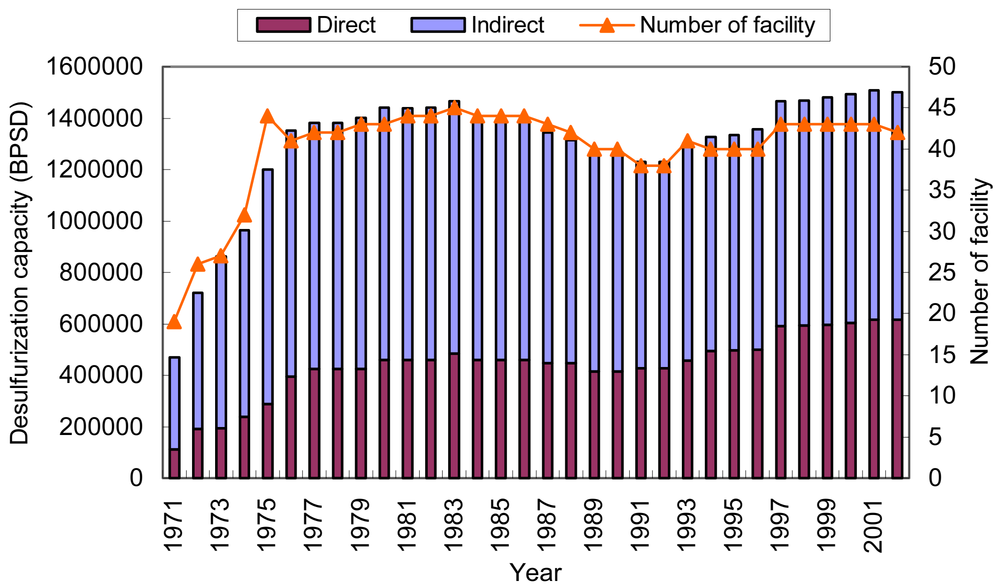
[17] Ibid. p.317
[18] Ibid. p.318
[19] Ibid. pp.318-319
[20] Ibid. p.319

protests of the petroleum refining industry. However, this limitation was to be drastically relaxed later[21].

The conflict of interests surrounding measures to lower the sulfur content in fuel in the petrochemical industry was basically the same as in the petroleum refining industry. For the petrochemical industry, the power industry's direct burning of crude oil without separating light-oil content, like naphtha, was a serious impediment to secure a stable supply of naphtha[22].

To prevent giving the power industry any more excuses to extend the use of direct burning of crude oil, the petroleum refining industry had to speed up their attempts at lowering the sulfur content of heavy oil. The introduction of desulfurization equipment of heavy oils into oil refineries and the development and improvement of technology progressed rapidly[23].

However, the low operation rates of the desulfurization equipment for heavy oil became evident as early as the latter part of the 1970s resulted from its excess capacity. The lowering operation rates of desulfurization equipment for heavy oil caused a drastic increase in unit production costs, and this was a common problem to all the oil refineries. The factors that caused excess capacity of the equipment were; 1) the desulfurization of heavy oil was overly emphasized among the measures for lowering the sulfur content in fuel, 2) due to the strengthening of regulations for SOx emissions, the desulfurization of heavy oil alone was not enough, and 3) the power industry, a major consumer, dealt with the strengthened regulations by the direct burning of low-sulfur crude oil and naphtha. The petrochemical industry had to speed up the desulfurization of heavy oil to prevent the expansion of direct burning of crude oil and naphtha in the power industry. This is probably one of the factors behind the excess capacity of desulfurization equipment for heavy oil. Figure 2.2.11 shows the capacity of desulfurization equipment for heavy oil, and it is apparent that the capacity has not grown since the latter part of the 1970s, and only investments for the renewal of equipment was made[24].



Note: Values as of at the end of each year.
Source: Petroleum Association of Japan, *Sekiyu Siryo Geppo*, each year

Figure 2.2.11 Trend in Capacity of Heavy Oil Desulfurization (1971-2002)

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21 Ibid. pp.317-318
22 Ibid. p.318
23 Ibid. pp.320-321
24 Ibid. p.321