The Role of Japanese Nuclear Power in World Energy Context

By Herman Franssen

The structure of the OECD energy market has altered significantly in the past decade, particularly since 1979. While no one can yet say with any degree of certainty how permanent structural changes in energy demand and modifications to the fuel mix will be, it is generally agreed that events in the energy market in the 1970s and early 1980s are a watershed in the history of postwar energy developments.

The period before the mid-1970s was characterized by rapid expansion and improvement of the OECD infrastructure. The growth in personal income from high rates of economic expansion brought about a high penetration of appliances, central heating, air conditioning and private transport resulting in fast growing demand for energy.

In the same period, multinational companies were looking for markets in the industrial world for the quantities of oil they had discovered in the Middle East. Oil was competitively priced with coal, and steadily replaced coal as the principal boiler fuel in the OECD countries. Outside the U.S., oil also became the main source of home heating fuel. In less than 15 years, the share of oil in the OECD energy mix almost doubled, while the share of coal fell by more than 50%. Of all major OECD countries, the shift from coal to oil was most pronounced in Japan. As shown in Table 1, coal use in Japan declined from 85% in 1950 to 17% in 1983, whereas the share of oil in the same period grew from 4% to 76% of primary composition.

For the OECD as a whole, energy demand grew at about the rate of GDP (gross domestic product) and demand for oil—the cheapest and most versatile fuel—grew at average annual rates of about 8%, substantially above the rate of GDP. Estimating future energy and oil demand at somewhat lower rates of economic growth and oil penetration, a study published by the U.S. National Petroleum Council in 1972 projected free world oil demand to reach 90 Mbd (million barrels per day) in 1985. To meet such staggering growth in world oil consumption, the countries of the Middle East would have had to produce 50 Mbd. While such a level of output could technically have been achieved, the rate of decline after production reached its peak would have been so rapid that no responsible government in producing countries could have consented to such a depletion pattern.

Energy planners in industry and governments—understandably—were unable to discern the changes yet to come in energy markets until the oil embargo of 1973/74 led to a quadrupling of oil prices.

A new nuclear power plant under construction

1973-1983: the decade of adjustments

The two oil shocks of the 1970s raised average world oil prices from about $3/barrel (bbl) in 1973 to about $12/bbl in 1974 and $35/bbl in 1981. The impact of these developments on the world economy and on energy demand have been significant.

Following the sudden and sharp price increases in 1973/74, the net oil import bill of the OECD countries almost tripled to $100 billion; the rate of inflation doubled and GDP growth turned negative. Before the world economy had fully recovered from the effects of the first oil shock, events in Iran resulted in another supply interruption in early 1979, causing oil prices to rise by some 160%.

Once again, the OECD oil bill doubled, inflation rose to double digit levels and economic growth was reduced sharply in the early 1980s. In order to contain inflationary pressures and rising budget deficits, OECD governments generally moved toward restrictive fiscal and monetary policies, which gradually reduced inflationary pressures, but at the cost of higher unemployment and low GDP growth.

The two oil shocks appear to have adversely affected the OECD economies for three to five years after the events

Table 1 Regional Energy Demand Growth in the OECD, 1950-1973 (in Mtoe)*

	1950			1960			1973		
	North America	Western Europe	Japan	North America	Western Europe	Japan	North America	Western Europe	Japan
Oil	320 (39)**	48 (12)	1.4 (4)	513 (45)	191 (30)	32 (33)	864 (45)	748 (60)	269 (76)
Natural gas	157 (19)	1 (0)	0.1 (0)	303 (27)	10 (2)	1 (1)	565 (29)	123 (10)	5 (1)
Coal	341 (41)	344 (86)	27.2 (85)	243 (22)	365 (58)	50 (52)	376 (19)	279 (23)	59 (17)
Other	13 (2)	9 (2)	3.3 (10)	70 (6)	64 (10)	14 (14)	130 (7)	89 (7)	20 (6)
TPE***	831	402	32.0	1,129	630	97	1,935	1,239	353
(Net oil imports in Mbd)	(0.4)	(0.9)	(0.02)	(2.0)	(3.5)	(2.0)	(6.0)	(15.0)	(5.5)

*Mtoe: Million tons of oil equivalent **Figures in brackets represent percentage share of primary energy demand. The figures do not necessarily add due to rounding.
***TPE: Total primary energy

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occurred. A study conducted by the OECD concluded that total loss in real income in the OECD arising from the higher oil prices of 1979/80 alone was in the vicinity of $1 trillion, or about $1,300 for every individual in the OECD countries. In the decade between 1973 and 1983, OECD economic growth was reduced to a yearly average of about 2%, less than half the pre-1973 trend and accounting for as much as half of the reduction in primary energy demand growth in the decade.

Energy demand: recent experience

During the 1960s, OECD primary energy demand grew at an average annual rate of 5.2% compared with an economic growth rate of 5.1%. Between 1973 and 1983, OECD economic growth rates averaged 2.1% per year and primary energy demand grew at less than 0.2% per annum. This indicates a significant reduction in energy intensiveness of the OECD economies in the past decade. As shown in Table 2, energy and oil intensiveness fell sharply in industry, the most price sensitive sector, and least in transportation.

The causes of the reduction in energy and oil intensiveness are both short- and long-term as well as temporary and permanent in nature. The immediate reaction of consumers to higher oil and other energy prices was to reduce motoring, turn down thermostats, improve load factors in air transportation, reduce heat losses in industrial processes, etc. Such short-term reversible energy reducing measures have been followed by longer-term—more permanent—measures. These include: fuel substitution, technological change, shifts in industrial output and long-term behavioral changes. Fuel substitution from oil to natural gas, coal, biomass and, in some cases, electricity, has come suddenly on a large scale after 1979 in certain energy-intensive industries such as paper and pulp, iron and steel and cement. While the pace of substitution away from oil has slowed down, the potential for additional conversion to non-oil fuels remains large in the industrial sector. The extent of further fuel switching is very sensitive to fuel price differentials, the economics of conversion, and in some instances, technological progress (pressurized fluidized bed combustion for industrial coal use, for example).

Technological changes have resulted in major improvements in automotive and aircraft fuel efficiency, as well as efficiency improvements in home appliances, furnaces, air conditioners, industrial machinery, homes, factories and commercial buildings. Most of the improvements made after 1973 were based on existing technologies. Current government policies, gradual shift of capital and consumer goods to more energy-efficient equipment, introduction of new technologies in competitive industries, as well as expectations of a future tightening of the oil market should lead to further improvements in energy efficiency in the future.

Table 2 OECD

		Industry	%	R/C*	%	Transportation	%
Energy/GDP	1973	100.0	—	100.0	—	100.0	—
	1974	98.1	-1.9	95.2	-4.8	97.6	-2.4
	1975	95.9	-2.2	92.8	-2.5	100.2	2.7
	1976	95.5	-0.4	94.5	1.8	98.7	-1.5
	1977	90.7	-5.0	92.2	-2.4	100.8	2.1
	1978	88.0	-3.0	90.3	-2.1	102.6	1.8
	1979	86.8	-1.4	89.5	-0.9	99.7	-2.8
	1980	83.1	-4.3	88.1	-1.6	95.3	-4.4
	1981	80.0	-3.7	85.4	-3.1	91.4	-4.1
	1982	75.5	-5.6	83.6	-2.1	91.7	0.3
	1983	71.2	-5.7	83.1	-0.6	90.2	-1.6
Oil/GDP	1973	100.0	—	100.0	—	100.0	—
	1974	95.4	-4.6	89.0	-11.0	97.6	-2.4
	1975	90.9	-4.7	84.1	-5.5	100.3	2.8
	1976	96.8	6.5	88.1	4.8	98.9	-1.4
	1977	91.8	-5.2	85.9	-2.5	100.9	2.0
	1978	92.8	1.1	79.8	-7.1	102.7	1.8
	1979	87.7	-5.5	76.2	-4.5	99.8	-2.8
	1980	77.3	-11.9	72.3	-5.1	95.2	-4.6
	1981	67.8	-12.3	65.6	-9.3	91.4	-4.0
	1982	62.2	-8.3	60.7	-7.5	91.6	0.2
	1983	52.6	-15.4	59.5	-2.0	90.0	-1.7

*R/C: Residential/commercial

The effects of behavior on short-term energy demand is not only difficult to measure, but equally difficult to predict. It is currently unknown to what extent behavior will change again, as incomes rise and prices stabilize. It is possible that consumer priorities have permanently shifted from energy to other goods and services, but recent experience in the United States shows that higher incomes and lower energy prices are reversing motoring trends and reducing energy-consciousness in purchasing of appliances.

High oil and gas prices have also stimulated a gradual shift of energy-intensive industries from high to lower energy cost countries. The aluminum and petrochemical (bulk petrochemicals) industries are examples of industries shifting increasingly to countries with cheap electricity and natural gas. A period of softening in energy prices could slow down industrial migration, fuel shifts, energy investments and conservation efforts, but in the longer term, the trends away from oil and toward increasing energy efficiency are likely to continue.

What changes in the OECD fuel mix

By the early 1970s, projections of the long-term oil supply outlook showed that oil was the scarcest of all hydrocarbon resources and that the rate of oil demand growth could not continue forever. Moreover, supply interruptions in 1973—reinforced by the events of 1979—convinced OECD governments that for both economic and supply security reasons, a better balanced energy mix was needed. Higher prices and to a lesser degree government policies have already had a remarkable impact on improving the OECD fuel mix in the past decade, as shown in Table 3.

The share of oil in OECD energy demand fell from a peak of 53% in 1973 to 43% last year, and the share of natural gas remained fairly stable. After several decades of steady erosion, the share of coal grew steadily in that decade. The fastest growth, however, was reserved for nuclear power which increased fivefold, from 42 to 212 Mtoe (0.9–4.4 Mbdoe) over the same period. OECD indigenous oil

Table 3 OECD Energy Demand Growth, 1973–2000*

	1973		1983		2000 (Projected)	
	Mtoe	Share of TPE %	Mtoe	Share of TPE %	Mtoe	Share of TPE %
Oil	1,914	53	1,551	43	1,650	33
Natural gas	697	19	676	19	800	17
Coal	741	21	860	24	1,370	29
Nuclear	42	1	212	6	560	12
Other	161	5	277	8	420	9
Total	3,599	100	3,576	100	4,800	100
(Net oil imports)	(27 Mbd)		(17.9 Mbd)		(21.0 Mbd)	

*Figures for IEA countries correspond with the 1983 Review of Energy Policies and Programs of IEA countries. Other OECD countries added from industry sources.

production stabilized in the early 1970s, but grew steadily thereafter.

In total, OECD indigenous supplies of energy grew by more than 400 million tons.

The impressive growth in OECD indigenous energy supplies is based on industry decisions to use lower cost options and government policies aimed at diversification of energy supplies. Energy investment decisions in the 1970s were generally based on expectations of higher future economic growth and energy demand than actually occurred. Hence, many OECD countries are now faced with temporary surpluses of electrical power capacity (mainly oil-fired), natural gas and coal. Most of these surpluses are expected to disappear by the end of this decade.

The net effect of the slow economic growth and decline in energy intensity has been to reduce OECD energy consumption by some 14 Mbdoe (million barrels per day of oil equivalent) below what otherwise would have been. Without the changes in price differentials between fuels and government policies to achieve a more balanced energy mix, OECD oil demand in 1983 might have been 7 Mbd higher than the 33.8 Mbd estimate for that year by the IEA.

Between 1973 and 1979, economic growth in the developing countries continued at close to the pre-1973 level, causing oil demand to grow by about 2 Mbd. Thereafter, economic growth in the developing countries plummeted due to recession in OECD countries and international debt problems. The net effect on oil demand in the developing countries as a group has been five years of no growth in consumption.

Future developments

The post-1979 fall in OECD oil demand was arrested in the autumn of last year, largely as a result of the effects of the economic recovery in the United States and Japan. While the growth in oil consumption in both countries has remained considerably below that of previous economic recoveries, the current trend suggest continued slow growth in OECD oil consumption in 1985 along with a continued recovery in the world economy. Preliminary data also suggests that oil demand in developing countries this year is growing at a rate of about 2%.

The medium- to long-term energy outlook remains uncertain. Projections of future energy demand, supply and prices are based on a number of key variables such as economic growth; the relationship between income, price and energy demand; and supplies of both oil and non-oil fuels. Every one of these variables is subject to change.

Based on specific assumptions of economic growth, energy/GDP relationship and indigenous supply prospects in member countries, the IEA recently released a study on Energy Policies and Programs of IEA countries. Member governments project that the share of oil in primary energy will fall from 44% in 1983 to 33% by 2000. However, as shown in Table 3—which has been adjusted to include France and Finland—the volume of oil is projected to rise slightly during this period. Assuming continuation of the current price relationships between natural gas and oil products, the share of gas is projected to decline modestly. The growth fuels in the IEA study are coal and nuclear power which—together with renewables—are projected to grow from 36% to 50% of primary energy by the end of the century. No specific projections of the period after 2000 are made, but long-term higher oil price expectations should widen the gap between oil prices and alternative fuels, leading to an even higher share of non-oil fuels in the post-2000 energy mix.

While in the next few years oil prices in real dollar terms may continue to decline due to over-capacity on both the downstream and upstream sides of the industry, even modest long-term world economic growth expectations will inevitably result in rising demand in the developing countries. Non-OPEC oil production is not expected to grow much in the next few years and may stagnate in the 1990s. In the OECD countries, oil production is expected to decline in the 1990s, but the extent of the decline will depend on reserve additions made over the next five years.

As shown in Table 5, the net result of growing world demand and declining OECD supplies is at first a gradual reduction in the current world oil surplus, followed by a significant tightening of the market in the 1990s.

Table 4 Energy Production, 1973–2000 (Mtoe)

	1973		1983		2000 (Projected)	
	Mtoe	Share (%)	Mtoe	Share (%)	Mtoe	Share (%)
Oil	621	27	748	28	630	18
Natural gas	701	31	606	23	596	17
Coal	701	31	835	31	1,390	38
Nuclear	42	2	212	8	560	16
Others	203	9	277	10	420	11
Total	2,268	100	2,678	100	3,596	100

Table 5 Free World Oil Demand and Supply, 1983–2000 (Mbd)

	1983	1990	2000
Demand*			
OECD	33.8	33-35	34-36
Developing countries	10.6	14-15	18-20
TOTAL	44.4	47-50	52-56
Supply Capacity			
OECD**	16.9	14-16	11-14
Non-OPEC LDCs	7.3	8.5-9.5	9-11
CPE*** net exports	1.6	0-1	0-0.5
OPEC****	18.5	29-33	27-33
	0.1	—	—
	44.4	51.5-59.5	47-58.5

* Including processing gain ** Product demand
***CPE: Centrally planned economies ****For 1990 and 2000, the figures represent production capacity.

Electricity demand

Electricity demand has consistently grown at rates higher than total energy requirements. In the 1960–73 period for example, when the annual growth in electricity demand in Japan was 11.2%, total primary energy demand grew by about 10.2% annually and GDP by 10.4%. Between 1973 and 1982 when economic growth slowed to an annual average of 3.7%, primary energy demand grew at 0.09% per year, while electricity demand rose at an annual rate of about 2.5%.

Hence, electricity requirements have grown at consistently higher rates than overall energy in periods of high and slow economic growth alike. The high penetration rate of electricity in the residential/commercial sector was related to rapid growth in appliances (including air conditioning) in households and growing use of specialized applications (robots, specialized furnaces) in the industrial sector.

Electricity demand in Japan is expected to continue to grow at rates higher than TPE. In the 1983 energy Review of Member Countries (published in the summer of this year), the IEA projects TPE growth in Japan at a rate of 2.4% per year through 2000 and electricity demand at 3.2%. The share of electricity in total final energy consumption would rise from about 19% in 1982 to almost 23% by the end of the century.

Projected growth in electricity demand is lower than in the period before 1973, but higher than it has been in recent years.

It appears that the reductions in the growth rate of electricity demand in the industrial sector caused by capacity reduction of some electricity-intensive industries like aluminum, has now bottomed out. From now on, electricity-intensive sectors such as machinery and services (office automation) are expected to expand their share in industrial output. Moreover, the growing residential sector is projected to show substantial growth in electric heat pumps for cooling/heating, and there is scope for further substitution of electricity for oil in water heating in the residential/commercial sector.

Table 6 Generating Costs—10% Real Discount Rate (1984 U.S. mill/kwh)

	Oil with FGD* 2×600 MW	Nuclear PWR 2×1100 MW		Coal with FGD** 2×600 MW	
		Lead Time		Coal Importing Region	
		6 years	10 years	$55/tonne constant	$55/tonne +2% p.a. real increase after 1990
Capital cost	13.6	27.2	32.9	19.0	19.0
Operating cost***	4.2	5.0	5.0	5.0	5.0
Fuel cost	43.2	10.0	10.0	20.3	24.3
Total cost	61.0	42.2	47.9	44.3	48.3
Capacity factor	70%	70%	70%	70%	70%
Reference: Construction lead time	3 years	6 years	10 years	4 years	4 years
Capital investment ($/kw)	865	1,730	2,094	1,210	1,210
(Initial investment) ($/kw)	(750)	(1,300)	(1,300)	(1,000)	(1,000)
(Interest during construction)($/kw)	(115)	(430)	(794)	(210)	(210)
Fuel cost	$180/t	—	—	—	specified
Conversion efficiency (net)	36%	34%	34%	36%	36%
Heat Rate (kcal/kwh)	2,400	2,500	2,500	2,400	2,400

* Plant with FGD using high sulphur oil.
** Besides SO_X, coal produces various pollutants such as No_X, dust, particulates and ashes. The costs of removing these pollutants to meet legal requirements are included in each cost component.
*** Operating cost in this study is the cost directly incurred in a plant. Actual operating cost could be higher with the distributable costs of overhead expenses, which differ by utility.

The role of the nuclear industry

Every fuel has a particular role to play in improving the OECD energy mix. For reasons of security and cost, it is essential to balance energy supplies to prevent difficulties which could arise from overdependence on any single source of energy. Nuclear power has made an important contribution in achieving a better balanced energy mix in the transition period of the 1970s. Without nuclear power, the combination of other fuels to meet overall energy requirements would have to be almost 4.5 Mbdoe higher than it is today. In Japan the growth of nuclear power in the past decade has been around 0.5 Mbdoe. Because surplus electricity capacity is largely oil-fired, demand for oil in the OECD would probably have been much higher today without the nuclear contribution.

IEA and other OECD nuclear capacity is projected to grow by the equivalent of another 7 Mbd by the end of the century, including about 1.3 Mbd in Japan. Without the contribution of nuclear power, coal, natural gas and oil would have had to fill the gap. In the post-2000 era, conventional liquid hydrocarbon resources are expected to become increasingly scarce, requiring—among others—an even larger role for electricity in the fuel mix of the OECD countries. There are currently only two proven technologies which can make very large contribution to growing electricity requirements: nuclear power and coal. Each of these two sources of electricity generation has specific advantages and disadvantages. For individual countries and for the OECD as a whole, it is therefore preferable that both sources be utilized in order to prevent over-reliance on one single power generation technology.

In Japan, the contribution of nuclear power to total electricity generation has grown from about 2% in 1973 to 20% today. Based on the current construction program and planned additional capacity, the share of nuclear power could rise to close to 40% of electricity generation by 2000, according to recent IEA projections. In addition to the need for a balanced energy mix and some degree of energy self-sufficiency, nuclear power has specific economic advantages in Japan. It has contributed to stability of electricity rates, improvement in the country's balance of payments, and creation of effective demand for the Japanese economy.

While generating costs differ greatly from country to country and from plant to plant, a study by the IEA of comparative generation costs of electricity between oil, nuclear power and coal shows that for new power plants, both nuclear and coal-fired facilities have lower overall costs than oil-fired ones at current prices and interest rates (see Table 6). Depending on the delivered cost of coal, environmental requirements, construction lead times and capital costs, nuclear power in most parts of the OECD has a competitive edge over coal. Recent studies by the Ministry of International Trade and Industry show the following indicative cost of power generation by new power plants in Japan: hydro, ¥20/kwh; oil and LNG ¥17/kwh; coal ¥14/kwh; and, nuclear ¥12.5/kwh.

A few years ago, when world oil and coal prices peaked, the differential between nuclear power and electricity generated from coal and oil-fired power plants was wider. It is possible that over the next few years, the cost gap will narrow further, but the longer-term outlook is for higher oil prices and thus a widening of the gap in generating costs.

In addition to lower generating costs, the nuclear power industry has also had a positive impact on the Japanese economy. The major power companies have invested more than ¥3,000 billion on nuclear power development during the past 10 years. According to research by the Japan Development Bank, the multiplier of investments by the power industry is about 2, leading to an effective demand created by the investments in nuclear power stations amounting to ¥6,400 billion in the past decade. These investments have created some 150,000-200,000 jobs per year. In addition, there has been some spin-off in the form of revitalization of regional economies.

By the summer of 1984, Japan had a nuclear power capacity of about 20 gigawatts (GW) and another 12.4 GW under construction. Overall capacity is projected to grow to 62 GW by the end of the century, which is almost twice current capacity plus capacity under construction. Completion of the program would double the share of nuclear power in electricity generation to almost 40% and nuclear power's share in total primary energy demand to about 16%. It is not going to be an easy task in view of the uncertainties related to electricity demand, competitiveness, public concern, and the long lead times required to complete new nuclear power plants. However, successful implementation of the program will contribute significantly to a reduction of energy supply vulnerability. It will also provide a reliable source of energy at predictable prices, and create significant long-term employment in major high-technology industries. ●