The Energy Revolution

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Background of the Energy Revolution

The transition from coal-based energy to oil-based energy in Japanese industry and utilities through the 1950s and '60s played an important role in Japan's postwar development as an economic power. In many Japanese industries the cost savings derived from the fuel conversion were necessary for their survival in the increasingly globalized marketplace. Across the board, however, adopting new and cheaper fuels reduced manufacturing costs while improving productivity and international competitiveness.

Although there were a few significant moves towards increasing industrial use of oil during the Occupation, a coal miners' strike that began a few months after the Occupation ended in 1952 and continued for 63 days triggered a wave of conversions; a wave that continued to grow, accelerating from 1955 onward. The fact that handling and transporting liquid fuel is much easier than solid fuels, combined with the rapidly declining price of oil were significant factors in the widespread conversion of fuel sources. The CIF (cost, insurance, freight) price of crude oil decreased steadily for nine years after a peak in 1957 (during the Suez Crisis). The FOB (free-on-board) price also fell steadily until 1962 (see Table 21.1).[1] The two prices initially fell together, as large oil fields were discovered and developed in the Middle East. But as the impact of this factor on prices began to level out, the CIF continued to decline as transportation costs fell with the introduction of supertankers. When looking at a comprehensive list of factors including items such as facilities, coefficients of utilization, transport and labor resources, with the merit value of fuel oil designated as 100, coal was calculated to be about 85. In other words, to produce one kilo-calorie of coal and one of oil, the costs of coal and oil were in the ratio of 85 to 100, and at this ratio their economic efficiency was considered to be roughly the same.[2]

The decline in the coal industry did not become apparent immediately. Although coal's share of the energy resources market was definitely declining, the market itself was growing at an ever-increasing rate. Deep structural troubles in the coal industry were further concealed when the Suez Crisis of 1957 temporarily interrupted oil supplies and the price rose sharply, highlighting the volatility and insecurity of relying on oil. Once this crisis was over, however, oil prices began a long decline. The coal crisis came to a

Table 21.1: Change of imported crude oil price (unit: yen)

Year	Domestic crude oil[a] Price after refining process at production site	Imported crude oil	
		FOB	CIF
1956	9,550	4,424	7,333
1957	9,550	4,511	7,690
1958	9,550	4,406	7,114
1959	9,265	3,838	5,965
1960	8,669	3,431	5,213
1961	7,620	3,283	4,939
1962	6,478	3,276	4,835
1963	-	3,326	4,759
1964	5,830	3,330	4,579
1965	5,830	3,305	4,471
1966	5,830	3,222	4,277
1967	5,830	3,215	4,392
1968		3,193	4,255

a Data on domestic crude oil are obtained from Bank of Japan, Statistics Division. Data on imported crude oil are obtained from Coal mining Bureau, Oil Planning Section.

Source: Kaigai Keizai Kyōryoku Kikin Chōsa Bu (Inquiry Section of the Overseas Economic Cooperation Fund), *Sekai no genyu jijō to waga kuni kaihatsu yuny* (World situation of crude oil and imports for developing our nation), 1970, p. 172

head earlier and more severely in coalfields producing inferior quality coal such as Ube and Jōban than at higher quality coalfields in Hokkaidō and Kyūshū.[3] Nevertheless, it soon became apparent that the growing number of bankruptcies in the coal sector and the withdrawal of large corporate conglomerates from the sector were due to structural changes in the sector rather than a slump in the business cycle (which, as mentioned, continued to boom).

As the coal-mining industry began to contract, it experienced a series of disturbances and accidents which each contributed to further price rises and further declines in the industry (refer to Figure 21.1), primarily due to domestic factors such as:

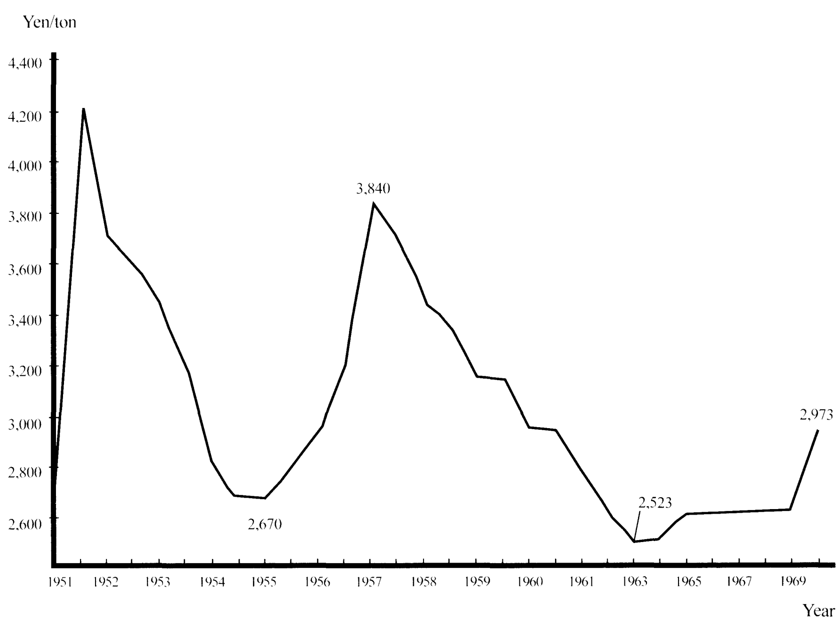
1 a 63-days miners' strike from October 1952
2 an extraordinary water shortage in the Autumn of 1956
3 a lockout at Mitsui Miike Coal Mine from January to October 1960
4 an extraordinary water shortage from January to March 1961
5 a large explosion at the Mitsui Miike Coal Mine in November 1963.

Around 1945, the merits of converting from oil to coal were frequently discussed in *Sekitan hyōron* (Coal review), a journal published by the Coal Association of Japan (Nihon sekitan kyōkai). The idea gradually began to filter through the industry, but no conversions had actually begun yet. From 1955, with an increasingly unstable supply and a continually rising cost of producing coal, energy consuming industries were urged to convert to fuel oil. Oil refining activities along the Pacific Ocean were reopened in 1949, and controls on the sales price and quantities of petroleum were lifted in July 1952. There was a trend toward removing the existing restrictions on converting to oil.[4]

Soon, however, new government regulations restricting fuel oil consumption were implemented in an effort to prevent the coal industry from collapsing. In 1955, two laws were enacted to this end: the Law on Extraordinary Measures for Rationalizing the Coal Mining Industry (Sekitan kōgyō gōrika rinji sochi hō) and the Law Concerning Temporary Measures to Restrict the Installation of Oil-fired Boilers (Jūyu boirā no sechi no seigen tō ni kansuru rinji sochi ni kansuru hōritsu). At the same time, customs excises of 2% and 6.5% were imposed on crude oil and fuel oil, respectively, and a new customs levy of 10% was introduced for light oil.

Around 1958, the repercussions of the decline in the coal industry were quite apparent, especially the economic devastation and high unemployment in the coalmining communities. The Liberal Democratic Party, the Socialist Party and the Democratic Socialist Party began, in 1958 or thereabout, to emphasize the need for 'policies that recognize coal as our primary energy resource and oil

Figure 21.1: Changes in unit price of coal in Kyūshū (Based on coal quality of 5,000 kcal/kg)



Source: *Kyūshū Denryoki Sanjūnen-shi* (Thirty-year history of Kyushi Electric Power), 1982, p. 65.

as secondary (tanshu yujū seisaku)'. However worthy their intentions, though, such a policy would be economically untenable unless manufacturing and chemical industries could procure coal at prices that remained internationally competitive with oil. The Japanese coal industry was by this time in such a mess that it could only sell coal at internationally competitive prices if it were propped up through government subsidies. The only effect of the government's efforts to protect the industry in the end, though, was to cushion the blow and delay the effects of the 'drastic change' that was being pushed by external forces. As Hiroshi Anzai of the Tokyo Gas Co. observed, 'The electric power companies are currently engaged in negotiations with the government about the price they can charge for electricity, and continue using coal only to avoid upsetting the government. It is probable that once the new price schedule has been agreed upon, they will quickly move towards using oil.' Although the electric power industry was initially rather slow (compared to the gas industry for example) to convert from coal to oil, the electric power companies swiftly converted later, just as Anzai had predicted.[5]

The Gas Companies

The energy revolution was far more beneficial to the gas supply industry than to anyone else. Table 21.2 presents comparative figures of the proportions of different raw materials (coal, oil and natural gas) that Tokyo Gas Co. used for manufacturing gas. Production of oil-based gas (LPG) began to increase in 1960 or so. The usage rate of city/town gas[6] was only 17% in 1953, and half of all households continued to use wood and charcoal for their cooking and heating fuel. Consumption of bottled LPG increased ten-fold in the late 1950s, jumping from 45,000 tons in 1956 to 441,000 tons in 1960. In 1961 bottled LPG was used in 4.12 million Japanese households, rapidly approaching the number of households (4.81 million) connected to the city/town gas systems. The increased use of gas reduced the burdens of domestic labor, such as cooking and heating bath water.[7]

In November 1952, Tokyo Gas Co. installed a pyrolytic oil gas producer at Senju Gasworks, and began producing gas from fuel oil. In April 1957, Tokyo Gas was the first Japanese gas company to receive a foreign currency allocation for importing crude oil, and began to produce gas from it. In mid 1960 crude oil became the only raw material used for producing gas. The last coke furnace facility built by Tokyo Gas was at Toyosu Gasworks in 1958. In 1960 Tokyo Gas imported 349,000 kiloliters of crude oil. This figure climbed to 528,000 kiloliters in 1962 and 659,000 kiloliters in 1965. This rapid growth was assisted by the installation of the pyrolytic oil gas producer and a customs duty exemption for crude oil.

At the same time, uses for the gas by-products of oil refineries and petrochemical plants – which traditionally had been disposed of by burning

Table 21.2: Changes of gas resources (Tokyo Gas)

	Coal based gas	Oil based gas	Natural gas
1955	85%	15%	0%
1964	38%	44%	18%
1965	33%	54%	13%

Based on p. 297 of *Tokyo Gasu hyakunen-shi* (One hundred year history of Tokyo Gas), 1986.

– were being developed. The by-products of petrochemical plants contained high levels of methane, while by-products of oil refineries contained high levels of hydrogen. In December 1959 Tokyo Gas signed a contract to purchase Nippon Petrochemical's gas by-products, beginning with 4.2 million m^3 in 1960. This increased ten-fold to 43.2 million m^3 in 1965 and by another twenty-fold to 800 million m^3 in 1972. The use of gas by-products contributed to reducing operating costs for the gas supply companies.

Before April 1961 naphtha was subject to customs duties under the volatile oil tax law and the local road tax, and was therefore too expensive as a raw material for producing city/town gas. With these duties lifted, however, Tokyo Gas began to purchase naphtha from Mitsubishi Oil Co. in December 1961. In 1966 Tokyo Gas used 260,000 kiloliters of naphtha. By 1975 this had almost tripled to 700,000 kiloliters. This sharp rise in the use of naphtha was due to several factors, including a declining price and the fact that gas-refining equipment was not required, reducing the capital investment required for a new production facility.[8]

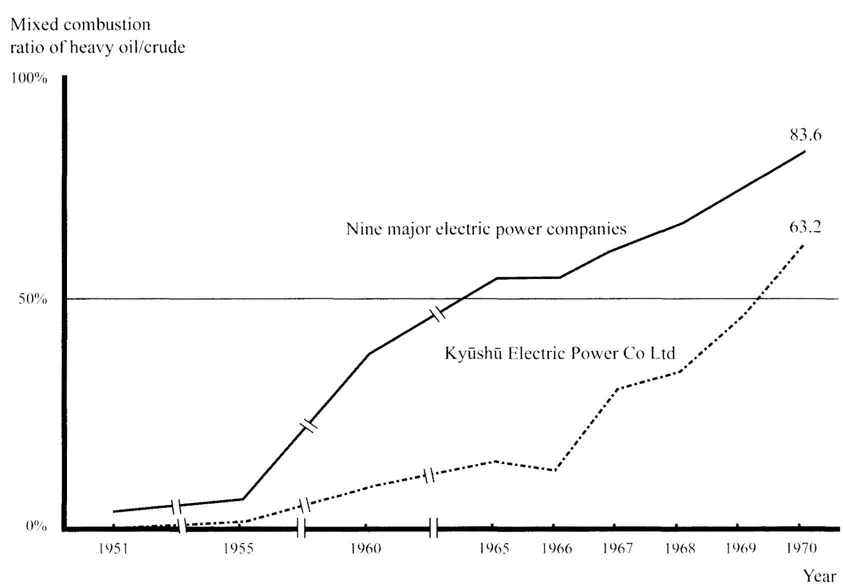
Osaka Gas Co. purchased four ONIAGEKI-type crude oil catalytic cracking gas plants (132,000m^3/day each) from H & G in England in February 1961. Osaka Gas also installed an ONIAGEKI plant at Kōbe Gasworks in January 1962, and another the following year. Subsequently, the company installed two CCR-type naphtha plants (developed by UGI in the US), the first in December 1963 and the second in January 1965. This naphtha reforming equipment with technical modifications by Osaka Gas (16,000 m^3/day each) was built at the Takasago Gasworks in January 1963, and subsequently four plants (60,000m^3/day each) at the Kyoto Gasworks, followed by four plants (220,000m^3/day each) at the Hokkō Gasworks. The use of gas made from oil increased from 9% (220,000m^3/day) in February 1956 to 49% (4,930,000m^3/day) of the total gas supply in the Kyoto-Osaka-Kobe area in February 1966.[9]

The Electric Power Industry

In 1951, only 20% of the electricity generated by the nine major electric power companies (kyū denryoku) was thermal power. (The remainder was hydroelectric.) Only about 20,000 kiloliters of fuel oil was consumed in thermal power generation that year, in contrast to 6.4 million tons of coal. Through the first half of the 1950s, the electric power companies consumed between 300,000 and 400,000 kiloliters of fuel oil per annum, doubling to 700,000 kiloliters in 1956 and reaching 5 million kiloliters in 1960. Fuel oil accounted for only 3% of the fuel consumption by the nine electric power companies in 1956, increasing to 36% in 1960. At Tokyo Electric Power Co., coal and oil consumption grew from 800,000 tons to 3.5 million tons (>4x), and from 20,000 kiloliters to 1.7 million kiloliters (85x), respectively from 1951 to 1960. As a result, the ratio of fuel oil used for power generation increased from 6% to 46%. Kyūshū Electric Power Co., which was located near the Chikuhō coalfield, had a relatively high rate of coal consumption; however, the consumption of fuel oil rapidly increased during the ten years from 1960.[10] (Refer to Figure 21.2)

Reforms to the 'Oil Boilers Control Law (Jūyu boirā kisei hō)', which had restricted the installation of new oil burning plant and equipment, are representative of the policy changes that reduced the government's protection for the coal industry. This reform and the decisions of the 23rd and 30th meetings of the government organized Electric Power Development Coordinating Council (Dengen kaihatsu chōsei shingikai) decided to allocate 2.68 million kiloliters to the usable fuel oil out of the total of 3.56 million kiloliters approved for newly constructed power stations. In May 1960, the construction of thermoelectric power plants designed to use fuel oil was approved. The number four facility of Mie Thermoelectric Power Plant of Chūbu Electric Power Co. became the

Figure 21.2: Changes of the mixed combustion ratio of heavy oil/crude oil



Source: Kyūshū Denryoku Sanjūnen-shi (Thirty-year history of Kyūshū Electric Power), 1982, p.69.

Table 21.3: Changes of fuel composition (unit: %)

year	Tokyo Electric Power					Nine major electric power companies					
	oil	heavy oil	crude oil	naphtha	LNG	oil	heavy oil	cude oil	naphtha	LNG	other gas
1961	56	44	–	–	–	59	41	–	–	–	–
1962	50	50	0	–	–	57	43	0	–	–	–
1963	55	44	1	–	–	58	40	2	–	–	0
1964	49	48	3	–	–	48	49	3	–	–	0
1965	40	56	4	–	–	46	51	3	–	–	0
1970	8	72	13	–	7	14	68	15	–	2	1
1973	0	51	35	4	10	4	53	36	3	3	1

Note: Where the distribution ratio is less than 0.5%, it is presented as 0%.
Source: Tokyo Denryoku Shashi Henshū Iinkai (The Editorial Committee to Record the Company History of the Tokyo Electric Power Co.) (ed.), *Tokyo Denryoku sanjūnen-shi* (The thirty year history of the Tokyo Electric Power Co.), Tokyo Denryoku (Tokyo Electric Power Co.), 1983, p. 624.

first plant to exclusively use fuel oil. Thereafter the use of fuel oil for electricity generation spread rapidly, soon becoming the main fuel in the industry. As Table 21.3 illustrates, fuel oil remained the principle fuel in the electricity industry even after the use of crude oil began in the early 1960s.[11]

The Steel Industry

The only steel manufacturing company in Japan that used both fuel oil and coal before WWII was NKK Corp (Nippon Kōkan). When the price of coal suddenly rose during the Korean War, NKK decided to install fuel oil furnaces to replace the existing open hearth furnaces at Tsurumi Steelworks. It was the first use of this particular type of fuel oil equipment in the steel manufacturing industry. Other steel companies which had previously used mixed gas furnaces with steam coal soon began to install the same type of fuel oil furnaces. NKK used 18,600 kiloliters of fuel oil in 1950, rising to 32,900 kiloliters in 1951. In contrast, the consumption of steam coal by the industry decreased sharply from 103,000 tons in 1951 to 61,000 tons in 1955 and 18,000 tons in 1960.[12]

Thus the Korean War was a turning-point in the steel manufacturing industry. As we have seen, after the Korean War there were a series of disruptions to coal supplies, which resulted in further conversions of steel furnaces from coal to fuel oil. From a different perspective, this process could be seen as having encouraged the accelerated use of an alternative resource, rather than making a complete volte-face in the patterns of resource usage. This trend also conformed with global trends in steel manufacturing technology.'[13]

Table 21.4 indicates that the consumption of fuel oil steadily increased in the steel industry from 1950 to 1957. Lignite was almost completely replaced and steam coal consumption fell by 30%. Even as the steelmakers turned

Table 21.4: Consumption of lignite, steam coal and heavy oil

	Lignite (1,000 tons)				Steam coal (1,000 tons)			Heavy oil (1,000 kiloliters)			
	open -hearth	rolling method	others	total	rolling method	others	total	open -hearth	rolling method	others	total
1950	691	264	187	1,142	280	1,043	1,323	195	56	6	257
1951	736	238	118	1,082	480	670	1,150	345	94	11	450
1952	436	224	196	856	225	985	1,210	429	153	41	623
1953	236	160	124	520	195	856	1,051	513	273	111	897
1954	93	80	86	259	131	929	1,060	506	316	143	965
1955	116	75	110	301	110	920	1,030	602	366	143	1,111
1956	98	70	123	291	108	839	947	722	455	195	1,372
1957	92	76	97	265	92	815	907	694	520	225	1,439

Source: Nihon Tekkō Renmei (Japan Iron and Steel Federation), *Sengo tekkō-shi* (History of iron and steel), 1959, p. 376

Table 21.5: Consumption of heavy oil for steel ingot

1956	92 liters/ton
1957	86 liters/ton
1958	55 liters/ton

Source: Nippon Kōkan Kabushiki Gaisha (Nippon Kokan Corp.), *Nippon Kōkan Kabushiki Gaisha gōjūnen-shi* (Fifty year history of Nippon Kokan Corp.), 1962, p. 910.

increasingly to fuel oil for their furnaces, they increasingly imported higher quality coking coal from the US and Australia, delivering a severe blow to the domestic coalmining industry.[14] To cite but one example, the ratio between imported coal and domestic coal at the Hirohata Iron Mill of Nippon Steel Co. (Shin Nihon Seitetsu Kabushiki Gaisha) was 43 to 57 in 1955, and 83 to 17 in 1965.[15] Subsequently, a mixed combustion of fuel oil and oxygen was introduced and the quantity of fuel oil used per steel ingot decreased (see Table 21.5).

The Ceramics Industries

Glass

The ceramics industries can be roughly divided into the glass and cement industries. Looking at the glass industry first: Asahi Glass Co. (Asahi Garasu) and Nippon Sheet Glass Co. (Nippon Ita Garasu) were the primary glass manufacturers during the immediate postwar period. GHQ/SCAP (General Headquarters of the Supreme Commander for the Allied Powers) recommended fuel oil for manufacturing window glass for schools. Following this advice, Asahi Garasu's Tsurumai Factory tested a fuel oil furnace in 1947. Nippon

Sheet Glass also researched fuel oil furnaces. Neither, however, installed such facilities until the coalminers' strikes from October to December 1952 interrupted coal supplies. Beginning in December 1952, each Nippon Sheet Glass factory installed equipment that burned either fuel oil or a mixture of producer gas and fuel oil. Nippon Sheet Glass's Maizuru Factory continued to use this mixed combustion method even after the coal situation improved. Nippon Sheet Glass Co.'s Wakamatsu and Yokkaichi Factories both adopted this method in mid 1953. The fuel oil burners were gradually improved, and technical problems such as local overheating were resolved. By 1958 fuel oil accounted for 70% of Nippon Sheet Glass's fuel supplies. After it was proven that the sulphur content of fuel oil C did not have any undesirable effects on the product,[16] Nippon Sheet Glass's Maizuru (mould furnace) Factory converted its plant to burn fuel oil C in April 1956. In November 1959, fuel oil C was adopted for use in the ordinary plate glass furnace at the Wakamatsu Factory in November 1959 and at the Yokkaichi Factory in April 1960. It is notable that the first of Nippon Sheet Glass's factories to convert was the mould

Table 21.6: Fuel consumption for manufacturing plate glass by Asahi Glass (Amagasaki Factory, Makiyama Factory and Tsurumi Factory) (unit: ton, kilo liter)

Year	Coal	Heavy oil
1947	77,872	2,131
1948	68,979	10,501
1949	100,448	9,448
1950	116,929	16,660
1951	126,865	15,987
1952	129,113	16,816
1953	113,386	26,177
1954	118,027	38,283
1955	119,847	35,829
1956	143,268	37,479
1957	165,136	49,778
1958	118,188	64,589
1959	34,161	119,092
1960	14,703	158,545
1961	14,827	174,874
1962	14,377	164,804
1963	12,147	192,152
1964	10,662	211,510
1965	8,955	208,575
1966	-	233,751

Source: Asahi Garasu Kabushiki Gaisha (Asahi Glass Co., Ltd.), *Sha-shi* (History of the company), 1967, p. 667.

factory, where the potentially undesirable effect of the sulphur content on the product appears to have been of less concern than the plate glass factories. In other words, only after the mould glass factory conversion proved satisfactory did the plate glass factories convert their fuel sources. The *Fifty Year History of Nippon Sheet Glass* (Nihon Ita Garasu Kabushiki Gaisha gojūnen-shi) explains that 'since fuel oil furnaces offered reduced fuel and labor costs as well as greater productivity from our facilities, the company examined various technical aspects thoroughly in order to make the fuel oil furnaces successful'. In the early 1960s, however, butane began to be used with a special burner that overcame the need for a mixture of refined gas and butane in a plate glass furnace. This new development made the gas generator at Maizuru Factory completely redundant in June 1962, at the Wakamatsu Factory in September 1962 and at Yokkaichi Factory in September 1963.[17] We should note that the research that enabled the use of fuel oil also resolved various technical difficulties and led to its replacement by butane gas.

According to Asahi's *Business History* (Sha-shi), the fuel used for manufacturing both mould and plate glass changed from LSB fuel oil (low sulfur fuel oil B) to LSC fuel oil (low sulfur fuel oil C). When they discovered that HSC fuel oil (high sulfur fuel oil C) was more profitable, the company turned to this lower priced fuel. Like Nippon Sheet Glass, Asahi began converting its mould factories from 1960 and their ordinary plate glass manufacturing facilities from 1965. Thus, after 1966 Asahi did not use coal at all.[18] (cf. Table 21.6 for the overall trend from coal to fuel oil at Asahi Glass.)

Cement

Ube Industries (Ube Kōsan) began to use fuel oil in their calcinations process in December 1951.[19] Onoda Cement Co. and Banjo Cement Co. soon followed suit. However Nihon Cement's *Hyakunen-shi* (One hundred year business history) observed that

> Following the enactment of the Fuel Oil Consumption Control Law (Jūyu shōhi kisei ho) in 1955 and the Suez Crisis in 1956, fuel oil was in short supply, and the price was slightly higher than coal. The trend of converting from coal to fuel oil was temporarily suspended. Subsequently, however, as the demand for cement rose with the growing economy after 1960, the need for fuel to produce this cement rose accordingly. At the same time, the price of fuel oil began to fall, and the industry rapidly converted from coal to fuel oil.[20]

In the 1960s Nihon Cement changed from coal to fuel oil at various factories in the Tokyo, Osaka and Shikoku areas, where the price of coal was expensive. Chichibu Cement Co. changed from coal to fuel oil at Kumagaya Factory in 1952. The company's *Fifty Year Business History* in 1974 noted the great impact of this change on the industry, calling it 'a great achievement in terms of simplifying processes, safety, reducing fuel costs, reducing electric power consumption, etc.'[21] Other advantages of the conversion from coal to fuel oil, as we have seen, included the higher calorie content and greater ease of handling liquid fuels.

Table 21.7 indicates the growth in the consumption of fuel oil C in the cement industry from 1956–62. During this period the price of bulk fuel oil C fell sharply, from 8,200 yen/kiloliter at the end of 1960 to 6,600 yen at the end of 1961 and 6,300 yen in the first half of 1962.[22]

Table 21.8 traces Onoda Cement's steadily increasing conversion from coal to fuel oil from 1961–65, by which time oil had completely supplanted coal as fuel. This might be explained by a 30% drop in the price of fuel oil from 1957 to 1960, while the price of coal only decreased by 15–20%.[23]

The price of fuel oil remained stable until the oil crisis of 1973 (in 1968 it was about 6,000 yen/kiloliter). However in 1980, one year after the second oil crisis, the price of fuel oil jumped again – this time from 17,000 to 50,000 yen per kiloliter. This set off a reverse trend in the cement industry, as companies

Table 21.7: Growth in the consumption of C fuel oil (cement) (unit: kiloliter)

	1956	**1957**	**1958**	**1959**	**1960**	**1961**	**1962**
C fuel oil	59,712	137,259	175,649	218,664	420,703	856,422	1,671,034
Index		100	128	159	306	624	1217
As compared with previous year		230	128	124	192	204	195

Note: C fuel oil is used for calcination and drying.
Source: Nihon Semento Kabushiki Gaisha (Nihon Cement Co., Ltd.), *Hachijūnen-shi* (History of eighty years), 1963, p. 130.

Table 21.8: Conversion of fuel by Onoda Cement

	Period	**Coal** (1,000 tons)	**Heavy oil** (1000 kiloliters)	**Consumption rate of heavyoil** (%)
1961	Second half of the year	312	85	30.1
1962	First half of the year	213	157	53.8
1962	Second half of the year	162	209	67.0
1963	First half of the year	100	243	79.0
1963	Second half of the year	93	278	82.5
1964	First half of the year	8	309	98.3
1964	Second half of the year	0	299	100.0

Note: Calculated based on heavy oil: 9800 kcal/l and 6200 kcal/kg.

Source: *Onoda Semento hyakunen-shi* (One hundred year history of Onoda Cement), 1981, p. 580.

began to convert their production plants from fuel oil back to coal.[24] As we have seen, cement companies converted their plant and equipment from coal to fuel oil to take advantage of potential cost savings, a motivation that saw wholesale changes from coal to fuel oil in the early 1960s but also a reverse conversion from fuel oil back to coal after the second oil crisis.

The Chemical Industry

The Japanese experienced severe food shortages in the immediate aftermath of WWII, suffering from a drought even whilst their infrastructure was being destroyed by Allied bombardment. Increasing agricultural production, and therefore fertilizer production, was a high priority for the Japanese government and the occupying Allied Powers (cf. chapters 19 and 26). The existing fertilizer manufacturers responded quickly to this demand, aided by their 'priority production' status. The Ministry of Agriculture, the Manufacturing Association of Ammonium Sulfate Fertilizer (Ryūan Hiryō Seizōgyō Kumiai) and the fertilizer manufacturers met on 1 September 1945 at the Imperial Hotel to discuss the production of ammonium sulfate and lime nitrogen. This was followed by a second 'informal meeting' between government officials and representatives of the private sector. The corporations attending these meetings included: Nippon Chisso, Mitsubishi Kasei, Nissan Chemical, Nittō Chemical, Japan Iron and Steel, Tōyō Kōatsu, Ube Industries, Nicchitsu Chemical, Shōwa Denkō, Sumitomo Chemical, Sumitomo Taki Chemical, Tōa Gōsei and Tōhoku Hiryō.

We should note that these companies diversified their fertilizer manufacturing businesses into the chemical industry and enjoyed tremendous growth during Japan's economic boom in the late 1950s and beyond. Our focus, however, is on the impact of the energy revolution on fertilizer manufacturing.

Ammonium sulfate ($(NH_4)_2SO_4$) is synthesized from the reaction with ammonia (NH_3) and sulfuric acid (H_2SO_4). The primary energy concern of the fertilizer industry was how to procure cheap hydrogen (H), because about 70% of the cost of producing ammonia is incurred in the production of hydrogen. Needless to say, if the newly available and increasingly inexpensive liquid fuels (crude oil and natural gas) could provide hydrogen cheaper than it could be extracted from coal, the energy revolution would sweep through the fertilizer industry too.

With support from the priority production system, the fertilizer industry quickly revived, increasing the output of fertilizer every year. By fiscal year 1949, production exceeded 1.18 million tons, marking the point of recovery to the 1941 level. The Korean War broke out on 25 July 1950, and consequently, the export price of fertilizer rose suddenly. The export price to the South East Asian market hit $60/ton. In this favorable environment, fertilizer manufacturers accelerated investments in their facilities. The capacity to produce ammonite increased from 1.87 million tons in April 1950 to 2.29 million tons in April 1951 to 2.65 million tons in April 1952. Fertilizer exports were 188,000 tons in 1950. When they suddenly rose to 503,000 tons in 1952, fertilizer produced for the domestic market was used for exports. When the domestic price of fertilizer began to decrease after a peak in February 1952, each manufacturer actively sought to expand their export activities. However, to compete with the Western nations who also exported fertilizer to the Asian market, Japanese manufacturers had to sell their fertilizer at a price below the domestic price. This became a political issue, when farmers' organizations complained that 'because of sacrifice exports, domestic farmers are forced to purchase comparatively expensive fertilizer'.[25]

As political pressure continued to mount, the government established the Fertilizer Measures Committee (Hiryō taisaku iinkai) on 17 January 1953, and introduced the so-called 'two measures regarding fertilizer (hiryō ni hōan)': the 'Temporary Law for the Stabilization of Ammonium Sulfate Supply and Demand (Rinji ryūan jukyū antei hō)' and the 'Temporary Measures for the Rationalization of the Ammonium Sulfate Industry and the Export Coordination Law (Ryūan kōkyō gōrika oyobi ryūan yushutsu chōsei rinji sochi hō)' at the end of May 1953. The effect of these measures was that Japan Ammonium Sulfate Export (Nihon Ryūan Yushutsu Kabushiki Gaisha) was established, and ammonium sulfate exports were restricted. For the next ten years the government determined the domestic price of ammonium sulfate and the manufacturers had no discretionary power over the price of these products.[26]

In response to these temporary measures, the Japanese Association of the Ammonium Sulfate Industry (Nihon Ryūan Kōgyō Kyōkai) submitted a five-year rationalization plan to the Ministry of International Trade and Industry (MITI), proposing that it be effective from the beginning of fiscal year 1953. MITI responded with a 'Five-Year Plan to Rationalize the Ammonium Sulfate Industry (Ryūan kōgyō gōrika gokanen keikaku) [the First Rationalization Plan (Dai ichiji gōrika keikaku)], which was announced as official policy in August 1953.

The key points of this plan were: changing raw materials for producing ammonium from coal to gas; expanding the production of urea fertilizer; and upgrading facilities by replacing outdated equipment. The plan also included targets to increase the production of ammonium sulfate by 30%. MITI estimated that this would reduce production costs by 24%, which would finally achieve the international production cost of $50/ton.[27]

To realize these goals, the manufacturers invested 77.3 billion dollars, twice as much as they had initially budgeted. The capacity to produce ammonium sulfate reached 4.575 million tons, an increase of only 21%, and the production cost never fell below $50/ton.

Another objective of the plan that remained unrealized was to ensure there was no increase in the need to import fertilizer. But one of the basic assumptions of the plan – that the international market price would remain around $50/ton – was incorrect. To make matters worse, from around 1957, the international price of fertilizer began to decline, and remained about ten dollars or so cheaper than the domestic price of $55/ton.

Unfortunately, due to the Nagasaki flag incident in May 1958,[28] relations between Japan and China took a turn for the worse, and fertilizer exports to China ceased.[29] The 'two measures regarding fertilizer' and their tight regulatory regime were extended for five years in 1959. According to the First Rationalization Plan, production costs were expected to fall to $47/ton by fiscal year 1963 by changing the types of fuels and fertilizers in use. However due to a significant decline in the international price of fertilizer, the amendment of the first plan became unavoidable, so a Second Rationalization Plan (Dai niji gōrika keikaku) was introduced. The Ministers of Finance, International Trade and Industry, Agriculture and the Economic Planning Agency agreed to the Second Rationalization Plan. It became effective from September 1961.[30]

In short, the aim of this revised rationalization plan was to improve manufacturing processes by adopting more efficient and cost effective fuels, thereby retaining the total existing capacity for producing ammonia by using newer and more efficient processes and facilities. The primary objective of this plan was to begin to use crude oil gas as the raw material for ammonium production. The plan stipulated that 13 factories should be converted to use crude oil gas, three to use natural gas, five to use COG (a gas by-product of burning coking coal), five to use petrochemical gas by-products, and two factories to use other materials. Rapid progress was made to this end: crude oil gas use increased from 7.3% to 37.8% of total production and natural gas from 8.2% to 19.6%, between April 1958 and April 1962. In the next few years, however, crude oil gas was gradually replaced with naphtha due to problems in the catalyst and the manufacturing costs of oxygen.[31]

From 1965, the export price of fertilizer continually increased as the worldwide consumption of fertilizer grew. Activities in the Japanese fertilizer industry continued to grow along with this growing demand. As things picked up, the regulations controlling fertilizer manufacture and distribution were relaxed, and the fertilizer industry became a cherished export industry. To increase international competitiveness, small facilities were abandoned, and newly developed equipment was adopted. Under these conditions, the epoch-making naphtha steam reforming method developed by the English company ICI for producing ammonia NH_3 was most welcome. Tōyō Kōatsu used butane as a raw material, while Sumitomo Chemical, Ube Industries, Shōwa Denkō and Nissan Chemical used naphtha. With their new facilities, fertilizer manufacturing plants were soon operating at their maximum capacity of 500 tons per day.

Gas from crude oil, which had dominated the industry until about 1963, declined from 42.4% to 25.3% of total fuel consumption while the use of the ICI method increased to 41.4%. In the chemical industry, as elsewhere, we find that the manufacturers' motivations to convert fuel and raw material resources were strongly cost conscious.[32] Having outlined the background to the fertilizer industry's responses to the energy revolution, we will now examine some specific manufacturers.

Japan Gas Chemical Company and the Natural Gas Boom

Japan Gas Chemical Co. (JGC: Nihon Gasu Kagaku Kōgyō) was established by Vice-Admiral Ryūichirō Enomoto and a former navy technician named Takashi Eguchi. They initially manufactured methanol from water-soluble natural gas produced in Nīgata, beginning in September 1952.[33] Enomoto obtained a loan from a reconstruction finance bank, and purchased an unused factory in Enoki from Tōyō Gosei Co. He also reused a high-pressure reaction chamber installed at an ex-navy fuel depot and the equipment and materials used by Hokkaidō Jinzō Sekiyu. JGC made every effort to acquire equipment and parts that had been designated for war reparations, and acquired other goods from second-hand equipment dealers. JGC's manufacturing operations were expanded from methanol to formalin, and plans were developed to begin manufacturing ammonite. In April 1955 the company signed a provisional contract with Chemical Construction Corporation (Chemico) in the US to import the latest technology for synthesizing ammonia, urea, and ammonium sulfate, etc. The formal contract was concluded in August that year.[34] This imported technology was revolutionary, disintegrating natural gas such that the entirety of the ammonia produced was converted to urea. The *Nihon Gasu Kagaku Kōgyō sōgyō jūgonen-shi* (Fifteen year business history of Japan Gas Chemicals) estimated that through this new process ammonia was produced at two-thirds the cost of the superseded methods. The monthly output of JGC had reached 6,000 tons of ammonia, 4,800 tons of urea and 12,000 tons of ammonium sulfate by the end of March 1959. Subsequently, output continued to grow at a tremendous rate, with ammonia production reaching 8,300 tons per month by October 1960. As of the end of April 1966, the monthly production of ammonia, urea and ammonium sulfate were 12,500 tons, 8,900 tons and 15,300 tons, respectively.[35]

In the wake of JGC's success, other companies, such as Tōyō Kōatsu, Tōhoku Hiryō, Nippon Suiso Kōgyō, Teikoku Oil, Sumitomo Chemical and Nissan Chemical began planning to adopt natural gas as a raw material for manufacturing fertilizers, sparking a natural gas boom in the fertilizer industry.[36] However, since domestic sources of natural gas were limited, these manufacturers, with the exception of JGC, were forced to look for new material resources such as crude oil, naphtha, LPG and LNG.

JGC initially purchased natural gas from Teikoku Oil. However, difficulties soon arose in their price negotiations. Enomoto, therefore began to seek alternative supply sources, acquiring 26,400m^2 of mining areas on the Kita Kanbara Plain, and underwater mining rights along the continental shelf.[37] These acquisitions offered a potentially bright future for the company, but such undertakings did not always proceed smoothly. For example, land subsidence began to occur in 1958 in Nīgata City, and water gas full of CH_4 was adversely affected. JGC therefore stopped extracting gas from underground water supplies. Fortunately, a large quantity of structural gas full of CH_4 was discovered, and the business prospered more than ever.[38] The success of JGC thus had as much to do with their advantage in materials resources as with the excellence of the former navy technicians they employed.

JGC eventually acquired an Alaskan natural gas field, and tried to construct a CH_4OH factory in Saudi Arabia. The company's farseeing capabilities were rewarded during the oil crises of the 1970s.

Nissan Chemical Industries: Fuel Oil Gasification using the Fouser Method

Nissan Chemical Industries (NCI) entered into a contract with the Italian company Montecatini on 27 August 1953 to import the Fouser technology for fuel oil gasification. The project was approved by the Foreign Currency Council (Gaishi shingikai) in November that year and full-scale operations began in September 1955. NCI was the first company in Japan to use fuel oil as a raw material for producing ammonia gas.[39] The production capacities at NCI's Toyama Factory in April 1954 had been 117,900 tons of ammonia per annum via the Winkler method (where hydrogen was obtained from coal) and 119,600 tons from electrolysis (where hydrogen is extracted from water) for a total productive capacity of 237,500 tons. By 1 April 1958, after the introduction of the new Fouser technology, they were producing 95,800 tons by the Winkler method, 135,700 tons by electrolysis and 64,200 tons using the new Fouser technology, bringing the total capacity to 295,700 tons.[40]

The Oil Boilers Control Law (Jūyu boirā kisei hō) that we mentioned earlier also imposed restrictions on NCI's operations, limiting the extent to which they could replace coal with fuel oil. After 1958, when crude oil became relatively cheaper than fuel oil, NCI turned increasingly towards this resource. In this move, as in the move to fuel oil in the first place, NCI lead the fertilizer industry in converting from solid to liquid raw materials.

NCI entered a technical assistance agreement with Sanyō Chemical in 1955. Moreover, as the sole Japanese agent for Montecatini, NCI entered into a technical agreement with Tokai Ammonium Sulfate Industries (Tōkai Ryūan Kōgyō) on 1 March 1955.[41] Another notable event was Shin Nippon Chisso Fertilizer Co.'s conversion from electrolyzing water to fuel oil with the Fouser method in 1957 at Minamata.

Nippon Suiso Kōgyō: Using Powdered Coal with the Koppers Method

Nippon Suiso Kōgyō (NSK) was heavily reliant upon coal from the nearby Jōban coalfield which, as we have seen, supplied inferior quality coal with poor calorie content. In an effort to improve the performance of this coal, NSK imported powdered coal gasification technology from Koppers of West Germany. This process was first used in Finland in June 1952, and NSK was only the second factory in the world to trial it.[42] The trials were reviewed one year later in the *Nenryō Kyōkai-shi* (Bulletin of the Fuel Association), which reported that 'in general, the gasification of powdered low-grade coal inexpensively produces large quantities of gas, and is therefore the best method Japanese industries could adopt. The gasification of fuel oil was merely a transient phenomenon while the gasification process for coal was developed.'[43] In other words, the authors expected that companies would increasingly return to using coal as this gasification process was refined and proven.

However, the *Gojūnen-shi* (Fifty year history) of Nihon Kasei Co. (Nihon kasei kabushiki kaisha – the successor to NSK)[44] explained that following a sudden rise in the price of coal from the Jōban coalfield, NSK's coal business did not yield satisfactory returns, and the company was forced to suspend dividends in 1957. It was well known that the coal produced from Jōban had a high fusing point, the cinder flow was not good, and time had to be spent for the improvement of the furnace. They soon also discovered that it was costly to make solid coal into powdered coal.[45] As a result of this, NSK tried to use natural gas, as well as crude oil gasification with the Fouser method.

Table 21.9: Conversion of gas resources of Nippon Suiso Kōgyō (Hitachi Kasei)

Year	Process	Gas resources	Notes
1940	Fiarg	coal (Jōban coal)	unsuccessful, conversion to coke
1947	Fiarg (aqueous, semi-aqueous)	coke	
1954	Koppers	coal (Jōban coal)	
1957	Koppers (adoption of natural gas)	coal (Jōban coal) natural gas	
1960	modified Koppers (crude oil conversion)	crude oil	for ammonia
1960	Fouser method	natural gas	for methanol
1965	Fouser method (crude oil suspended)	COG	for ammonia
1970	Topsoe method (naphtha conversion)	naphtha	for ammonia

Source: Hitachi Kasei Kabushiki Gaisha, *Gojūnen-shi* (Fifty-year history), 1987, p. 100.

Magazines related to technology indicated that Japanese corporations turned their attention to the Koppers method. However, the oil gasification method attracted the attention of the industry one year later and proved to be more effective. The early commercializers thus ended up failing to reap the fruits of their endeavors.

NSK's experience with attempting to retain its traditional raw material resource in the face of the energy revolution is informative. Their efforts to import cutting-edge technology in order to make their poor coal supplies more efficient ultimately ended in failure. Interestingly, NSK had experienced difficulty in finding financing for this project, perhaps because they were going against the current of the times. In hindsight, though, it appears that those who rejected their applications were correct – the technology they selected showed a clear lack of foresight (refer to Table 21.9). In contrast to JGC, NSK's management had little experience of failures of such magnitude, and the sudden decline in the natural gas supply severely affected them.

Beppu Chemical Industries and Ube Industries: Importing Crude Oil

Beppu Chemical Industries (BCI: Beppu Kagaku Kōgyō) was, by 1958, synthesizing urea using the Fouser-style semi-cycle method. They also adopted the Texaco-style compression gasification method. The latter method had already become well established in Japan since it employed natural gas that, unlike coal, was not restricted to particular locations. However when BCI adopted the Texaco method, they were aiming to use crude oil as a cheap resource instead of natural gas, and Texaco had little experience using either heavy or crude oil.

BCI therefore consulted with Chemico and Texaco. According to Fumitada Matsumoto, head of the technology department at BCI, the company began to investigate the Texaco-style oil compression gasification furnace in late 1955. BCI signed a technical cooperation agreement with Chemico and received drafts of the design in May 1956. Shortly thereafter, Matsumoto and his team visited America, where they held further discussions with Chemico. Upon completing their business in the US, they visited Montecatini in Italy for discussions about ammonia synthesis equipment, then returned to Japan in late October 1956. Then, BCI started to build a new ammonia manufacturing factory with an annual capacity of 33,000 tons of ammonia.[46]

Among the many companies that adopted crude oil as a raw material, Ube Industries (Ube Kōsan) stands out as indicative of the depth and breadth of the impact that the energy revolution had on Japanese industries and communities. Ube is a coal mining town built over the Ube coalfields, and Ube Industries had traditionally consumed the local coal in its manufacturing processes. However, with changes in the coal mining industry and global improvements in petroleum supplies and prices, some time in 1958 Ube Industries began to contemplate converting to crude oil. A team was sent overseas to meet with companies about potential technical cooperation agreements. They entered into provisional contracts with Texaco for crude oil degradation equipment, Montecatini for synthetic ammonia processing and Chemico for engineering related projects such as gas refinery equipment. Application was made for the government's approval of these arrangements in October 1958 (in accordance with the Foreign Capital Law (Gaishi hō)) and approval was granted in April 1959.

Since Ube Industries was receiving subsidies from the government's funding for rationalizing the coal industry, though, MITI's Coal Mine Bureau had objected to the applications. Fortunately for the company, MITI's Light Industries Bureau was in favor of the project and supported their applications. The factory was completed in January 1960. Subsequently, Ube Industries actively and steadily converted from coal-based gas resources to crude oil until finally shutting down the coal gas furnace for the last time in 1962. Shutting down the coal furnace in a coalmining town in favor of crude oil is a symbolic event in the history of the energy revolution. Ube Industries again converted from crude oil to naphtha in the second half of the 1960s.

Without these adventurous undertakings and the wise decision making of Kan'ichi Nakayasu, the president of Ube Industries, the company would have been weakened by its dependence on coal as the coal situation deteriorated and its later success would not have happened. A comparison of Ube Industries' success and NSK's failure, both organizations located near poor-quality coalfields, was used as a textbook example in business management training for many years.

Other projects that successfully reduced fuel costs included the introduction of the COG method in the iron and steel industry and the use of petrochemical gas by-products by Shōwa Denkō (Chemical Company) and Nippon Sekiyu Kagaku (Oil Refinery Company).

New Naphtha Technology from ICI Sparks a New Wave of Material Conversions

The English company ICI, in a joint effort with the American Kellogg Corporation, developed a process for mass producing ammonia using a naphtha compression steam reformer and a low pressure centrifugal machine. Theoretically, this groundbreaking technology could produce 2,000 tons of ammonia per day from a single factory, and many Japanese fertilizer manufacturers – including Nissan Kagaku, Tōyō Kōatsu, Ube Industries, Shōwa Denkō, Mitsubishi Kasei, Nihon Gasu Kagaku and Sumitomo Chemical – were planning to expand their operations, following a global trend towards larger-scale mass production. The Japanese Ammonium Sulfate Industry Association played a role in coordinating the manufacturers' applications to the government to expand their fertilizer manufacturing operations, and turned to MITI for administrative guidance to ensure they did not build so many plants as to make them unprofitable. Between 1965 and 1968, numerous large-scale ammonia production facilities were built and commissioned. However, it took each company more than six months after construction was completed to commission their facilities and commence operations, indicating a variety of difficulties that were experienced during the commissioning process. The price of ammonia-based fertilizer exported to the Chinese market fell sharply again in 1967. Consequently, MITI encouraged each company to construct much larger facilities. Once ICI's technology was adopted, the other manufacturing methods rapidly disappeared[47] and naphtha became a primary raw material.

Bibliographic Guide

Note: I have avoided duplicating the references to the coal industry documents already cited by Gotō in chapter 20 of this volume.

[1] Hiromi Arisawa (ed.), *Gendai Nihon sangyō kōza IV: Kagaku kōgyō* (Series on modern industry of Japan IV: Chemical industry), Iwanami Shoten, 1959.

[2] Tsūshō Sangyō-shō Kōzan-kyoku Sekiyu-ka (Bureau of Mines, Petroleum Division, Ministry of International Trade and Industry) (ed.), *Sekiyu sangyō no genjō* (Present situation of the oil industry), Sekiyu Tsūshin-sha, 1962.

[3] R. Guglielmo, *Sekai no sekiyu kagaku* (Petrochemistry of the world), translated by Okada, Hakusui-sha, 1963.

[4] Nihon Ryūan Kōgyō Kyōkai (Japanese Association of the Ammonium Sulfate Industry), *Nihon ryūan kōgyō-shi* (History of Japan's ammonium sulfate industry), not for sale, 1968.

[5] Haruo Suzuki, *Kagaku sangyō-ron* (On the chemical industry), Tōyō Keizai Shinpō-sha, 1968.

[6] Tokuji Watanabe, et al. (eds), *Sengo Nihon kagaku kōgyō-shi* (History of the chemical industry in postwar Japan), Kagaku Kōgyō Nippō-sha, 1973.

[7] H. J. Bard and K. Weissermel, *Kōgyō yūki kagaku* (Industrial organic chemistry), translated by Hiroshi Terada, Tokyo Kagaku Dōjin, 1978.

[8] Toraji Imai, Hisataka Satō and Yoshiharu Ozaki, *Gendai kagaku kōgyō* (Modern industrial chemistry), Sankyō Shuppan, 1980.

[9] TakashiĪjima, *Nihon no kagaku gijutsu: Kigyō-shi ni miru sono kōzō* (Science and technology of Japan: Its structure analyzed from the perspective of corporate history), Kōgyō Chōsa-kai, 1981. This contains a bibliography of corporate histories.

[10] Katsumi Shimono, *Sengo Nihon sekitan kagaku kōgyō-shi* (History of the coal chemical industry in postwar Japan), Ochanomizu Shobō, 1987. This contains a detailed list of references.

[11] Yoshitarō Wakimura, *Chūtō no sekiyu* (Oil in the Middle East), Iwanami Shoten, 1957.

[12] Toshirō Kuroiwa, *Nihon shigen-ron* (On the resources of Japan), Tōyō Keizai Shinpō-sha, 1972.

[13] Nihon Chōki Shinyō Ginkō Sangyō Kenkyūjo (Long-Term Credit Banks of Japan Industrial Research Institute), *Shuyō sangyō sengo nijūgonen-shi* (Twenty-five year history of main industries in the postwar period), Sangyō to Keizai, 1972.

[14] Tsūsan Shiryō Chōsa-kai (Research Association of Trade and Industry Data), *Shiryō enerugī nenkan* (Yearbook of energy data), 1976.

[15] Takahide Nakamura, *Nihon keizai: Sono seichō to kōzō* (Japanese economy: Growth and structure), Tokyo Daigaku Shuppan-kai (University of Tokyo Press), 1978.

[16] Nihon Sekiyu (Nippon Oil Co.), *Nihon Sekiyu hyakunen-shi* (One hundred year history of Nippon Oil), 1988.
[17] Shigeru Suzuki, *Nihon no enerugī kaihatsu seisaku* (Policies of the energy development of Japan), Minerva Shobō, 1985.
[18] Shin'ichi Yonekawa, Kōichi Shimokawa and Hiroaki Yamazaki (eds), *Sengo Nihon keiei-shi* (History of management in postwar Japan), vols 1–3, Tōyō Keizai Shinpōsha, 1990.
[19] Tsūshō Sangyō-shō (Ministry of International Trade and Industry) (ed.), *Tsūshō sangyō seisaku-shi* (History of policies of international trade and industry), vol. 3, Tsushō Sangyō Chōsa-kai, 1992.
[20] Laura E. Hein, *Fueling Growth: The Energy Revolution and Economic Policy in Postwar Japan*, Harvard University Press, 1990.
[21] Nippon Tekkō Renmei (Japan Iron and Steel Federation), *Sengo tekkō-shi* (History of iron and steel in the postwar period), 1959.
[22] Nihon Semento Kabushiki Gaisha (Nihon Cement Co.), *Hachijūnen-shi* (Eighty year history), not for sale, 1963.
[23] Chichibu Semento Kabushiki Gaisha (Chichibu Cement Co.), *Chichibu Semento gojūnen-shi* (Fifty year history of Chichibu Cement), not for sale, 1974.
[24] Nihon Gasu Kagaku Kōgyō Kabushiki Gaisha (Japan Gas Chemicals Co.), *Nihon Gasu Kagaku Kōgyō sōgyō jūgonen-shi* (Fifteen year history of Japan Gas Chemicals), not for sale, 1966.
[25] Ryūichirō Enomoto, *Kaisō hachijūnen* (Recollection of eighty years), Hara Shobō, 1976.
[26] Sumitomo Kagaku Kōgyō Kabushiki Gaisha (Sumitomo Chemical Industries Co.), *Sumitomo Kagaku Kōgyō Kabushiki Gaisha-shi* (History of Sumitomo Chemical Industries Co.), not for sale, 1981.
[27] Nissan Kagaku Kōgyō Kabushiki Gaisha (Nissan Chemical Industries Co.), *Hachijūnen-shi* (Eighty year history), not for sale, 1969.
[28] Nihon Kasei Kabushiki Gaisha (Nihon Kasei Co.), *Gojūnen-shi* (Fifty year history), not for sale, 1987.
[29] Hideo Takeuchi, Mataji Takakura and Noboru Ueno, *Hinata mokutan keizai-shi* (Economic history of Hyūga Charcoal), limited circulation, 1965.

Notes

1 Takeo Takamatsu, *Sekai no genyu jijō to waga kuni kaihatsu yunyū* (World situation of crude oil and imports for developing our nation), Kaigai Keizai Kyōryoku Kikin Chōsa-bu (Inquiry Section of The Overseas Economic Cooperation Fund, Research data 82), 1970, p. 172.
2 Sangyō Keikaku Kaigi (Industrial Planning Council), *Sangyō Keikaku Kaigi kenkyū hōkoku* (Reports of the Industrial Planning Council), vol. 5, Jitsugyō no Nihon Sha, 1961, pp. 40–1.
3 Toshifumi Yada, *Sengo Nihon no sekitan sangyō: Sono hōkai to shigen no hōki* (The coal industry after the war: Its collapse and the abandonment of resources), Shinhyōron, 1975, p. 136.
4 Tōa Nenryō Kōgyō Kabushiki Gaisha (Tōa Nenryō Industries Co.), *Tōnen sanjūnen-shi* (Thirty year history of Tōnen), vol. 1 [not for sale], 1971, pp. 236 and 397. Their conversion to fuel oil progressed from the latter part of 1951 (p. 376).
5 Hiroshi Anzai, 'Gasu kōgyō no mitōshi (Prospects of the gas industry), *Nenryō Kyōkai-shi* (Bulletin of the Fuel Association), vol. 40, no. 408, 1951, pp. 447–51.
6 City/town gas refers to natural gas supplied by pipeline into homes and businesses.

7 Though the period covered in the article is different, Fumio Makino wrote the excellent article on domestic energy found in 'Katei enerugī no shakai keizai-shi (Socio-economic history of domestic energy)', in *Tokyo Gakugei Daigaku kiyō dai-3 bumon shakai kagaku* (Bulletin of Tokyo Gakugei University, the third section, social sciences), vol. 43, January 1992, pp. 33–79.

8 Tokyo Gasu Kabushiki Gaisha (Tokyo Gas Co.), *Tokyo Gasu hyakunen-shi* (One hundred year history of Tokyo Gas), not for sale, 1986, pp. 291–308; Nihon Gasu Kyōkai (The Japan Gas Association, ed.), *Nihon Gasu Kyōkai-shi* (History of the Japan Gas Association), 1976; Gōdō Gasu Kabushiki Gaisha (Gōdō Gas Co.), *Gōdō Gasu yonjūnen-shi* (Forty year history of Godo Gas), 1970.

For details of Tokyo Gas's furnace, refer to 'Tokyo Gasu shiki sesshoku abura gasu hassei sōchi (Pyrolytic oil gas producer of the Tokyo Gas method)', in *Nenryō Kyōkai-shi* (Journal of the Fuel Society of Japan), vol. 39, no. 398, 1960, pp. 448–53.

For detailed information about CNG, see Kazuo Yamada, 'ICI nafusa rifōmingu (ICI naphtha reforming)', in *Nenryō Kyōkai-shi* (Journal of the Fuel Society of Japan), vol. 44, no. 453, 1964, pp. 37–45. Yamada was an employee of Mitsubishi Kakōki (Mitsubishi Kakōki Kaisha).

9 Osaka Gasu Kabushiki Gaisha (Osaka Gas Co.), *Asu e moeru: Osaka Gasu hachijūnen* (Burning for the future: Eighty years of Osaka Gas), not for sale, 1986, pp. 78–9, 92–3, 176–7; Osaka Gasu Kabushiki Gaisha, *Osaka Gasu saikin no jūnen* (The last ten years of Osaka Gas), not for sale, 1966, pp. 130–45.

10 Kyūshū Denryoku Kabushiki Gaisha (Kyūshū Electric Power Co.), *Kyūshū Denryoku sanjūnen-shi* (Thirty year history of Kyushu Electric Power), not for sale, 1982, pp. 65–9.

11 Tokyo Denryoku Shashi Henshū Iinkai (The Editorial Committee to Record the Company History of the Tokyo Electric Power Co.) (ed.), *Tokyo Denryoku sanjūnen-shi* (The thirty year history of the Tokyo Electric Power Co.), Tokyo Denryoku (Tokyo Electric Power Co.), 1983, pp. 253–348, 622–39.

12 Nippon Kōkan Kabushiki Gaisha (Nippon Kōkan Corp.), *Nippon Kōkan Kabushiki Gaisha gojūnen-shi* (Fifty year history of Nippon Kōkan Corp.), not for sale, 1962, pp. 909–10.

13 Nihon Tekkō Renmei (Japan Iron and Steel Federation), 1959 [21] p. 374.

14 Jūnen-shi Hensan Iinkai (Editorial Committee of Ten Year History), *Tekkō jūnen-shi Shōwa sanjūsan-nen – yonjūni-nen* (Ten year history of iron and steel 1958–1967), Nippon Tekkō Renmei, 1969, pp. 423–36 and 448–51.

The consumption rate of domestic coal by The Yawata Iron Works was as high as 70% in 1950, but it decreased to 50% in 1960 and 20% in 1969. In 1958, eight steel manufacturers entered into a five year contract to cooperatively purchase foreign coal. Coal was purchased from Australia, USSR, Canada, etc.

15 Shin Nippon Seitetsu Kabushiki Gaisha (Nippon Steel Corp.), *Hirohata Iron Mill, Hirohata Seitetsujo sanjūnen-shi* (Thirty year history of the Hirohata Iron Mill), not for sale, 1970, p. 646.

16 Fuel oil C is the cheapest of the three fuel oils A, B, and C. It has the highest sulfur content of the three, and a viscosity between 50 and 250 cSt.

17 Nihon Ita Garasu Kabushiki Gaisha (Nippon Sheet Glass Co.), *Nihon Ita.*

18 Garasu Kabushiki Gaisha, *Garasu Kabushiki Gaisha gojūnen-shi* (Fifty year history of Nippon Sheet Glass Co.), not for sale, 1968, p. 340.

19 Ube Kōsan Kabushiki Gaisha (Ube Industries), *Nakayasu Kan'ichi den* (Biography of Kan'ichi Nakayasu), not for sale, 1984, p. 288.

20 Nihon Semento Kabushiki Gaisha (Nihon Cement Co.), *Hyakunen-shi* (One hundred year history), not for sale, 1983, p. 156. Nihon Semento Kabushiki Gaisha, 1963 [22] p. 13.

21 Chichibu Semento Kabushiki Gaisha (Chichibu Cement Co.), 1974 [23] p. 177.
22 Nihon Semento Kabushiki Gaisha, 1963 [22] p. 132.
23 Onoda Semento Kabushiki Gaisha (Onoda Cement Co.), *Onoda Semento hyakunen-shi* (One hundred year history of Onoda Cement), not for sale, 1981, p. 580.
24 Chichibu Semento Kabushiki Gaisha, 1974 [23] p. 384.
25 Nihon Ryūan Kōgyō Kyōkai (Japanese Association of the Ammonium Sulfate Industry), 1968 [4] pp. 394–5, 399.
26 Nihon Ryūan Kōgyō Kyōkai, 1968 [4] pp. 400–12.
27 Nihon Ryūan Kōgyō Kyōkai, 1968 [4] pp. 412–18.
28 The 'Nagasaki flag incident' refers to an incident in which Japanese protestors defaced a Chinese flag.
29 Nihon Ryūan Kōgyō Kyōkai, 1968 [4] pp. 458–60, 465.
30 Nihon Ryūan Kōgyō Kyōkai, 1968 [4] pp. 478–9. The government laid out the following policies: (1) the cost of ammonium sulfate will be reduced to $43.48/ton by the 1963 fertilizer year, (2) eight billion yen will be financed from the Japan Development Bank at 6.5% per annum from 1961 to 1963, (3) the special repayment system will be expanded and (4) the two measures regarding fertilizer will be reexamined.
31 Nihon Ryūan Kōgyō Kyōkai, 1968 [4] pp. 486–93, 516, 581 and 587–92.
32 Nihon Ryūan Kōgyō Kyōkai, 1968 [4] pp. 607–14; *Zoku Nihon ryūan kōgyō-shi* (History of ammonium sulfate of Japan), 1981, p.44.
33 Nihon Gasu Kagaku Kōgyō Kabushiki Gaisha (Japan Gas Chemical Co.), 1966 [24] pp. 68, 87, 93 and 114.
34 Nihon Gasu Kagaku Kōgyō Kabushiki Gaisha (Japan Gas Chemical Co.), 1966 [24] pp. 137–41.
35 Nihon Gasu Kagaku Kōgyō Kabushiki Gaisha (Japan Gas Chemical Co.), 1966 [24] pp. 168–9, 173.
36 Sumitomo Kagaku Kōgyō Kabushiki Gaisha (Sumitomo Chemical Co.) 1981 [26] pp. 258–9 and 579; Nissan Kagaku Kōgyō Kabushiki Gaisha (Nissan Chemical Industries), p. 172; Nippon Kasei Kabushiki Gaisha (Nippon Kasei Chemical Co.), 1987 [28] pp. 11–108; Nihon Ryūan Kōgyō Kyōkai, 1968 [4] p. 572.
37 Enomoto, 1976 [25] pp. 300–1.
38 Enomoto, 1976 [25] pp. 321–3.
39 Nissan Kagaku Kōgyō Kabushiki Gaisha, 1969 [27] p. 132; Nakanishi, Inoue and Hidaka visited Italy, and signed a provisional contract in 1951. However the official history of the company records this provisional contract as being signed in 1953.
40 Nissan Kagaku Kōgyō Kabushiki Gaisha, 1969 [27] p. 136.
41 Nissan Kagaku Kōgyō Kabushiki Gaisha, 1969 [27] pp. 140–1.
42 Nippon Kasei Kabushiki Gaisha, 1987 [28] pp. 94–9.
43 'Shōwa nijūhachi nendo ni okeru jūyō naru nenryō kankei jikō (Important agenda related to fuel in the 1953 fiscal year)', in *Nenryō Kyōkai-shi* (Bulletin of the Fuel Association), vol. 33, no. 324, April 1954, p. 187.
44 Nippon Kasei Kabushiki Gaisha, 1987 [28] p. 99.
45 Refer to *Nenryō Kyōkai-shi*, vol. 35, no. 352, August 1956, p. 187.
46 Fumitada Matsumoto, 'Tekisako hō ni yoru anmonia gōsei (Synthetic ammonia processing with the Texaco method)', in *Ryūan gijutsu* (Ammonium sulfate technology), vol. 13, no. 2, 1960, pp. 12–17.
47 Nihon Ryūan Kōgyō Kyōkai, 1968 [4] pp. 607–14; Sumitomo Kagaku Kōgyō Kabushiki Gaisha, 1981 [26] pp. 455–8.