OIL IN POWER GENERATION

INTERNATIONAL ENERGY AGENCY

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It carries out a comprehensive programme of energy co-operation among twenty-four* of the OECD's twenty-nine Member countries. The basic aims of the IEA:

- to maintain and improve systems for coping with oil supply disruptions;
- to promote rational energy policies in a global context through co-operative relations with non-Member countries, industry and international organisations;
- to operate a permanent information system on the international oil market;
- to improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use;
- to assist in the integration of environmental and energy policies.

** IEA Member countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, the United States. The Commission of the European Communities also takes part in the work of the IEA.*

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to conbribute to the development of the world economy;
- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter: Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996) and the Republic of Korea (12th December 1996). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

FOREWORD

Oil-fired power generation plays a small, but important, economic role in the electricity supply of OECD countries. This report describes that role of providing: electricity in periods of peak demand, operating and planning flexibility, and generation in isolated electricity systems. It provides a review of the trends in oil-fired generation, including comprehensive statistics on generation, capacity, oil products used and plant utilisation rates.

On average oil provides less than 10% of total generation today. This is a substantial drop from the situation in the early 1970s, when oil contributed over one quarter of OECD generation.

The outlook for oil-fired power generation is one of a continuing decrease in share. However the absence of economic substitutes in some countries means that oil will not disappear entirely from OECD electricity supply systems. Indeed, oil-fired power generation could retain a value to both refining and power generation with two factors coinciding: on the one hand, the shift towards lighter products in overall petroleum product demand has left refiners searching for ways to profitably upgrade or dispose of heavy refining residuals; and on the other, electricity market liberalisation may provide refiners with new opportunities to dispose of residuals via power generation.

The energy security dimension to oil-fired power generation has not disappeared. This report outlines the policy issues regarding oil in power generation.

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UNITS AND ABBREVIATIONS

bbl	barrel
Btu	British thermal unit
GWe	gigawatt (electric capacity)
GWh	gigawatt-hour
kt	thousand tonne (10^6 kg)
kWh	kilowatt-hour
LPG	liquefied petroleum gases
m^3	cubic metres
Mt	million tonne (10^9 kg)
MWe	megawatt (electric capacity)
NG	natural gas
NGL	natural gas liquids
NO_x	nitrogen oxides
SO_2	sulphur dioxide
toe	tonne of oil equivalent (10^7 kcal)
TWh	terawatt-hour
WEO	World Energy Outlook
yr	year

EXECUTIVE SUMMARY

HISTORICAL SUMMARY AND PROSPECTS

This report reviews trends in oil-fired power generation since the establishment of the IEA in 1974 and discusses their implications for IEA Member countries. In the OECD as a whole, oil's share of power generation has decreased from nearly one quarter in 1974 to less than 9% in the 1990's. In all but six OECD countries, oil-fired power generation is below this 9% average. Oil-fired capacity has declined steadily since the 1970's and is likely to continue on this trend. Utilisation rates (average plant output compared to potential output) of oil-fired power plants are substantially lower than in the 1970's. The potentially adverse effect on overall energy security of oil use in power generation has thus, in most IEA countries, decreased in parallel with oil's decreased role in power generation.

Oil's role in the majority of electricity supply systems in OECD countries is to provide:

- peaking and intermediate load;
- flexibility in meeting unexpected interruptions in the supply of electricity from other fuels;
- planning flexibility when generating plant additions are delayed;
- power in isolated systems such as on islands or in remote areas.

In several countries, generation from existing oil-fired power plants increased dramatically, but temporarily, in response to disruptions in the supply of other fuels. This is a natural role for peaking plants but of particular importance for oil-fired plants because of the flexibility in supply and transportation options for oil products. Countries with higher than average oil use for power production tend to have few other economic options for generating peak and intermediate load. Typically, hydroelectric capacity and natural gas are expensive or have not been consistently available in these countries. Political constraints on alternative power plant types, particularly coal and nuclear, have also played a role. In all cases, oil has few or no economic replacements as a power plant fuel.

The primary petroleum product used in power generation is residual fuel oil, accounting for 80% of oil energy input. Crude oil, at 14% of energy input, is used exclusively in Japan. Distillates and other petroleum products account for the remaining 6% of oil energy input to power generation. There is continued pressure to use petroleum products with lower sulphur content or to use flue gas desulphurisation in oil-fired plants, which is economically justified only for low value fuels such as petroleum coke, refinery tars, or bitumens. The use of low value products has been increasing in recent years as a fraction of energy input.

Both the IEA and national governments project oil use in power generation to continue decreasing. This is a consequence of the high marginal cost of oil-fired generation in existing plants and the high cost of electricity in new oil-fired plants. The use of fuel oil is expensive because:

- it is (often) more expensive on a thermal basis than other fuels;
- the maximum efficiency obtainable from conventional oil-fired boilers is about the same as boilers fired on other fuels, but lower than that from gas-fired combined cycles;
- the capital cost of oil-fired power plants, including flue-gas desulphurisation, is high.

Oil can be economic in existing plants, mainly in competition with gas in conventional boilers, but is rarely the least expensive option in new baseload plants. On average throughout the OECD, coal prices would have to increase by one third and natural gas prices would have to double for new oil-fired boilers to be competitive, although local fuel costs and plant construction costs can change the results of interfuel competition. Very few exclusively oil-fired power plants are planned in the OECD, with the exception of relatively small peaking plants used for short periods each year or plants in isolated systems. The increased role of natural gas in power generation expected throughout the OECD will tend to further reduce the potential for new oil-fired power plants.

The potential for increased generation from existing oil-capable plants is very large. Existing underutilised oil-fired plants, multifuel plants, and a limited number of mothballed oil-fired power plants could be called upon to produce up to five times the current generation of power from oil, subject to logistical and technical limitations. The potential for increased generation from oil-capable plants is an important element of flexibility in electricity supply systems.

POLICY CONSIDERATIONS

IEA policy on the use of oil in power generation has consistently been based on the goals of:

- discouraging the construction of new exclusively oil-fired power plant, although with exceptions;

- encouraging the conversion of existing oil-fired plant to other fuels or multifuel firing;

- reducing the utilisation of existing oil-fired plant.

The basic IEA policy was stated in the 1977 "Principles for Energy Policy" and re-affirmed in the 1979 "Principles for IEA Action on Coal". The latter explicitly discouraged new or replacement oil-fired power plants with a minimum of exceptions. Later statements on the subject in 1987 and 1990 clearly showed a lessening in specificity of the policy, describing instead the need to "diversity the other sources of energy used in the [electricity] sector" and to decide on the best mix of fuels used in power generation based upon particular national circumstances. In 1990 the IEA Governing Board agreed that the policy on oil in power generation "should not be changed". This was the last statement on the policy made by the Governing Board. The IEA's 1993 statement of Shared Goals makes no explicit reference to the subject.

The 1990 Governing Board statement requested the IEA Secretariat to monitor and report on developments concerning oil in power generation. This report has been prepared as a periodic response to this request. It does not re-define IEA policy, which can be done only by the IEA Governing Board.

The trends of the past 20 years and the current role of oil-fired power generation may warrant a reconsideration of some national policies. Some level of oil-fired power generation can be seen to increase the security of energy supply to the electricity supply industry inasmuch as:

- diversity of fuel supplies implies a non-zero level of oil use;

- oil does play an important economic role in supplying peak and intermediate load electricity;

- oil contributes to flexibility to respond to disruptions in other fuel supplies;

- oil provides an economic outlet for residual products of refining.

The over-riding concern of policy makers in past years was that use of oil in power generation, at any level, exposed both electricity sectors and national economies to damaging economic effects in the event of a disruption in oil supply. This remains a vital, important concern for OECD countries that must be assessed in the national context for each Member country. However, the level of oil use in power generation in the OECD as a whole is such that the likely severity of disruption in supplies of fuel oil in a general oil supply disruption appears low because of the inelastic demand for light oil products and the fact that there are relatively few other uses for residual fuel oil. In fact, the use of oil in power can now be seen as providing an important *source* of energy security in relation to potential disruptions in other fuels, none of which are completely without risk of disruption.

I – INTRODUCTION

This report examines long-term and recent trends in oil-fired power generation within OECD Member countries[1]. The potential implications of current and prospective patterns of oil use in the electricity sector on electricity markets, the environment, and energy security are examined. The policy considerations regarding oil use in power generation are presented. This report is one response (among others) to an IEA Governing Board request to monitor and report on developments concerning oil-fired power generation.

Since the oil price shocks in 1974 and 1979, OECD oil use in power generation has declined by about 40%, from over 250 Mt/yr in the late 1970's to 150 Mt/yr in 1994. Total oil-fired capacity dropped by 25%. Oil's share of OECD power generation has declined even more dramatically, from over 25% in 1973 to 9% in 1994. This drop was primarily due to the reaction of market forces to the steep rises in oil price though also to a successful policy of diversification away from what constituted, in the 1970's, an over-reliance on a single fuel which proved to be susceptible to supply disruptions. Many of the policies instituted in response to the oil crises are still in effect today and have contributed to the present patterns of fuel choice for power generation.

Yet oil market conditions have changed significantly since the 1970's. In response to high crude oil prices, exploration and production of crude oil in non-OPEC countries, OECD countries included, increased oil supply to the point that the cartel price of crude oil was unsustainable. The price of crude oil fell precipitously in 1986. New entrants to the oil industry engendered competition and increased the geographical and commercial diversity of supply sources. In many industries, not only the electricity sector, the use of heavy fuel oil was reduced. There was a shift in energy-intensive industries from OECD countries to developing countries. Changes in other energy markets have had significant effects upon the oil market. For example, the increased availability and use of natural gas in some countries and the commissioning of nuclear power plants have affected the overall demand for fuel oil. This is shown by the shares of each of the primary energy supply sources (Figure 1) since 1970. The growth of nuclear power appears to have been of particular importance in reducing oil use in power generation. The sum of nuclear's and oil's contributions to the total primary energy supply has been constant to within three percentage points for over 20 years.

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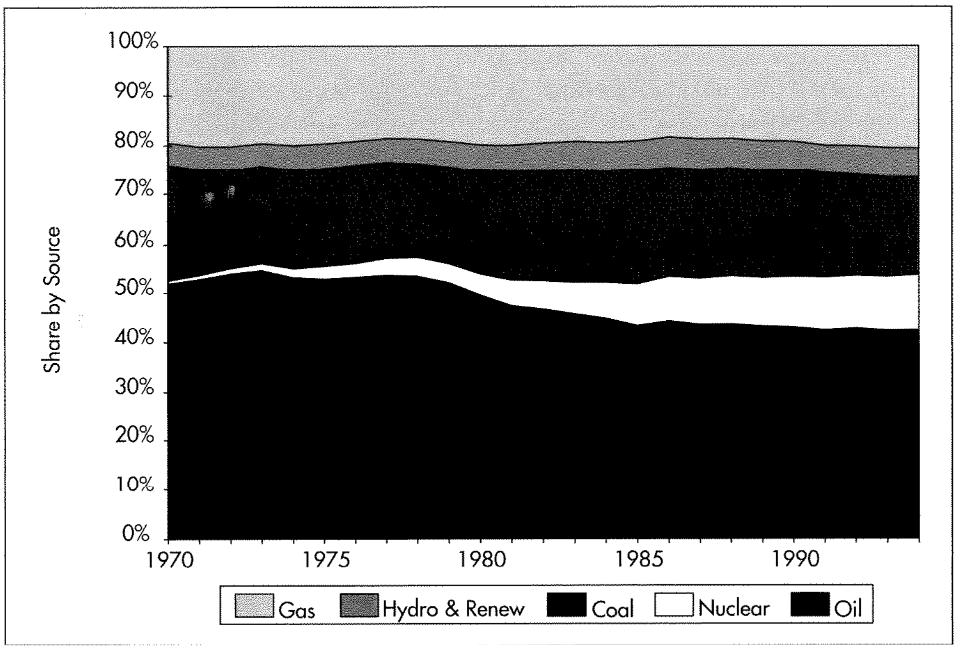
1 In this report, the following OECD countries are those on which statistics and commentary are based: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.

Figure 1

OECD Total Primary Energy Supply



Source: IEA, *Energy Balances of OECD Countries.*

Over time the mix of petroleum fuels has shifted towards lighter products, particularly transportation fuels. This in turn has had impacts in the refining industry, which has found it necessary to install product upgrading capacity to convert heavy products to higher value lighter products. The large expense of installing additional upgrading capacity, combined with today's product prices, imply a potential decrease in the price of residual products relative to light products in the near term. Petroleum coke, refinery tar, and heavy fuel oil can all be used for power generation and will continue to decrease in value to refiners as the share of light products increases. The commercial appearance of a low-cost natural bitumen for power generation, Orimulsion, may also affect the future product mix and price of petroleum fuels used for power generation. Although the long term cost trends for petroleum products are as uncertain as ever, it is already the case today that, particularly for peaking loads, the cost of electricity from oil-fired stations is competitive with that from other conventional stations.

Environmental concerns have become increasingly important in recent years. Emissions of sulphur and nitrogen oxides (NO_x) are regulated in all OECD Member countries and are relevant in oil-fired power stations because of the sulphur content of fuel oils and the potential for NO_x creation. As with coal-fired power stations, oil-fired power stations can be equipped with flue gas desulphurisation equipment and low-NO_x burners or NO_x reduction equipment. However, most existing oil-fired power stations do not have such equipment installed. Thus environmental considerations must also be taken into account when projecting trends in oil-fired power generation.

The general situation of oil in power generation in the OECD may thus be summarised as follows:

- The move away from oil has reduced oil-fired capacity and output.

- Oil-fired power generation generally supplies peak and intermediate load demand.

- The price of oil for power generation is at a level which, in certain cases, still makes it an economic choice, particularly in older, depreciated plant used for peak and intermediate loads and in new peak load plants.

- In most cases, use of oil will continue to shift towards meeting peak load as old oil-fired plants are retired and gas increases in power generation fuel share.

- The technical potential exists for a considerable increase in oil-fired power generation without construction of new, oil-fired power plants.

- Oil's share of power generation will remain higher than average in countries or regions with limited alternatives for supplying peaking and intermediate load.

Oil has provided a significant element of flexibility in meeting energy supply disruptions to the electricity supply industry. At the relatively low proportions of generation provided in most countries, it is likely to add to rather than detract from energy security.

IEA policy on oil use in power generation has been primarily to discourage the use of oil in all power generation plants. However, individual countries must inevitably give specific consideration to their own situations in considering the security implications of oil use in power. The diverse situation of many IEA countries suggests that the need for a policy uniformly restricting market choice has lessened in importance over time.

These observations are developed in greater detail in the remainder of this report. Section II of this report quantitatively describes historical patterns in oil-fired power generation in the OECD. The primary source of information for this analysis is IEA data provided by Member governments. Section III examines the potential future patterns in oil-fired power generation, considering recent history, generation economics, and the major trends in electricity markets. Section IV concludes with a discussion of policy issues.

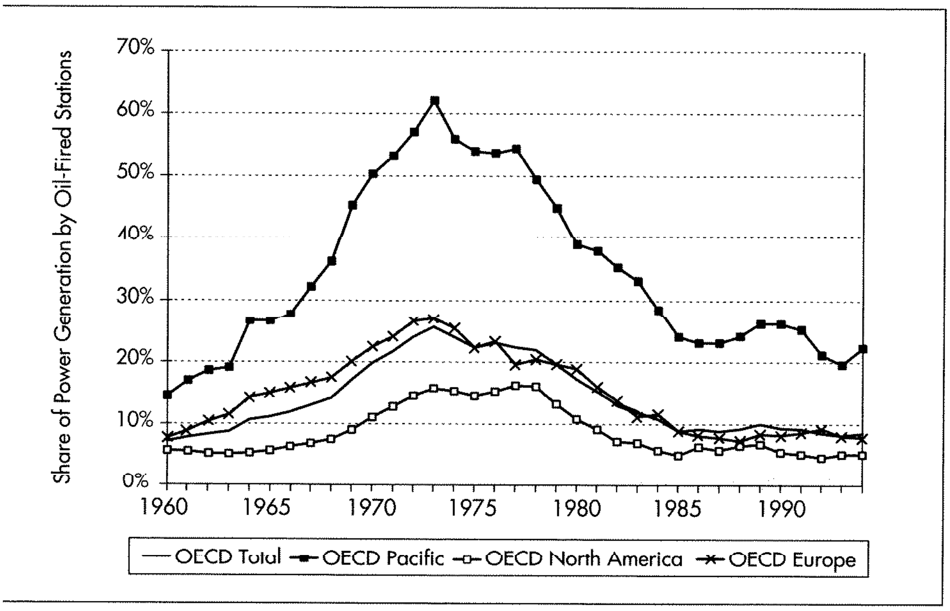
II - HISTORICAL PATTERNS

OIL-FIRED GENERATION AND CAPACITY

Oil-fired power generation today provides roughly 9% of OECD total generation. This is about the same fraction as it was 35 years ago. From 1960 to 1973, this fraction increased steadily in response to consistent growth in electricity demand and the favourable competitive situation of oil-fired generation in relation to other fossil-fuelled power production. A peak contribution of 26% was reached in 1973. From 1973 onward, the trend was reversed due to the oil price increases in 1974 and 1979. The evolution of oil's share of OECD power production is shown in Figure 2. As oil's contribution to electricity production decreased after 1973, underlying growth in electricity demand was met primarily by increased contributions of nuclear and coal-fired power plants. The sharp drop in oil prices in 1986 effectively stopped the trend towards decreasing contribution of oil in the power generation mix, which has since remained between 8% and 10% of the total.

Figure 2

Oil's Share of OECD Power Generation



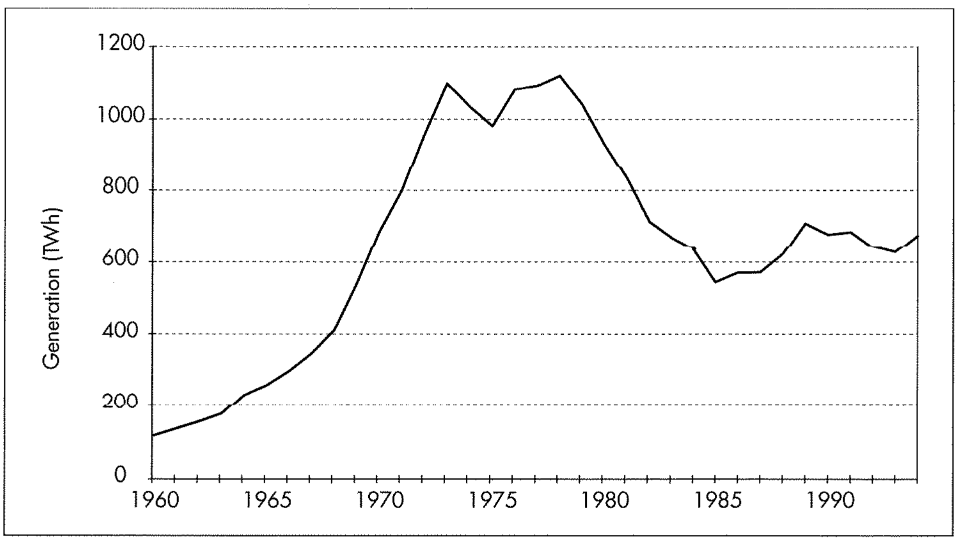
Source: IEA, *Electricity Information*.

A review of the trend in absolute oil-fired generation reveals a similar pattern, as shown in Figure 3. Steep increases in total generation peaked at 1100 TWh in 1973, dropped in response to the price increases of 1974, but recovered in the following five years as total electricity demand increased and the rate of introduction of other generation sources could not keep pace. A second peak of 1120 TWh was attained in 1978, after which oil-fired power production fell without interruption until 1985 to 545 TWh, an average annual decrease of 10%. When oil prices dropped abruptly in 1986, oil-fired power generation responded rapidly, growing at a rate of 6% per year for four years. This trend was halted in 1990 due to stagnation in electricity demand combined with increased production by coal- and gas-fired power plants. Since then, oil-fired power production has dropped in competition with increasing production at gas-fired power plants. In 1994, oil-fired power production stood at 680 TWh, or about the same level as in the early 1980s.

This roller coaster trend refers to total output from oil-fired stations, not MWe capacity. Oil's share of generation capacity has declined steadily since 1976, without interruption. Indeed, the absolute capacity of oil-fired power stations has been decreasing steadily since 1980, starting at a peak of 270 GWe and declining to 200 GWe by 1994, as shown in Figure 4. There were only two net increases seen during this period: one of less than 2% from 1988 to 1989 and one of 3% from 1992 to 1993. These resulted from strong growth in only two or three countries. The first resulted from capacity increases of 1700 MWe in Japan,

Figure 3

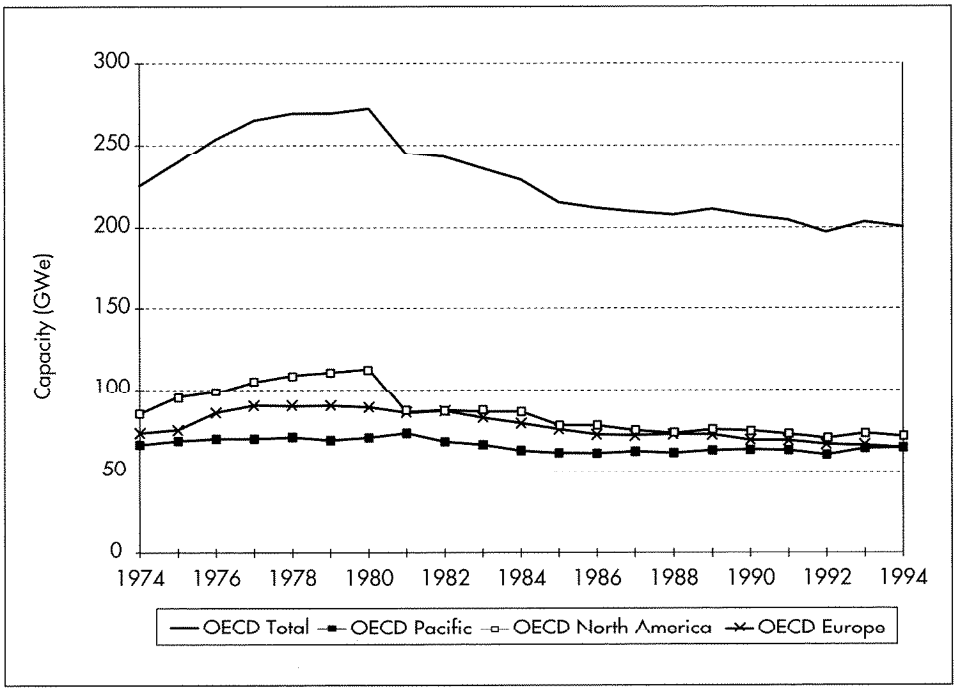
Oil-Fired Electricity Generation in the OECD



Source: IEA, *Electricity Information*.

Figure 4

Oil-Fired Generation Capacity in the OECD



Source: IEA, *Electricity Information*.
Notes: Sharp drop in North American capacity over 1980-1981 due to statistical reclassification of multi-fuelled power plants.
Mexican capacity included beginning 1982.

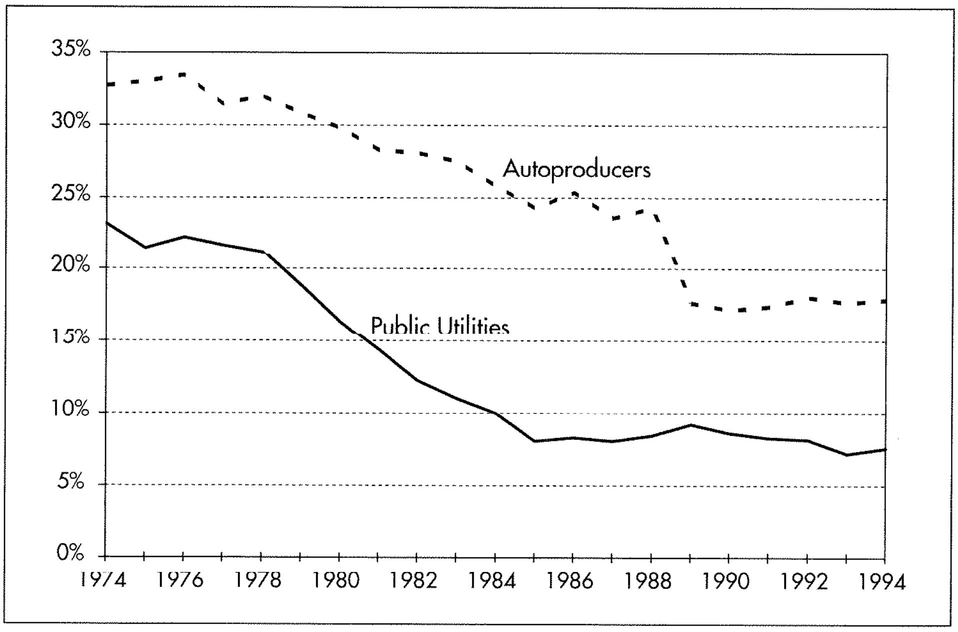
1400 MWe in the United Kingdom, and 600 MWe in United States. The second was concentrated in a 4000 MWe increase in Mexico and a 3500 MWe increase in Japan.

Flue-gas desulphurisation equipment is installed in oil-fired plants essentially only in Japan. In the OECD countries accounting for 90% of oil-fired capacity (Japan, United States, Italy, United Kingdom, France, Spain, Canada, and Germany), there are no known oil-fired plants with flue gas desulphurisation, except in Japan and for several plants burning Orimulsion. This situation has resulted because most oil-fired power plants were planned or put into service in the late 1960's and 1970's, when the stringent emissions regulations that are applicable throughout the OECD for new power plants were not in force. These plants have typically been allowed to continue operation without scrubbers. If local authorities require upgrades to the environmental control systems of an existing oil-fired plant, the economic choice is most often to cease plant operations or convert it to natural gas. This is because in most countries oil-fired plants are used to meet peak and intermediate load, for which the high investment in emissions control equipment is not warranted.

Oil's share of electricity production is higher among autoproducers than among public utilities (Figure 5). This is at least partly a consequence of the large contribution to autoproduced electricity by the petrochemical industry, which typically uses some portion of lower grade products for electricity production. Total oil-fired generation by autoproducers did not experience the same drop as did overall oil-fired generation from 1974 to 1985, falling 30% compared to 40% overall. Since 1986, autoproduced oil-fired generation has increased at an average rate of 6.8% per annum, led by a 38% growth rate in the United States. In 1991 it reached its highest level since 1974. Given this growth in oil-fired autoproduction and decrease in overall oil-fired generation, oil-fired autoproduction has consistently increased in share relative to public electricity production since 1986 (Figure 6). It reached almost 20% of total oil-fired generation in 1994. The United States, Japan, and Italy showed the largest absolute increases in oil-fired autoproduction. From 1986 to 1994, increases in these countries were 17.2 TWh in the United States (data from 1989 to 1994 only), 12.6 TWh in Japan, and 4.0 TWh in Italy.

Figure 5

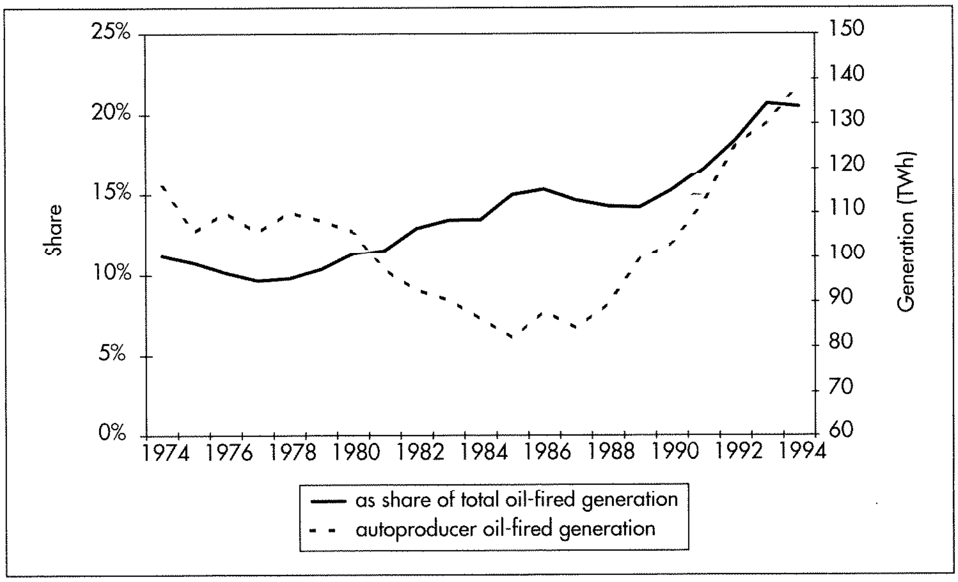
Oil's Share of Power Generation among Autoproducers and Public Utilities



Source: IEA, *Electricity Information*.

Figure 6

Oil-Fired Electricity Generation by Autoproducers



Source: IEA, *Electricity Information*.

Regional Trends

The general trends noted above for use of oil in power generation in the OECD as a whole apply also to many individual Member countries. The differences among countries are a consequence of, primarily:

- different levels of oil-fired power generation immediately prior to the price increases of the 1970's;
- indigenous energy sources;
- potential for substitution of other fuel sources for electricity production;
- national policy actions.

Table 1 summarises the production and capacity of oil-fired power stations in OECD Member countries in the year of each country's maximum levels and in 1994. Tables 2 to 4 list (for individual Member countries in decreasing order): oil-fired generation, oil-fired generation as a fraction of country total generation, and oil-fired capacity. In absolute values, Japan, the United States, Italy and Mexico accounted for 86% of oil-fired generation and a similar fraction of capacity. Over one quarter of total electricity generation is met by oil-fired plants in Mexico, Italy, Portugal, and Japan. Mexico has

Table 1

Production and Capacity of Oil-Fired Power Generation in the OECD
(Maxima and 1994)

	Max Oil-Fired Prod. (TWh)	1994 Oil-Fired Prod. (TWh)	Decrease from Max. (%)	Max Oil-Fired Capacity (GWe)	1994 Oil-Fired Capacity (GWe)	Decrease from Max. (%)
Australia	5.9	3.6	39	1.7	1.3	23
Austria	5.8	2.4	59	1.2	0.3	78
Belgium	21.8	1.6	93	2.2	0.6	71
Canada	18.2	9.2	49	8.3	6.2	26
Denmark	16.7	3.1	82	3.6	0.8	78
Finland	8.3	1.8	78	1.4	0.9	34
France	73.3	5.6	92	12.8	9.0	30
Germany	44.8	8.8	80	12.3	5.7	54
Greece	9.1	8.0	12	2.1	2.1	0
Iceland	0.1	0.0	94	0.2	0.1	6
Ireland	7.2	2.8	61	1.8	0.7	60
Italy	116.3	116.3	0	19.0	18.3	3
Japan	341.0	255.8	25	71.3	63.0	12
Luxembourg	0.5	0.0	97	0.0	0.0	38
Mexico	87.8	87.8	0	18.0	18.0	0
Netherlands	25.5	3.1	88	1.1	0.0	97
New Zealand	1.7	0.2	88	0.5	0.3	31
Norway	0.4	0.0	100	0.2	0.1	43
Portugal	13.9	8.0	42	2.7	2.7	0
Spain	43.1	10.5	76	8.2	7.7	6
Sweden	18.8	4.0	79	7.9	4.6	43
Switzerland	3.6	0.3	93	0.8	0.8	0
Turkey	7.4	5.5	25	2.1	1.9	8
United Kingdom	91.7	17.7	81	20.4	8.0	61
United States	390.6	120.5	69	104.6	47.1	55
OECD Total	**1120**	**677**	**40**	**272**	**200**	**26**
OECD Pacific	**347**	**260**	**25**	**73**	**65**	**12**
OECD North America	**435**	**217**	**50**	**113**	**71**	**37**
OECD Europe	**397**	**200**	**50**	**90**	**65**	**28**

Source: IEA.
Notes: Oil-fired capacity estimated by IEA Secretariat for Sweden. OECD total and regional maxima are for a single year and therefore do not correspond with the sums from column above. The median year for maximal oil-fired power generation was 1978. In most countries (2/3 of OECD countries) the maxima was reached before 1982.

Table 2

Oil-Fired Generation in OECD Countries, 1994

	1994 Generation (TWh)	OECD Share
Japan	255.8	38%
United States	120.5	18%
Italy	116.3	17%
Mexico	87.8	13%
United Kingdom	17.7	3%
Spain	10.5	2%
Canada	9.2	1%
Germany	8.8	1%
Portugal	8.0	1%
Greece	8.0	1%
France	5.6	<1%
Turkey	5.5	<1%
Sweden	4.0	<1%
Australia	3.6	<1%
Netherlands	3.1	<1%
Denmark	3.1	<1%
Ireland	2.8	<1%
Austria	2.4	<1%
Finland	1.8	<1%
Belgium	1.6	<1%
Switzerland	0.3	<1%
New Zealand	0.2	<1%
Luxembourg	0.0	<1%
Iceland	0.0	<1%
Norway	0.0	<1%
OECD Total	**677**	**100%**

Source: IEA.
Note: Includes public and autoproducer supply.

indigenous supplies of crude oil which have encouraged use of oil products for electricity production. Italy, Portugal, and Japan are in the opposite situation and have had less potential for substitution of other fuels to reduce oil-fired power generation. The particular situation of these countries is described in greater detail below.

Table 3

Oil's Share of Total Country Generation, Maximum and 1990s

	Year of Max. Share	Maximum Share (%)	1990s Average (%)
Mexico	1994	59	54.6
Italy	1973	62	49.4
Portugal	1981	59	34.2
Japan	1973	72	27.3
Greece	1973	50	21.8
Ireland	1978	69	14.4
United Kingdom	1984	32	8.7
Turkey	1973	52	6.8
Spain	1976	47	6.8
Austria	1976	15	4.8
Denmark	1971	81	4.5
Netherlands	1966	47	4.2
United States	1977	17	3.7
Canada	1968	5	2.5
Finland	1973	32	2.5
Luxembourg	1972	21	2.4
Australia	1974	7	2.3
Belgium	1971	54	2.2
Germany	1969	13	2.1
France	1973	40	2.0
Sweden	1970	31	1.8
Switzerland	1972	11	0.7
New Zealand	1974	9	0.2
Iceland	1966	7	0.1
Norway	1960	1	0.0
OECD Total	**1973**	**26**	**8.8**
OECD Pacific	**1973**	**62**	**22.9**
OECD North America	**1977**	**16**	**5.2**
OECD Europe	**1973**	**27**	**8.4**

Source: IEA.

Within the United States, five utilities in Florida, the New York City area, and Hawaii accounted for half of total US oil consumption for power production in 1994. One large utility in Florida consumed 29% of oil used in

Table 4

Oil-Fired Capacity in the OECD, 1994

	GWe	OECD Share
Japan	63.0	31%
United States	47.1	23%
Italy	18.3	9%
Mexico	18.0	9%
France	9.0	4%
United Kingdom	8.0	4%
Spain	7.7	4%
Canada	6.2	3%
Germany	5.7	3%
Sweden	4.6	2%
Portugal	2.7	1%
Greece	2.1	1%
Turkey	1.9	<1%
Australia	1.3	<1%
Finland	0.9	<1%
Denmark	0.8	<1%
Switzerland	0.8	<1%
Ireland	0.7	<1%
Belgium	0.6	<1%
New Zealand	0.3	<1%
Austria	0.3	<1%
Iceland	0.1	<1%
Norway	0.1	<1%
Netherlands	0.0	<1%
Luxembourg	0.0	<1%
OECD Total	**200**	**100%**

Source: IEA.
Note: Capacities estimated for Sweden.

power stations. Thus, within the United States, oil use in power plants is not evenly distributed geographically.

Countries showing the biggest absolute drops in oil-fired capacity are the United States, Japan, the United Kingdom, and Germany. Together these countries account for 80% of the total reduction in oil-fired capacity of OECD Member countries. The

United States alone accounts for one half of oil-fired capacity removed from service. In 20 of 25 OECD countries the drop in oil-fired power generation was 33% or greater.

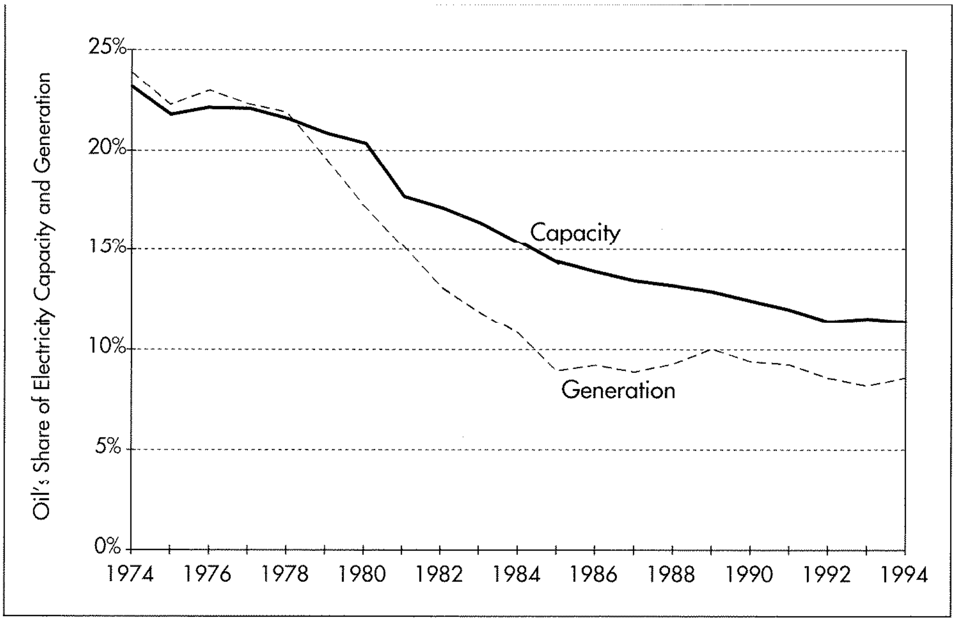
A small number of countries stand out in contrast to the overall trends in oil-fired generation, showing little change or increases in oil-fired generation production and capacity: Italy, Mexico, Greece, Portugal, and Turkey. Italy and Mexico have consistently increased oil-fired power generation in the last 10 years. From 1985 to 1994, Italy's annual rate of growth in oil-fired generation was 5%; in Mexico it was 6%. In both countries, oil's share of total electricity generation was roughly one half. Greece, Portugal, and Turkey showed essentially constant levels of oil-fired power capacity over the same period, while output decreased by 30% or less.

UTILISATION RATES OF OIL-FIRED UNITS

Figure 7 shows oil's share of total OECD power generation capacity and production from 1974 to 1994. Up to 1978, oil-fired generation provided roughly equal shares

Figure 7

Oil's Share of OECD Electricity Capacity and Generation



Source: IEA, *Electricity Information*.

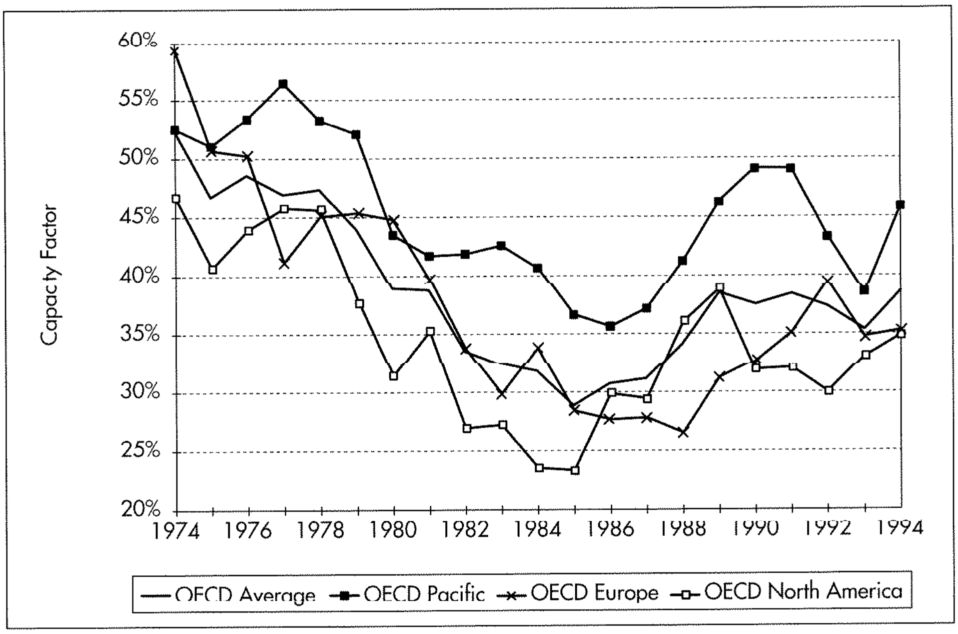
of both total generation capacity and production. After the second oil price increase, however, production began to be reduced more quickly than capacity. This reflected steadily decreasing utilisation rates (capacity factors) from 1978 to 1985. Based on IEA data, utilisation rates of oil-fired plants declined from an average of 47% in 1978 to 30% in 1985, as shown in Figure 8. The situation varied considerably by region and by country, but the tendency in the OECD as a whole was to use oil-fired power plants as intermediate- and peak-load plants.

As with other trends in oil-fired generation, the trend towards lower utilisation was reversed following the 1986 oil price drop. Since 1989 the OECD average has remained between about 35 to 38%. Utilisation rates of oil-fired power plants are thus approximately at the same level as in the early 1980's.

The countries showing the greatest fraction of electricity generation using oil also have the greatest utilisation rates of oil-fired power plants. Figure 9 shows the capacity factors of Italy, Mexico, Japan, Portugal and Greece, all of which have over 20% of total generation met by oil-fired plants, and all of which consistently had utilisation rates above the OECD average. Italy is the only country in which oil-fired plants are used predominantly for baseload service. Portugal's utilisation

Figure 8

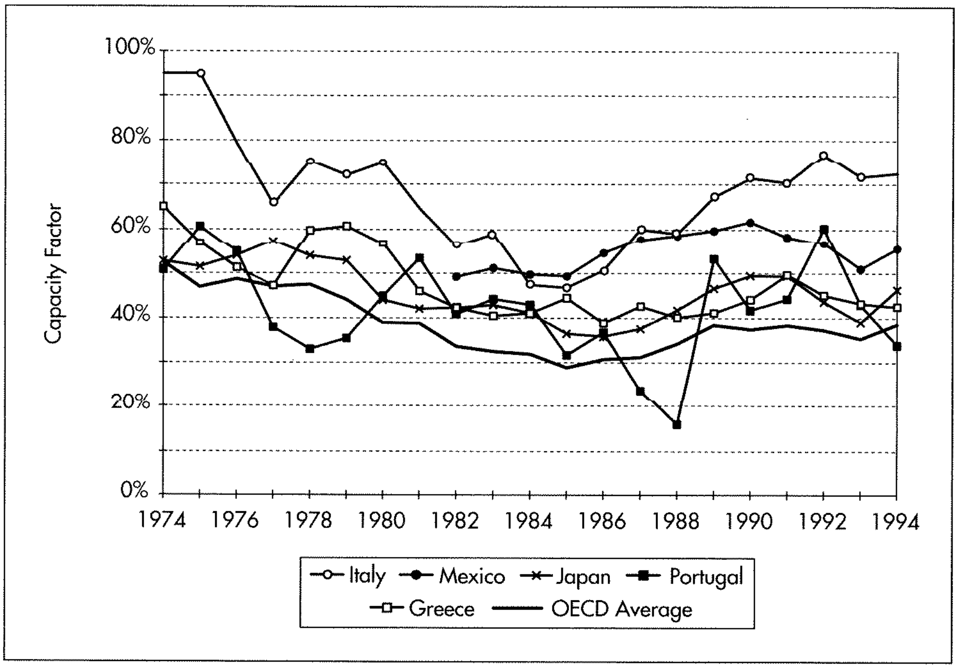
Oil-Fired Plant Capacity Factors, OECD Regions



Source: IEA, *Electricity Information*.
Note: Mexican figures are included beginning in 1982.

Figure 9

Capacity Factors of Oil-Fired Power Plants in OECD Countries with More Than 20% of Electricity Produced by Oil



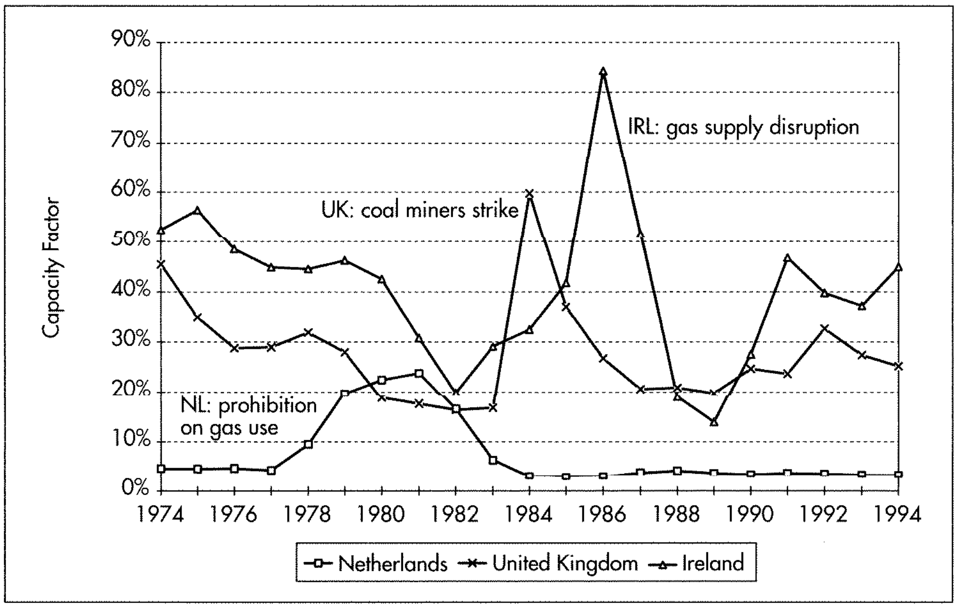
Source: IEA, *Electricity Information*.

rate, as with total oil-fired generation, is intimately related to total hydroelectric production available in any given year. This has led to wide variations in utilisation rate, from less than 20% in 1986 to 60% in 1992.

The ability of oil-fired generation to rapidly accommodate a shortfall in electricity production from other fuels has been shown in the United Kingdom, Ireland, and the Netherlands (Figure 10). A rapidly varying pattern of utilisation was evident in the United Kingdom due to the effect of the coal strike there in 1984. Oil provided a substitute fuel when coal availability was restricted, causing oil-fired plant utilisation factors to increase by a multiple of nearly four in one year. A similar spike in plant utilisation factors was seen in Ireland from 1985 to 1987 when supplies of natural gas to the Irish Electricity Supply Board were interrupted due to a legal dispute involving the gas supply companies. From 1985 to 1986 utilisation rates of oil-fired plants more than doubled. A final example of oil's role as a flexible backup fuel similar is given by the Netherlands in the mid-1970's. The decision by the national government to discourage natural gas use in power generation in the mid-1970's led to a five-fold increase in utilisation rates of oil-fired plants in four years.

Figure 10

Capacity Factor of Oil-Fired Power Plants in Ireland, the UK and the Netherlands



Source: IEA, *Electricity Information*.
Note: Utilisation rate of plants in the Netherlands based upon declared liquid and liquid/gas capacities.

Note that utilisation rates in this section are calculated as:

$$\frac{\text{total oil-fired power production}}{8760 \times \text{oil-fired capacity}}$$

This calculation does not provide an accurate estimate of "technical" capacity factor because of the effect of dual-fuel, multifuel and combined heat and power plants whose output may be produced using oil but whose capacity is not counted in the oil-fired total. The statistical data required for the technically rigorous calculation is not available from the IEA data bases. That is, the capacity of multifuel plants using oil as the predominant fuel is not known. Therefore, technical capacity factors are lower than those reported here. This is probably most noticeable in the United States, where there is a large installed capacity of multifuel power plants and fuel switching is technically and economically possible. It is estimated that capacity factors of US oil-fired plants are overstated by one third in 1993 using the above formula because approximately 25 GWe of multifuel power plants is primarily oil-fired, while single-fuel oil-fired capacity is roughly 50 MWe.

The conclusions regarding utilisation rates are not altered by the difference between capacity factors reported here and "technical" capacity factors. Actual capacity factors will tend to be lower than estimated above, confirming the conclusion that oil-fired plants, whether single or multifuel, are used primarily for peaking and intermediate load in the OECD.

ROLE OF OIL-FIRED POWER GENERATION

As described in the previous section, in most OECD countries oil-fired power generation provides peak load and intermediate load electricity. Oil-fired power plants have, on average, the lowest utilisation rates of any other type of plant except for pumped hydro plants, which are specifically designed for peaking duty. Oil-fired power plants have in many cases assumed this role as a result of increased oil prices, not by initial design. Many oil-fired power plants constructed in the 1960's and 1970's were at the time economically viable in baseload and intermediate load duty. However, as the price of heavy fuel oil increased in the 1970's, oil-fired plants became more expensive to operate and were used less as other plants provided a greater share of baseload and intermediate load power.

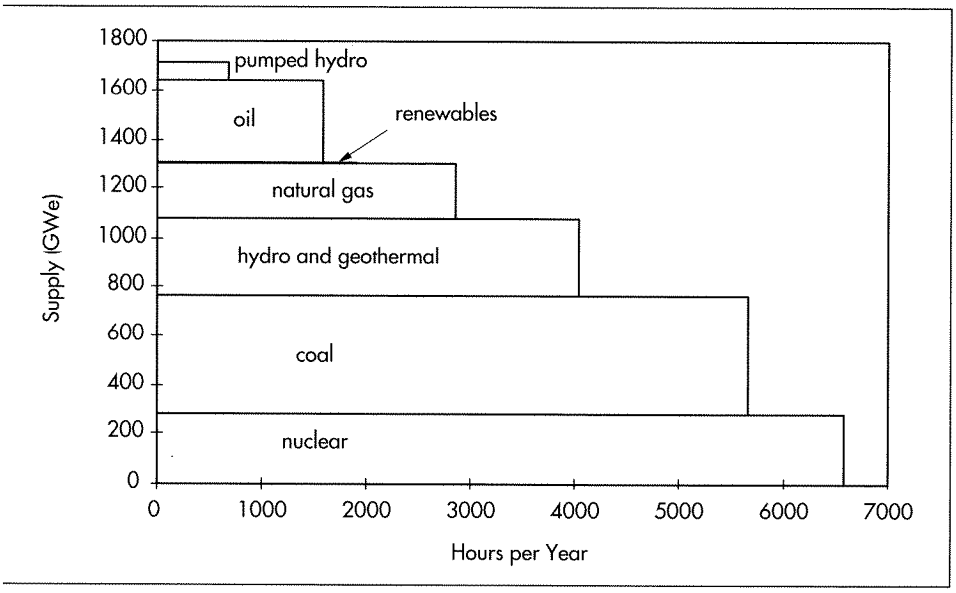
The role of oil today is illustrated by the overall OECD electricity supply curve, shown in Figure 11. This shows the gigawatt contribution of each electricity energy source to overall electricity supply over a certain number of hours per year. Coal and nuclear power plants provide baseload power, while hydro, geothermal, and natural gas provide intermediate load power, on average. Oil and pumped hydro provide peaking power, on average. This typical role of oil-fired power generation does not apply in all countries. The later section on economics of oil-fired power generation (Section III) describes the supply curve in greater detail.

Since oil-fired generation generally occupies the role of peak supply, it is often called into use when extremes of weather are reached. For example, high summer electricity demand due to air conditioning loads are often met by increased oil-fired power output. This is typical, for example, in Japan and in the southern United States. Similarly, during severe cold weather oil-fired power plants may be called into service to meet peak loads, particularly if natural gas supplies to gas-fired power plants are limited by competing space-heating demand. In countries that rely upon hydroelectric power to meet peak loads, such as Sweden and Portugal, a dry year can lead to increased oil-fired power generation. Oil-fired power generation may also increase in response to long-term load growth before new plants can be constructed to cover the growth.

Oil-fired power plants are used not only for meeting daily and seasonal peaks in electrical demand, but for supplying power when fuel supplies to other plants are interrupted. Examples of this are shown in Figure 10. This role falls naturally to plants having the lowest utilisation factors in electricity supply systems, but oil-fired

Figure 11

OECD Electricity Supply Curve, 1993



Source: IEA, *Electricity Information*.
Notes: Multifuel capacities assigned to each respective fuel per IEA Secretariat estimates.
Hydroelectric plants are economically operated at all load levels (baseload, load-following, and peak) depending on the characteristics of the water supply. Figure 11 presents production time for OECD hydroelectric plants on average.

power plants are particularly suited to this duty because of the flexibility and diversity of supply options for oil.

It is this flexibility and diversity of supply that makes oil-fired power generation a valuable option when other energy sources for power generation are not available, either through lack of infrastructure or for reasons of public policy. That is, if energy sources typically used for baseload power generation are limited in a particular region or country, oil may be used to meet a greater portion of the electricity supply. This is the situation in Italy, for example, where political constraints on nuclear and coal-fired power production have left few economic options for baseload power generation.

Oil-fired power plants are well suited to small, isolated electricity supply systems, such as found on islands or in remote wilderness areas. In such cases, internal combustion engines, gas-turbine based plants, or small boilers fuelled on petroleum products can be the most economic options for meeting the entire demand curve. Examples of this are found in the Greek islands of the Aegean Sea and in the Hawaiian Islands of the United States.

CHARACTERISTICS OF NATIONS WITH HIGHEST PERCENTAGE OF OIL-FIRED GENERATION

The OECD countries with an average fraction of oil-fired power generation greater than 10% for the for the period 1990-1994 are:

Mexico	55%
Italy	49%
Portugal	34%
Japan	27%
Greece	22%
Ireland	14%

None of these countries except Ireland have significantly reduced oil use below levels observed in the 1980's. The countries may be categorised as having the following characteristics:

Low fuel oil price: Mexico. Mexico is a significant producer and exporter of crude oil. Its average fuel oil prices delivered to power plants are the lowest in the OECD. Relative to both natural gas and coal Mexico's fuel oil prices have also been low. There are also strong links between oil refining and power production in Mexico through the state-owned companies responsible for those industries. Eight power plants are linked directly to refineries through fuel oil pipelines. Power plants consumed the equivalent of 57% of Mexican refinery output of fuel oil.

Limited non-oil capacity: Portugal, Greece, and Ireland. These countries have reduced oil use largely by substituting solid fuels. Portugal has substituted imported coal, Greece has used indigenous lignite, and Ireland has used indigenous peat and imported coal. However, each of these countries is constrained in its economic alternatives to oil-fired generation for power. Portugal has abundant hydroelectric power used for peaking, but must retain a significant share of oil-fired generation for dry years in which that source is limited. Natural gas has not been available. In Greece, natural gas has not been available, hydroelectric capacity has reached a plateau, and there are numerous isolated electrical supply systems on islands. Ireland's Electricity Supply Board substituted first gas in the early 1980's, then hard coal beginning in 1986 to reduce oil's contribution to overall generation. The latter involved the introduction of a 915 MWe coal-fired plant, which provided a reserve margin of over 40% to the 3800 MWe system. The possibility of economically substituting new non-oil peaking capacity in the existing collection of plants thus became limited. Gas provides the intermediate load and oil provides mainly peaking power.

Politically constrained: Italy and Japan. Italy's power generation sector has been constrained by political restrictions on the use of nuclear or coal plants. A moratorium on nuclear plants has effectively eliminated their contribution to the electricity supply, and coal plants have been, individually, exceedingly difficult to construct due to local political opposition. This has left oil, hydroelectric, and, more recently, gas as the practical alternatives. Oil has therefore retained a high share of generation in Italy.

Japan has considerably reduced oil-use in power generation, but has done so under the moderating influence of government guidance: the Ministry of International Trade and Industry, working with the 10 major electricity supply companies, has established long-term targets for oil-fired generation. One goal was to preserve the large investment in existing stock of oil-fired power plants, relatively few of which have been converted to use other fuels (less than one fifth). Another important factor in Japan's case, as in Portugal, Greece, and Ireland, is the lack of economic alternatives for meeting intermediate and peak load. Japan's electricity demand has experienced more pronounced summer peaks in recent years as the use of air conditioning has grown. Hydroelectric power, while it has grown, is limited in contribution, and natural gas must be imported as expensive liquefied natural gas. This has left oil in existing plants as a valuable alternative.

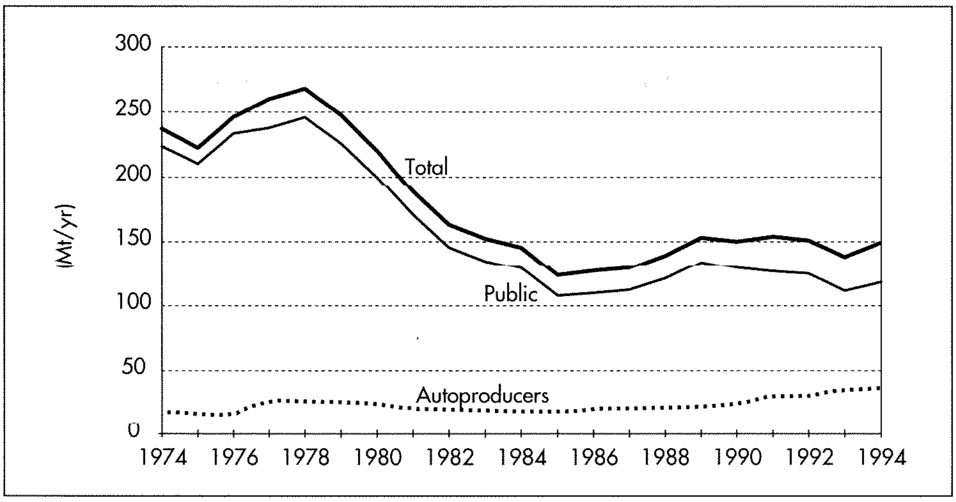
OIL PRODUCT MIX

Figure 12 shows the use of all oil products for power generation in the OECD. Figures 13 and 14 provide the breakdown on individual oil products and Figure 15 shows the product shares of the three largest products. Total oil product consumption has dropped from a peak of 250 000 kt/yr to about 150 000 kt/yr, or an absolute drop of 40% parallelling the drop in oil-fired generation. Fuel oil has, by far, the single largest share of oil products used in power generation, at about 80% of energy supplied. The next single largest product is crude oil, which accounts for 14% of total OECD oil use for power generation. Distillate oil and diesel together are the third largest product type, at about 4%. Other products are all less than 2% each. Crude oil and natural gas liquids (NGL) are burned only in Japan. Naphtha and liquefied petroleum gases (LPG) are also used almost exclusively in Japan, with minor use of naphtha in Sweden and the United Kingdom and LPG in Italy.

The type of oil product used relates to the type of power plant in which it is burned. Fuel oil and crude oil are suitable for use in boilers, while the lighter, clean products may be used in internal combustion engines and gas turbines. The fuel shares noted above thus indicate that most oil in power generation is burned in conventional boiler steam electric power plants. The product mix also relates to the economic role of the

Figure 12

Total OECD Oil Input to Power Generation



Source: IEA, *Oil and Gas Information*.
Note: Apparent rise in autoproducer oil input over 1990-1991 due to addition of US data.

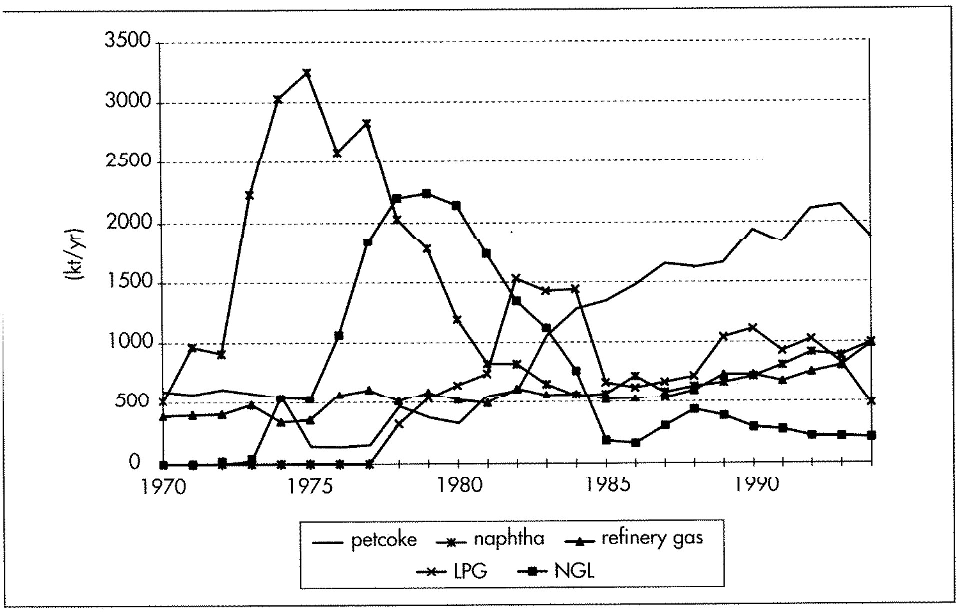
Figure 13

Use of Oil Products in Electricity Generation

Source: IEA, *Oil and Gas Information*.

Figure 14

Use of Oil Products in Electricity Generation, Fuel Oil, Crude Oil, Gas Oil Excluded



Source: IEA, *Oil and Gas Information.*

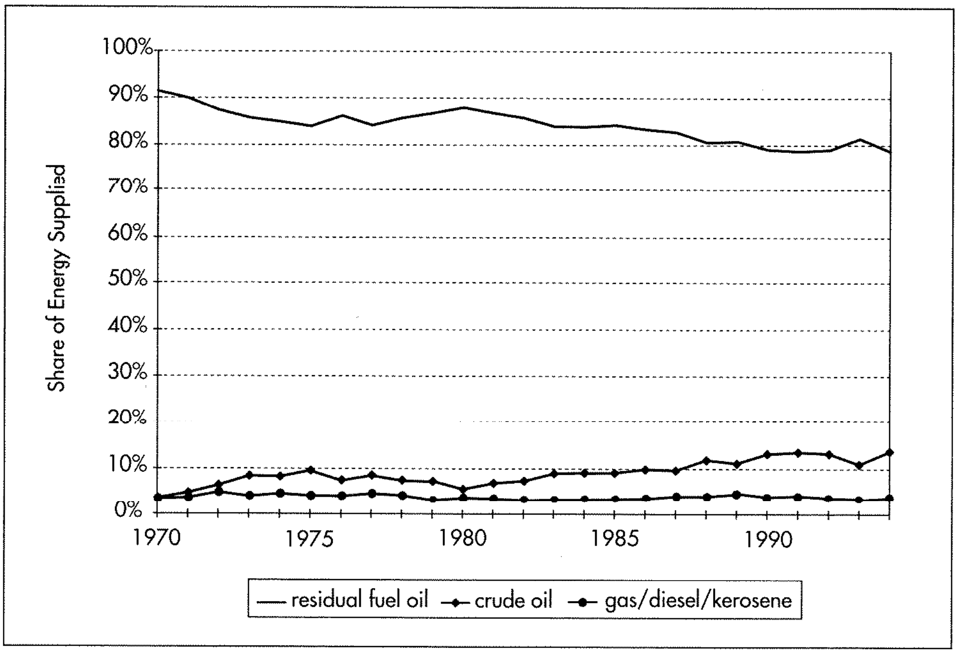
different petroleum products in meeting electrical demand. Typically, fuel oil can be used economically for meeting peak and, in some systems, intermediate load. The higher price of lighter products restricts their economic use to meeting a smaller fraction of peak electrical demand, hence the lower use of these fuels.

Over time the relative quantities of heavy fuel oil and lighter refined products have remained quite stable. Gas oil, diesel, and kerosene together have provided about 4% of the energy input to oil-fired power generation for over 20 years. Successive, relatively small peaks of naphtha, LPG, and natural gas liquids were seen in the 1970's and early 1980's but these had only a minor effect upon fuel-oil's energy share. This is represented in another way by Figure 16, which shows the trends in weighted average density of petroleum products used for power generation. Omitting crude oil, the average density has remained close to 960 kg/m^3 for 20 years. If crude oil is included, the average density has increased, indicating a greater share of crude oil in the overall product mix. The use of crude oil is discussed further below.

One trend of note is the increasing use of petroleum coke in certain countries. Petcoke for power generation has been increasing at an average rate of

Figure 15

Petroleum Product Shares in OECD Power Generation



Source: IEA, *Oil and Gas Information*.

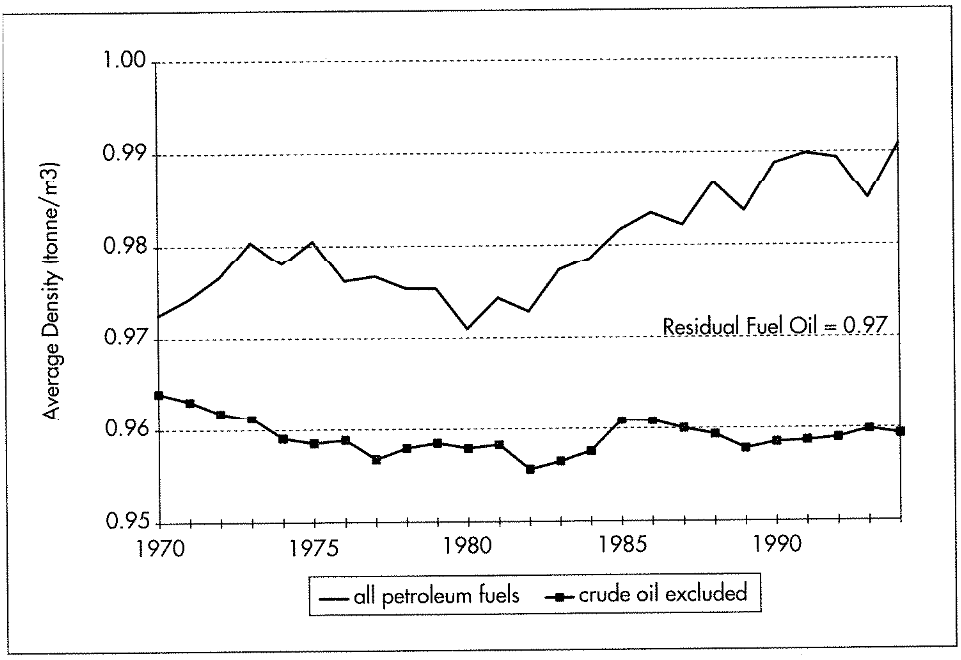
over 130 000 tonne/yr since 1980. This increase is due to nearly equal increases in the United States and Japan of about 80 000 tonne/yr while at the same time France decreased usage by about 40 000 tonne/yr. Because of petroleum coke's low reactivity, it is normally co-fired with coal at less than 40% of total thermal input. Its share of OECD oil-fired energy input was 1.4% in 1994. Power plants consume less than 5% of total OECD petcoke production.

Low vs. High-Sulphur Fuel Oil

As the products of crude oil refining, petroleum products used for power generation inevitably contain sulphur. This element tends to be concentrated in the residual products of refining, such as heavy fuel oil. Thus limits on emissions of sulphur dioxide (SO_2) from oil-fired power plants are relevant and place a constraint upon the absolute quantities of fuel used in power generation. Installation of flue gas desulphurisation equipment in existing oil-fired plants has not been economically justified.

Figure 16

Average Density of Petroleum Fuels Used in OECD Power Generation



Source: IEA estimates.

Although the effect of emissions limits on the use of oil in power generation is not easily quantifiable, there has been a clear incentive to individual utilities to reduce fuel oil use in order to reduce SO_2 emissions, substituting generation by natural gas, coal-fired plants with emissions controls, or nuclear. Where switching to other fuels has not been possible or economic, the incentive has been to use low-sulphur fuel oil, generally defined as having 0.3% to 1.0% sulphur.

The use of low-sulphur fuel oil in power generation is well established in Japan and the United States. The average fuel oil sulphur content used in power stations was 0.8% in Japan and 1.0% in the United States from 1987 to 1994. There was not a marked shift towards the use of low-sulphur fuel oil for power generation in Japan or in the United States over this period. In Italy, where many oil fired power plants are used for baseload service, the sulphur content of fuel oil supplied to ENEL's power stations has declined steadily over that same period from 1.9% in 1987 to 1.2% in 1994. ENEL's plans call for further significant reductions in sulphur level used in their plants, shifting consumption to 0.25% sulphur fuel oil. Table 5 summarises sulphur levels in fuel oil supplied to utilities in these three countries accounting for 70% of OECD oil-fired generation.

Table 5

Sulphur Levels of Fuel Oil Delivered to Electric Utilities in Japan, the United States, and Italy

	1987	1990	1994
Fuel Oil Use, Mt			
Japan	21.4	27.8	28.5
USA	27.6	25.7	20.2
Italy	19.4	21.8	24.3
Average Sulphur, %			
Japan	† 0.8	0.8	0.8
USA	1.0	0.9	1.0
Italy	1.9	1.4	1.2

Sources: JEPIC, EIA, ENEL.
Notes: † 1985 value.
Sulphur levels for Italy estimated by IEA Secretariat using data provided by ENEL (ENEL, 1994).

In Japan, where crude oil accounts for a significant fraction of oil-fired power generation, the sulphur content of crude oil used for power generation has consistently been near 0.1% for the last 10 years.

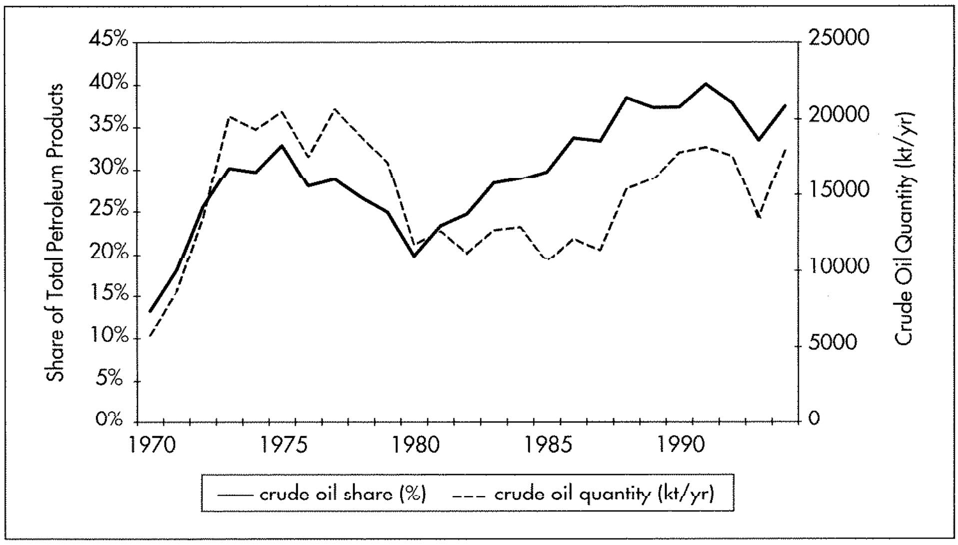
Crude Oil

Crude oil accounted for about 14% of total OECD oil-fired power generation in 1994. Within the OECD, only Japan burns crude oil directly in power plants. Figure 17 shows the trends in crude oil use in Japan since 1970. Crude oil as a fraction of total petroleum product use has been increasing steadily as a share of total petroleum product use since 1980. In absolute terms, crude oil use remained constant during most of the 1980's, then increased dramatically from 1987 to 1991. Most recent figures show roughly 1/3 of all Japanese oil-fired power generation is met with crude oil, or approximately 15 000 kt/year. The low-sulphur crude oil is primarily Indonesian Sumatran Light (60%), Chinese Daqing (23%), and smaller quantities of Vietnamese, Brunei, and Gabonese crudes.

Two factors have contributed to Japan's use of crude oil: the high cost of fuel oil compared to crude and the availability of low-sulphur crude oils from regional suppliers.

Figure 17

Use of Crude Oil in Japanese Oil-Fired Generation



Source: IEA, *Oil and Gas Information*.

Using fuel prices from IEA statistics, it appears crude oil has been a rational economic choice at the level of individual utilities, since fuel oil's unit delivered price to electric utilities in Japan, on a thermal basis, is greater than that of crude oil. This is an unusual situation, as in all other OECD countries, the price of fuel oil delivered to power stations is less than the average price of crude oil. Assuming similar conversion efficiencies and capital requirements for crude-burning and fuel-oil-burning plants, electricity production costs from crude oil would be less expensive than for fuel oil in Japan. This price situation results from a combination of high import duties on fuel oil relative to crude oil and the heretofore exclusive importing rights of Japanese refiners. The import duty adds roughly 20% to the cost of low-sulphur fuel oil (2.54 ¥/litre). In addition, the monopoly import position of Japanese refiners has allowed them to recover a variety of costs in their fuel oil price which might not be possible in a more competitive market. These include "safety costs", stockpiling costs, and indemnities for foregone production of light oil products from certain crude feedstock (JPET, 1995).

The prices of petroleum products for power generation are related to tight restrictions on sulphur emissions. There is a perceived environmental advantage to using crude oil for power generation because, as noted above, the sulphur content of crude oils used in Japan is very low - on average 0.10% (JEPIC, 1996). Low-sulphur heavy fuel oil or very-low-sulphur fuel oil are both more expensive than 0.1% sulphur crude oil in the

Japanese market. As crude's share of total oil-fired generation has been increasing over the past 15 years, the average sulphur content of fuel oil and crude oil combined has dropped, reducing total emissions of sulphur dioxides from oil-fired power plants.

Orimulsion

Orimulsion is the trade name for an emulsion of 70 % bitumen, 30% water, and a small quantity of surfactants (<0.5%) marketed for power generation by Bitúmenes Orinoco S.A. (Bitor), a subsidiary of the Venezuelan state oil company. The source of this product is the Orinoco basin in Venezuela, which is estimated to contain 120 billion barrels of economically recoverable bitumen (Petrostrategies, 1994). Seven power plants around the world, six of which are in OECD countries, are using Orimulsion (Table 6). Figure 18 shows the growth in Orimulsion for power generation since 1990, when the Ince B plant in the United Kingdom first began regular operation with this fuel. The current installed capacity of power plants burning Orimulsion is roughly 2000 MWe. Increased capacity coming on line within several years could be a 2000 MWe plant at Pembroke in the UK and a 660 MWe unit at Brindisi in Italy.

Orimulsion has properties similar to those of heavy fuel oil, but has high levels of sulphur and metals. Typically it contains 2.7% sulphur and its ash contains 19% vanadium (ChemE, 1995) as vanadium pentoxide. Transportation, handling, and storage methods are similar to those for heavy fuel oil. With suitable modifications, coal-fired or oil-fired power plants may use Orimulsion. The most significant modification needed is the installation of flue gas desulphurisation and particulate control equipment if not already present. Ash handling must be revised as well because the ash contains relatively high levels of heavy metals (Armor, 1996). Only two plants in the OECD have used Orimulsion without flue gas sulphur removal equipment. Both are owned by PowerGen in the United Kingdom. One of the two, Richborough, was severely criticised for its emissions, which were said to damage crops at a nearby farm. Both plants were closed at the end of their permitted operating periods when faced with the cost of installing flue gas desulphurisation equipment. The plant in Lithuania is currently operating without flue gas desulphurisation.

The price of Orimulsion is tied to a basket price of coals on the world market and is currently selling at about 35 US$/tonne fob Venezuela and 44 to 50 US$/tonne cif Europe (Petrostrategies, 1994; CST, 1996). This compares with OECD average import costs of roughly 40 US$/tonne for coal and 120 US$/tonne (18 US$/bbl) for crude oil. In the European Union it is classified as a natural bitumen for tax purposes in April 1994, and is therefore exempt from EU heavy oil duties of 13 ECU/tonne. Bitor has aimed its marketing of Orimulsion at coal-fired power plants and underutilised or closed oil-fired power plants.

Table 6

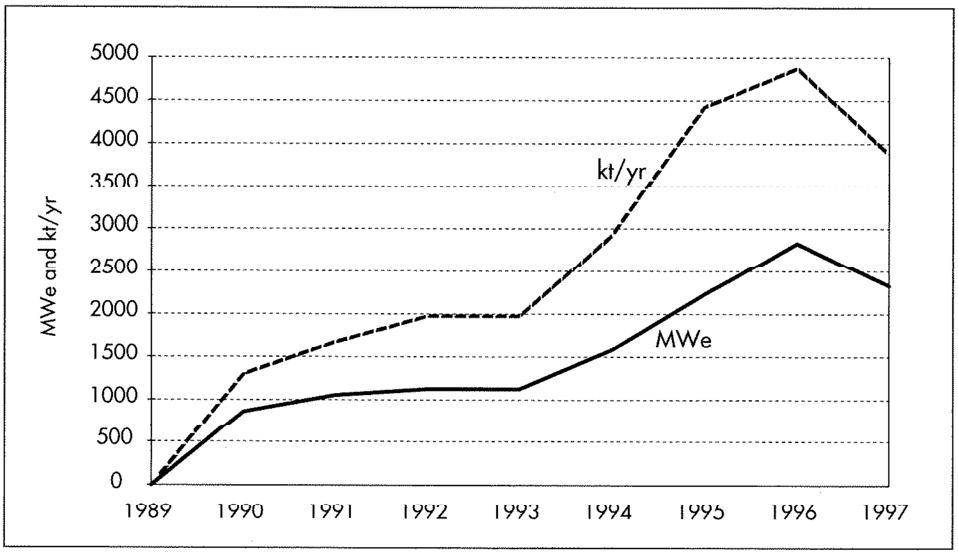
Use of Orimulsion for Power Generation

Country	Owner	Plant Name	Location	Startup Year	No. of Units	Total MWe	Orimulsion kt/yr
In Operation							
Canada	New Brunswick Power	Dalhousie	New Brunswick	1994	2	300	750
Denmark	SK Power	Asnaes # 5	Kalundborg	1995	1	650	1500
Japan	Hokkaido Electric	Shiriuchi	Hokkaido	1996	1	350	400
Japan	Kansei Electric	Osaka	Osaka	1994	1	156	200
Japan	Mitsubishi Kasei		Mizushima	1992	1	70	300
Japan	Kashimi Kita	Kashima	Kashima	1991	2	195	375
Lithuania	Lithuanian State Power	Lietuvos Elektrine	Vilnius	1996	2	300	250
Potential Users							
Italy	ENEL	Cerano	Brindisi	1997	4	660	500
Taiwan	Intergen (IPP)	Lizhe	Suao region	2000	2	1500	3400
United Kingdom	National Power	Pembroke	Wales	2001	4	2000	6000
Closed							
United Kingdom	PowerGen	Richborough	Richborough	1990	3	360	300
United Kingdom	PowerGen	Ince B	Chesire	1992	1	500	1000

Source: IEA.
Notes: Richborough (UK) closed in March 1996.
Ince B (UK) closed in March 1997.
Cerano (Italy) in test period during 1997.

Figure 18

Growth of Orimulsion in Power Generation



Source: IEA.

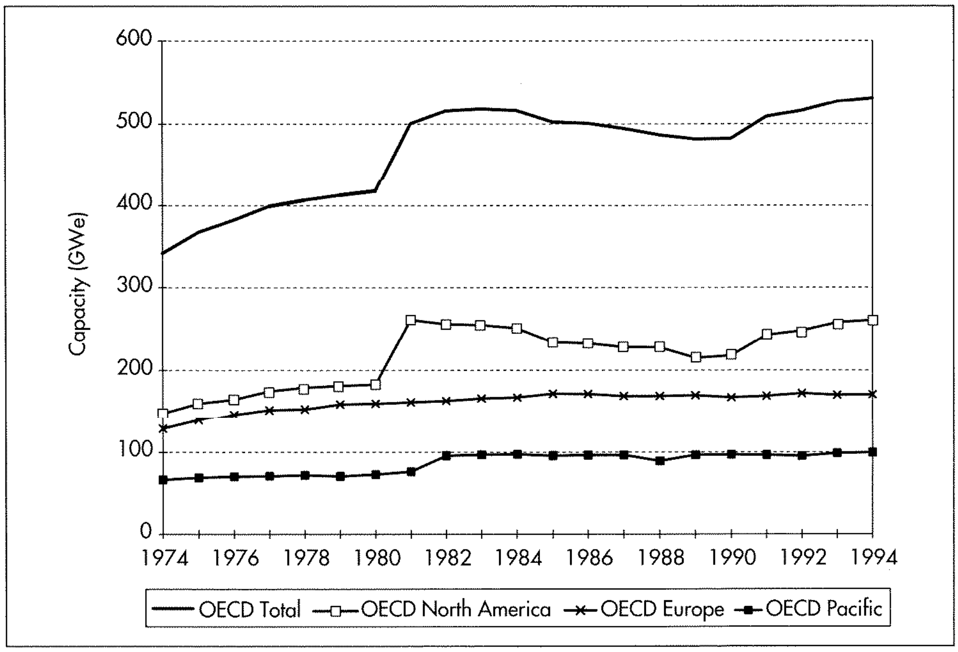
TRENDS IN MULTI-FIRING INVOLVING OIL

Oil-capable capacity refers to plants in which oil may be burned as at least one of the fuels. Although OECD oil-fired capacity has been dropping since 1980 (see Figure 4), oil-capable capacity has remained relatively constant at roughly 500 GWe since 1982, the first year when multifuel capability data was systematically collected (Figure 19). In the OECD Europe and Pacific regions, total oil-fired capacity was very stable. It was only in North America that oil-capable capacity showed at first a gradual decrease to 200 GWe by 1989 and then an increase to 260 GWe by 1994. This latter rise took place over the same period in which North American oil-fired capacity (single fuel capability) declined from 75 GWe to 71 GWe. The North American trends must be interpreted with caution, however, due to breaks in the statistical series for determining oil-capable capacity. Table 7 summarises capacity in the OECD that was oil-capable in 1994.

Figure 20 shows the trends in multi-firing when considered as a fraction of plants burning combustible fuels that are oil-capable. This fraction was in 1994 at the same level as it was in 1974, in round figures about one half. There is a sharp break in the statistics over 1980 to 1982 due to the introduction of dual- and multifuel capability to the statistics, but the break is revealing in itself. In the Pacific the fraction of combustible fuel plants that was reported as oil-capable in 1982 is about the same as in 1974, after a period of decline in singly-fired oil plants there from 1974

Figure 19

OECD Oil-Capable Capacity



Source: IEA, *Electricity Information*.
Notes: Mexican multifuel capacity not included.
Sharp increase in North American capacity over 1980-1981 due to break in statistical series.
Swedish capacity estimated by IEA secretariat after 1990.

to 1981. This suggests that plants formerly classified as oil-fired were converted to burn other fuels, but retained their oil-fired capability.

Similarly, in North America (excluding Mexican multi-fuel capacity), the fraction of oil-capable plants increased dramatically when the multi firing categories were introduced. This could indicate that oil-fired capacity planned or under construction before the oil-price increases of the 1970's was completed, but converted to dual or multi firing. In Europe there was not a dramatic change in fraction of oil-capable plants.

Since 1974 among individual OECD countries, only five experienced drops in the fraction of oil-capable capacity greater than 20%: Norway, Sweden, Turkey, Portugal, and Greece.

We may conclude from the above discussion that dual- and multi-fired plants have largely absorbed most reported decreases in oil-fired capacity since 1974. As a fraction of combustible fuel plants, in many countries oil-capable plants were at

Table 7

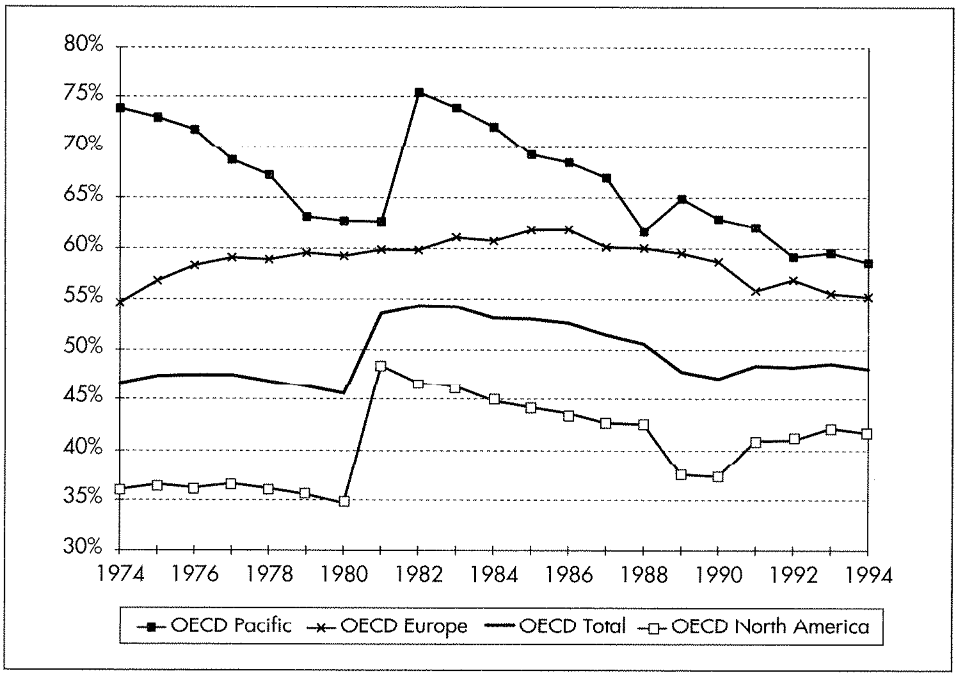
Oil-Capable Electric Capacity in OECD Regions, 1994 GWe

	Europe	North America	Pacific	Total
liquids	65	71	65	200
liquids/solids	45	14	11	71
liquids/gas	46	147	23	217
liquids/solids/gas	15	28	1	44
total oil-capable	**171**	**261**	**99**	**531**
total combustible fuels	310	625	170	1105
% oil-capable	**55**	**42**	**59**	**48**

Source: IEA
Notes: Swedish capacities estimated by IEA secretariat.
Sum of regions may not equal total due to rounding.

Figure 20

Fraction of Combustible Fuel Capacity That is Oil-Capable



Source: IEA, *Electricity Information.*
Notes: Mexican multi-fuel capacity not included.
Sharp increase in fractions over 1980-1981 due to break in statistical series.
Swedish capacity estimated by IEA secretariat after 1990.

the same level in 1994 as in 1974. Of the existing stock of oil-capable plants, few plants other those reported as "oil-fired" appear to currently use oil as the primary fuel, as is evident from the low calculated utilisation rates of the oil-fired plants. For example, in the United States, only about 16% of multifuel plants considered oil-capable actually consumed oil as the primary fuel (EIA, 1995b: p. 20).

RELATION TO OIL MARKETS AND THE REFINING INDUSTRY

Power generation is the single largest consumer of residual fuel oil, accounting for 44% of all OECD residual fuel oil demand in 1994. This fraction has remained between 39% and 45% since 1976, although the absolute quantities of fuel oil used in power generation have declined in parallel with the drop in oil-fired power generation. Since 1976, both the share and absolute quantity of residual fuel oil used in all other inland uses of fuel oil have declined steadily. Only the use of fuel oil in international marine bunkers has increased in absolute consumption and share. The trends in fuel oil demand shares are shown in Figure 21.

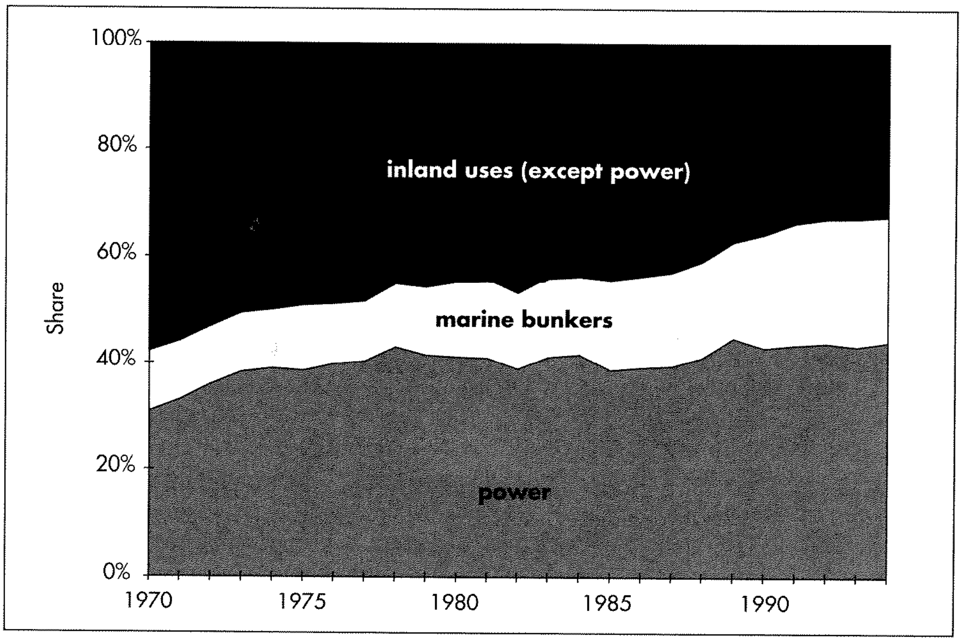
In certain fuel oil markets, power generation plays a significant role. For example, the Italian state power company ENEL is the single largest consumer of fuel oil in Europe and its purchases can have noticeable short-term effects upon fuel oil pricing.

Figure 22 shows the use of all oil products in the OECD since 1970. Electricity production accounted for 11% of total oil use in 1974. By 1994 this share declined to 7% as oil-fired electricity production declined and other uses, primarily transportation, increased in relative importance. Similar developments have been observed in global oil markets as well, with fuel oil declining in share from 23% in 1983 to 16% in 1994. More than half the world's fuel oil is consumed in non-OECD countries.

The shift in demand patterns towards lighter products has been observed since the early 1980's. This shift, or "lightening" of product demand, has been observed both within the OECD and globally, and is expected to continue. To meet this lightening demand, the oil industry has made major investments in refinery capacity which converts the heavy residue from primary crude distillation into light products. The percentage of residue converted has varied amongst regions depending upon the particular mix of products demanded. The highest level of residue conversion is in North America, where fuel oil now represents only about 5% total oil demand. To reach these low levels of fuel yield "deep conversion" of heavy residues from vacuum distillation and other processes must be used. Deep conversion processes are much more costly than the processes used to convert lighter feedstock because of the impurities in the residual oil and its higher carbon content.

Figure 21

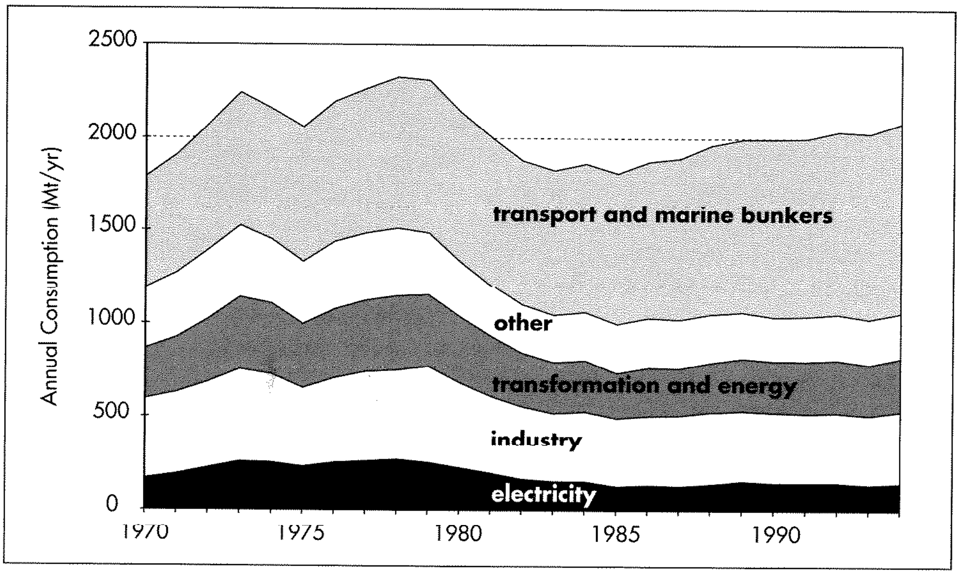
OECD Demand Shares of Residual Fuel Oil



Source: IEA, *Oil and Gas Information*.

Figure 22

Use of Oil Products in the OECD



Source: IEA, *Oil and Gas Information*.

The quality of crude oil feedstock also has a bearing upon the refinery processes used to obtain the final product mix. The fraction of crude that may be physically separated into lighter products, or its "lightness", varies according to the source of the crude. There has been a relatively small increase in the lightness of the global crude production mix recently as a result of increased production of North Sea and Saudi Arabian light crude oils. The outlook is for the average gravity to be essentially unchanged in the medium term. In the longer term, as reserves of lighter crudes such as those in the North Sea are depleted, there is likely to be a tendency towards decreased crude oil lightness.

With petroleum product demand tending towards lighter products and crude oil supply likely, in the long term, to become heavier, the refining industry is expected to need to build additional residue conversion capacity over time. This will allow them to convert otherwise surplus, low-value fuel oil to more valuable lighter products to supplement the light products made by primary distillation of crude oil. But the rate at which additional conversion capacity is added depends upon the potential to realise gains from the difference in price between light and heavy products. If an apparent long-term difference in price would be sufficient to cover the investment costs for upgrade capacity, plus the cost of the residual feedstock, there is an incentive to construct this capacity. The evolution of this price difference is key in determining capital investments in upgrade capacity.

It appears that the difference in price between heavy and light products does not currently provide an adequate incentive to construct conversion or upgrade capacity. This could lead to a period of increasing differential in price between light and heavy products if demand for light products continues to grow faster than for heavy oils. In the long term investment in conversion capacity could be expected to take advantage of the increased price differential, better matching production rates of both heavy and light products in relation to demand, and leading to a cyclical return to lower price differential.

III - FUTURE USE OF OIL IN POWER GENERATION

PROJECTIONS OF TOTAL AND OIL-FIRED ELECTRICITY GENERATION

The 1995 edition of the World Energy Outlook (IEA, 1995c) projects electricity generation in the OECD under two growth scenarios. An "energy savings" case projects energy growth assuming that energy conservation and energy efficiency improvements are implemented at a relatively high rate, while a "capacity constraints" case estimates growth assuming energy prices rise at rates consistent with potential constraints on the production capacity of fossil fuels. In the energy savings case, electrical generation is projected to increase at an annual rate of 1.4% between 1992 and 2000 and 0.9% between 2000 and 2010. During these same periods, oil-fired electricity generation would decrease by 2% per year and then increase at 0.1%. The decrease follows the historical trend away from oil-fired power generation shown in nearly all OECD countries. The slight uptake of oil-fired generation after 2000 results from continued growth of oil-fired generation in the OECD Pacific region. In the capacity constraints case, oil-fired electricity generation decreases 1.1% between 1992 and 2000 and 0.6% from 2000 to 2010.

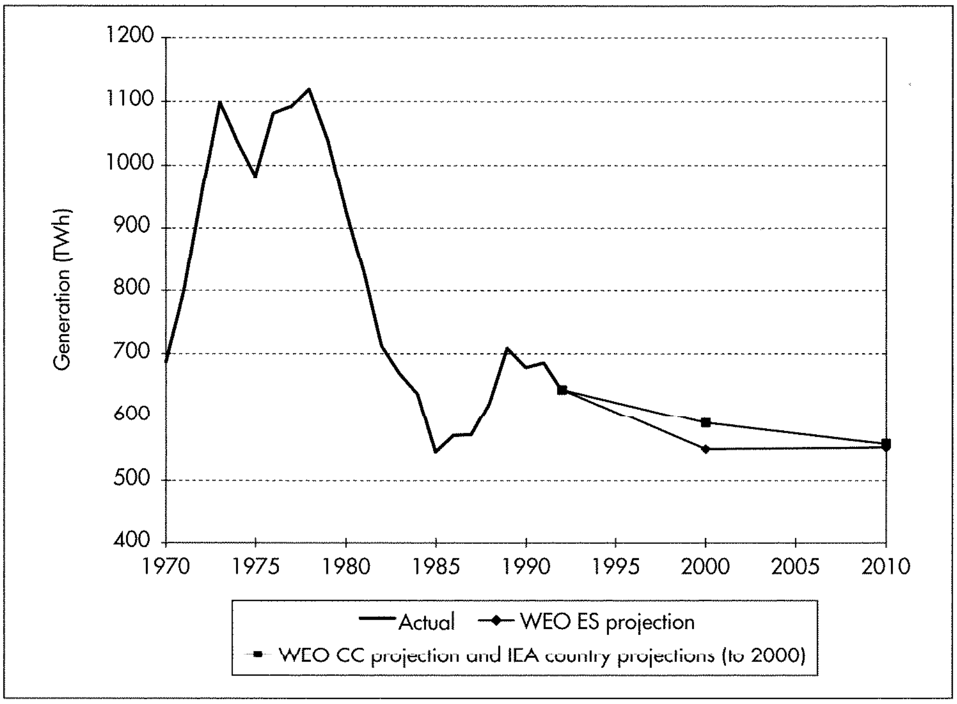
The projections to 2000 may be compared with those provided by IEA Member governments in the annual IEA survey (IEA, 1995a). These show an aggregate decline in oil-fired generation that closely matches the World Energy Outlook prediction. Natural-gas fired power plants and coal-fired power plants gain in share at the expense of oil-fired plants. Figure 23 summarises the projections.

These predictions should be regarded as indicating current trends, but not capable of capturing the short-term patterns of oil-fired power generation within the OECD. Since oil-fired generation tends to occupy a position of intermediate or low capacity factor in most OECD countries, short term variations in weather, indigenous energy supply, local energy prices, or economic activity can significantly affect total output. For example, the drop in oil-fired generation from 1992 to 1993 was nearly 10%, exceeding the projected eight year drop from 1992 to 2000 by both IEA Member countries and the World Energy Outlook. This drop was experienced most sharply in Japan, whose growth in gross domestic product slowed to only 0.5% in 1993.

The figures for both world energy outlook cases indicate that, in the absence of unexpected changes in current economic trends, oil-fired power generation will continue to decrease within the OECD.

Figure 23

History and Projections of Total Oil-Fired Generation in the OECD



Source: IEA.
Note: World Energy Outlook projections are normalized to 1992 actual generation data.

Oil-Fired Capacity

Projections for new oil-capable power plants are summarised in Table 8. There is only one currently planned power plant over 10 MWe capacity in OECD Europe and Pacific regions that will be fired exclusively on oil: a 150 MWe gas turbine in France to be fuelled on distillate. This is an example of a plant used for only a short period each year in which the use of expensive distillate is warranted, without recourse to natural gas. All new conventional thermal units will be fired on coal or natural gas, with certain among them capable of burning fuel oil as well.

In the United States up to 5000 MWe of new oil-capable capacity is planned or under construction for 2004 (EIA, 1995b; Secretariat estimates). Roughly 85% of this capacity is in three utilities that plan on adding dual-fired simple cycle gas turbines used for summer peaking. Natural gas is intended as the normal summer fuel in two of these utilities, but the seasonality of natural gas demand for peaking power plants makes firm gas supply contracts expensive for those plants.

Table 8

Planned Power Stations Having Oil as a Potential Fuel

Year	Country	Plant Name	Net MWe	Plant Type	Fuel
OECD Europe					
1997	Austria	Timelkam 2†	60	B	C/NG/O
1997	Austria	Timelkam 3†	115	GT	NG/O
1998	Austria	WSF-HAPA	84	B	C/O
1998	Austria	FHKW Klagenfurt II	35	CC	NG/O
2001	Austria	FHKW Linz Mitte†	74	B	C/O
2005	Austria	GuD Anlage Wien	350	CC	NG/O
1997	France	Vitry	150	GT	O
1998	Germany	Karlsruhe	345	B	NG/O
2005	Germany	Plattling	48	B	NG/O
1997	Italy	Montalto 2-3	1272	B	NG/O
1998	Italy	Montalto 4	636	B	NG/O
OECD Pacific and North America					
1999	USA	Maalaea (Hawaii)	58	CC	O
2000	USA	planned/proposed	3030	GT	NG/O
2000	USA	planned/proposed	80	IC	O
2004	USA	planned/proposed	1710	GT	NG/O
2004	USA	planned/proposed	6	IC	O
2000	Canada	authorised	132		
2005	Canada	authorised	951		
	Mexico		n.a.		
	Australia		0		
	Japan		0		
	NZ		0		

Sources: EURPROG, 1996 for OECD Europe;
EIA, 1995b for United States (nameplate capacities)
IEA, 1995a for other countries

Notes: † Repowering project
Projection not available for Mexico
Plant types: B - boiler; GT - gas turbine; CC - combined cycle; IC - internal combustion engine
Fuel: C - coal; NG - natural gas; O - oil

Therefore, interruptible gas supply contracts are used, with distillate fuel providing energy for winter peaks. In the third utility system, accounting for 2283 MWe of planned capacity, distillate oil is intended as an interim fuel for most of the capacity additions until natural gas becomes available at the plant sites. Each of the 15 units of about 150 MWe capacity planned on this system would operate typically less than 200 hours per year.

Since current utility plans within the OECD do not include new, large single-fuel oil-fired capacity, projections of the stock of oil-fired capacity depend on the rate of retirement of existing plant.

Influence of Other Plant Types

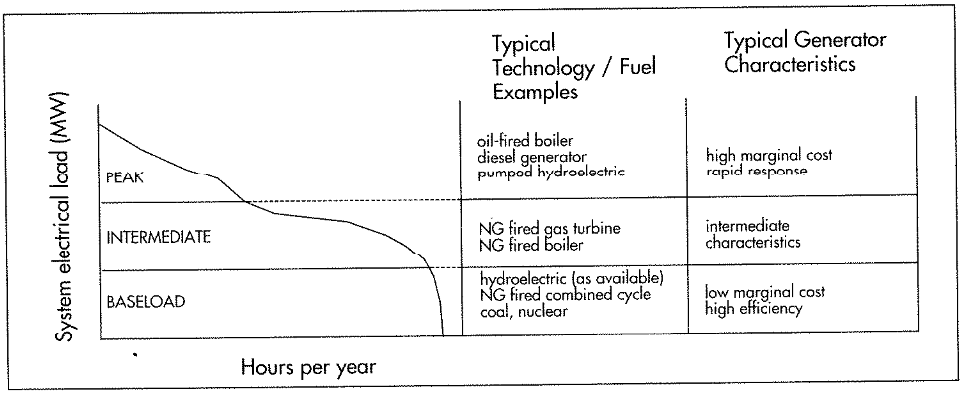
Just as oil is the swing supplier of energy, so oil-fired power generation can be expected to play the role of swing supplier of electricity. The above projections for both oil-fired generation and capacity depend on the introduction of new plants using coal or natural gas as well as a continued reliance on plants using the current mix of fuels. For example, in a number of countries the use of natural gas in power generation is expected to increase rapidly in the next five to ten years. Examples are Italy, Mexico, Spain, the United Kingdom, and the United States. Nuclear plants contribute about one quarter of OECD electricity supply, effectively displacing the equivalent amount of fossil-fuelled generation. Should projections of the rate of introduction of gas or coal-fired plants be too high in specific instances, or should nuclear's share of generation be reduced significantly, oil-fired power generation could be greatly affected. The existing, large inventory of oil-fired power plants with low utilisation could be used to make up some of the shortfall. In addition, new oil-fired or oil-capable plants might be able to economically fill the void in certain instances where constraints on other fuels prevented the faster introduction of other plants.

GENERAL ECONOMICS OF OIL-FIRED GENERATION

A generic description of the role of various generation options in meeting electrical demand helps to situate the economic role of oil-fired power generation. Figure 24 shows a typical "load curve" of an electrical supply system and the plant technology/fuel options used to satisfy the different parts of the curve. The generation options are chosen by utilities to minimise total production cost by successively calling upon options of increasing marginal cost as total electrical demand increases. The steady, baseload component of demand is met by plants having the lowest marginal cost, typically natural gas-fired combined cycles, coal-fired steam electric plants, nuclear plants, and hydroelectric plants. The intermediate and peak components of demand required for shorter total periods throughout the year are met by plants having the highest marginal costs. In many countries of the OECD, these are oil-fired steam electric plants.

Figure 24

Relation Between System Demand and Generation Technologies



The short-run marginal cost of producing electricity using fossil fuels (i.e. the marginal variable cost) depends mainly on the unit thermal cost of the fuel and the efficiency with which the fuel energy may be transformed into electricity, since variable operation and maintenance costs are relatively small. Fuel oil generally has a high marginal cost because:

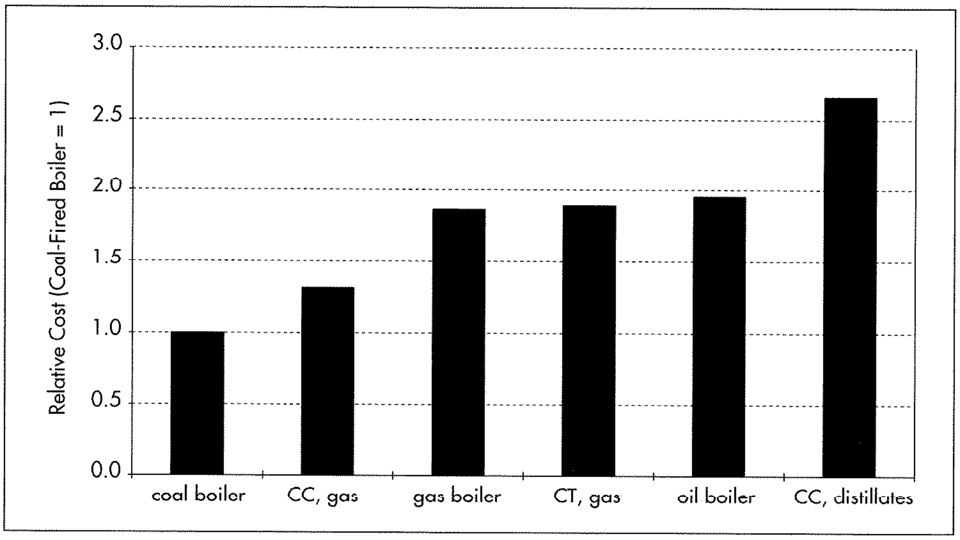
- it is often more expensive on a thermal basis than other fuels;
- the maximum efficiency obtainable from conventional oil-fired technology (steam boiler plus turbine) is about the same as for coal- or gas-fired boilers, but low compared to gas-fired combined cycles.

In the case of distillates, the marginal cost of electricity is even higher because their cost per unit heating value is, on average, double that of heavy fuel oil. Although distillates may be burned in more efficient combined cycles, the higher efficiency does not outweigh the higher fuel cost. Figure 25 summarises the relative marginal generation costs for the principal fossil-fuelled generation options. The marginal costs are based upon 1994 OECD average prices of fuels delivered to power stations and, in the case of distillates, the price of light fuel oil for industry. Coal boilers and gas-fired combined cycles have the lowest marginal costs. Gas-fired boilers, gas-fired simple cycles, and oil-fired boilers have higher marginal costs that are relatively close. The differences among them depend primarily on fuel price because simple cycle gas turbines and oil or gas boilers have similar efficiencies.

The fact that long-term gas supply contracts often include a fixed component of cost (take or pay clause) tends to decrease the effective marginal cost of natural gas compared to oil. The European gas market is characterised by long-term

Figure 25

Short-Run Marginal Cost of Generation Options



take-or-pay contracts. Since a certain amount of gas must be paid for regardless of actual use, the variable cost for gas use below the threshold can be regarded as zero. Oil products are not normally sold with this type of provision. Therefore, the marginal cost of oil can be high compared to gas even in regions where the unit price of each is about the same. In electricity systems where gas-fired boilers, gas-fired simple cycle gas turbines, and oil fired boilers are present and compete for generation, gas supply contract provisions can favour natural gas use even when gas and oil prices are the same on a unit thermal basis.

Another aspect of natural gas pricing which has an effect on the use of oil in power generation is the linkage of natural gas and fuel oil prices. In many natural gas supply contracts throughout the OECD there is an indexation of natural gas price to that of low-sulphur heavy fuel oil. As the price of heavy fuel oil increases or decreases, so does natural gas supplied under such contracts. This is a common feature of gas supply contracts in Europe and in North America. This type of pricing tends to maintain the relative cost of the two fuels in the near term for power generation. It also tends to maintain oil's current role as a peaking fuel. In the long term this sort of linkage would not necessarily remain of importance because contractual conditions could change if there were a trend towards readjustment of real relative fuel prices or increased competition in energy markets. In the United Kingdom, for example, the liberalisation of the gas market has led to changes in contract structures and to a diversification in price escalators away from oil exclusively.

The competition between natural gas and fuel oil for power generation has been explicitly decoupled in a small proportion of natural gas supply contracts in Belgium, the Netherlands, and Norway via so-called "indifference pricing". Under this pricing principle, the operating and capital costs of a gas-fired power plant and a coal-fired power plant are compared and the gas price set equal to the difference between total costs for the coal plant (including fuel costs) and the operating and capital costs of the gas-fired plant, so that the buyer is indifferent between the two alternatives (IEA, 1995b: p. 54). This could allow for more rapid readjustment of the relative prices of fuel oil and natural gas than is presently common in OECD Europe.

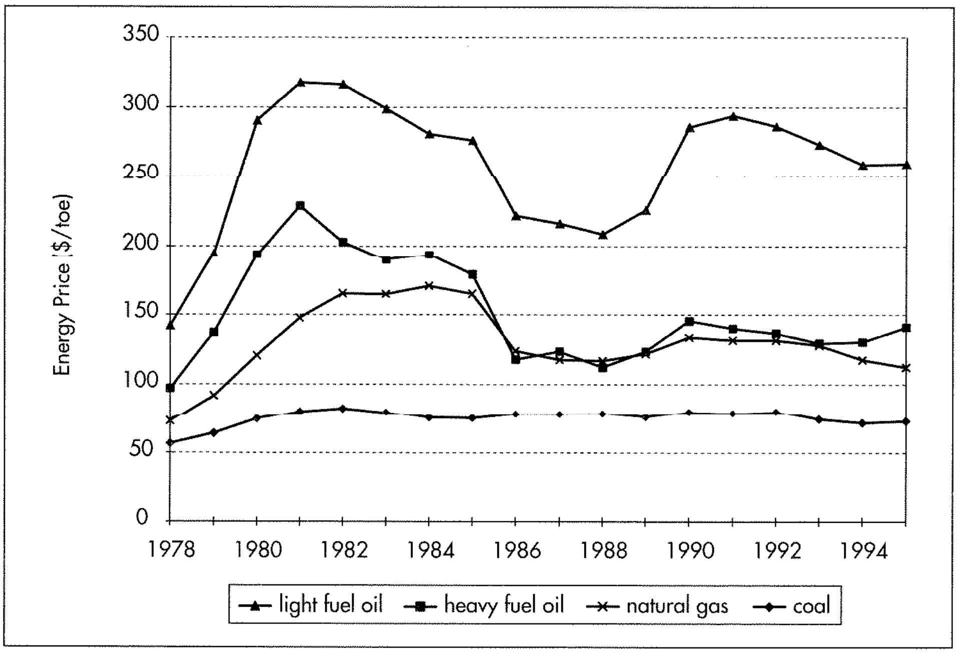
In Japan, the price of liquefied natural gas is indexed to a basket of crude oils used for power generation, the so-called Japanese Crude Cocktail. Liquefied natural gas has been sold at a premium compared with crude oil on a heat equivalent basis. This pricing principle arose during the early history of the liquefied natural gas business in Japan. This has in the past tended to maintain the relative prices of oil and natural gas for power generation. Future relative prices are more difficult to project because of the gradual liberalisation of oil markets in progress in Japan and a gradual introduction of new pricing principles for liquefied natural gas in the Asian market that tend to reduce the direct linkage between gas and crude oil.

The seasonality of demand for natural gas and electricity can have an important effect upon the economics of oil products versus natural gas for meeting peak loads. If a utility's peaking load is largely seasonal, it may be relatively expensive to enter into firm gas supply contracts for provisions during only the short period of high electrical demand. If this is the case, oil products may be competitive as peaking fuels. In the case where the peak in demand for electricity coincides with the normal period of low gas demand, there is an additional possibility. Utilities can obtain gas via interruptible contracts or in the gas spot market (if one exists) for the peak electrical season and rely upon oil products for backup during the off-season. To do this requires that the power plant so operated be capable of firing both natural gas and the oil product: existing oil-fired boilers must be capable of burning both natural gas and heavy fuel oil; gas turbine systems (typically simple cycle for peaking duty) must be capable of burning natural gas and distillate fuels. This is a common strategy in the United States, where some utilities face high peak electrical loads in the summer when natural gas demand is low.

Figure 26 shows the past prices of fossil fuels supplied to power stations in the OECD. In light of the discussion on marginal cost above, these help to explain the patterns in oil-fired power generation since the late 1970's (see Figure 3). Oil use declined dramatically after 1979 as the price of fuel oil doubled. It continued to decrease until 1986, when the prices of fuel oil and natural gas converged and dropped closer to coal's price. Fuel oil use increased in existing boilers from 1986 to 1990, but it was not low enough in price to warrant the construction of new oil-fired power stations. The economic slowdown of the early 1990's and the introduction of new gas turbine based power plants, which are generally more economic than oil-fired plants at any capacity factor, caused oil-fired generation to decrease once again.

Figure 26

Historical Prices of OECD Power Station Fuels



Source: IEA, *Energy Prices and Taxes*.
Note: Price of light fuel oil is for industry. Other prices are as delivered to utilities.

Ultimately, the relative fuel prices in each country or electricity supply system and the mix of plant types available determine the relative contribution of each fuel to overall generation. However, the relative marginal costs shown in Figure 25 indicate that existing oil-fired power plants will generally be most economic in intermediate and peaking duty.

Distillate-fired systems are used only where options for other fuels are limited, such as in island systems or in systems with narrow demand peaks. As an example, the planned 150 MWe distillate-fuelled gas turbine in Vitry, France will be operated for less than 30 hours per year. Although a gas-fired turbine could in principle provide a lower cost of electricity based on typical gas prices, when the cost of providing the needed gas supply capacity for this short period is included, gas becomes uneconomic.

While marginal costs are key factors in decisions of how existing plants may best be used, decisions regarding the construction of new plants are based on estimated cost of electricity including fixed operation and maintenance charges and capital recovery charges. Simple estimates of the cost of electricity based upon OECD average fuel costs and "international" equipment prices indicate to what extent oil-fired plants could economically contribute to an "average" electricity supply system in the absence of specific local constraints. Such estimates show the following tendencies:

- New oil-fired boilers, including flue gas desulphurisation equipment, have the highest cost of electricity, across all utilisation rates, compared to gas- and coal-fired plants.

- Even if fuel oil dropped considerably in price, new oil-fired boilers would not be competitive. For example, to compete with baseload coal plants, fuel oil's unit cost differential above coal would have to decrease to 30 \$/toe (approximately 0.75 $\$/10^6$ Btu), as compared with 60 \$/toe (1.50 $\$/10^6$ Btu) at present. Even at prices approaching that of coal, new oil fired boilers would not compete with gas-fired combined cycles.

- The cost of electricity from gas-fired gas turbines and combined cycles is significantly less than that from new oil-fired plants. Simple cycle gas turbines are more economic at peak load, while combined cycles are more economic at intermediate load and baseload.

- The cost of electricity from oil-fired steam electric plants is close to that from gas-fired boilers; neither is competitive with plants using gas-fired gas turbines.

There are at least two instances where oil-fired plants can be economically attractive compared to options for new generating plants:

- fully depreciated oil-fired boilers used for peak load duty (capital carrying charges are not considered);

- fully depreciated oil-fired boilers that are retrofitted with flue gas desulphurisation systems, used for intermediate and baseload duty, and fired with a petroleum product of unit cost approaching that of coal. Such boilers would be competitive if the capital cost of the desulphurisation equipment alone is included in the cost of electricity calculations.

The lack of natural gas or peaking hydro capacity in an electricity supply system can make oil the most economic fuel for peaking and, potentially, intermediate load. This has been the case in Portugal and Greece, for example.

Summarizing the above points, using current fuel prices new oil-fired power plants are in general not competitive at any plant use rate. Even a significant drop in fuel oil price would not appreciably change this situation because of the high capital cost and operations and maintenance cost of oil-fired steam electric plants. However, existing, depreciated oil-fired plants can be economic for peak load or, when retrofitted with flue gas desulphurisation equipment, for baseload if the fuel price approaches that of coal. Currently only Orimulsion has a unit thermal price close to coal's price. (The exception is to this is in Germany, where the price of heavy fuel oil is at present on average much less than that of coal.)

These general points are by no means valid in all OECD countries. The local cost of fuel, equipment, labour, and other inputs to the cost of electricity production vary significantly among countries and affect the economics of oil-fired power generation compared to other fuels. Oil-fired power generation can play a larger role in electricity supply systems where generation options with lower marginal cost are not available or are in short supply. It can be entirely absent from systems, at no economic loss, in which natural gas-fired gas turbines, hydroelectric plants, or other less expensive peaking options are available.

In some OECD countries, tax or regulatory structures add to oil's disadvantage for oil-fired power generation. This is the case, for example, in Japan and Germany. In Japan, taxes on petroleum products for power generation and restrictions on the importation of refined products have elevated the cost of oil compared to alternative energy sources for electric power generation, particularly liquefied natural gas. This situation is currently changing as import restrictions are relaxed. In Germany, an excise tax of 30 DM/tonne and a special tax of 25 DM/tonne on heavy fuel oil (about 37 $/tonne total) have strongly disadvantaged fuel oil. In the United States, the risk of liability for environmental damages from oil spills appears to be an important factor in the economic evaluation of oil-fired power generation by some utilities.

When a generating option based upon oil is considered by a utility, a risk premium may be added to the estimated oil-fired generation cost. This premium would reflect the perceived risk that the supply or price of oil could be disrupted due to political events. Although not systematic or necessarily even formal, a risk premium may reflect the particular utility's or region's historical experience with oil-fired power generation. In principle, the 15 years since the last major oil disruption and the diversification of crude oil supplies has reduced this premium to a small value relative to fuel price.

POTENTIAL GENERATION IN EXISTING OIL-FIRED UNITS

There is considerable technical potential for increased oil use in power generation, without construction of new capacity, based on higher utilisation of currently operated plants, multifuel plants, and mothballed plants. Although this potential is not likely to be realised because of the price of oil, it does indicate that oil could provide an important measure of flexibility in meeting disruptions in the supply of electricity generated from other energy sources.

Currently Operated Plants

The overall utilisation rate of oil-fired power plants in the OECD is 36%, assuming, as in Section II ("Utilisation Rates of Oil-Fired Units"), that all oil used for power generation is burned in single-fuel oil-fired plants. The existing stock of oil-fired plants, used as baseload producers at a utilisation rate of 65%, could produce an additional 480 TWh per year, or 6% of total OECD electricity production in 1994. This indicates that OECD countries, considered as a whole, could nearly double the output of oil fired plants if required merely by increasing their utilisation rates. The additional oil required for this output would be approximately 110 Mt/yr (1.9 million bbl/day), assuming constant thermal efficiencies. The potential contribution in each country depends upon current utilisation factors, the amount of existing oil-fired capacity, and the ability to supply increased quantities of fuel to the plants. Estimates for increased output from existing plants are given in Table 9. In principle, Spain, Iceland, Portugal, and Sweden could obtain above 15% additional generation from existing oil-fired plants if they were used as baseload units.

Multifuel Plants

It appears that few dual or multifuel plants are currently using oil as their primary fuel. The capacity of plants capable of using oil but not currently doing so is thus almost twice the amount of single-fuel oil-fired capacity: 330 GWe of multifuel plants compared to 200 GWe oil-fired plants. The accuracy of the data is subject to some debate because of the difficulty in consistently identifying or categorizing multifuel capacity on a common basis among national administrations, and the lack of specific data on actual fuel use in multifuel plants. The actual ability to switch back to oil is uncertain for a portion of the plants. However, the magnitude of the plant capacity categorised as multifuel indicates that there is substantial potential for oil-fired generation in this type of plant.

If multifuel plants were to switch to oil firing and operate at base load (65%), the potential annual increase in oil-fired output could reach 1883 TWh and consume 457 Mt oil (8 million bbl/day). Multifuel plants could thus produce the equivalent of up to one quarter of total 1994 electrical generation. This would be an enormous increase giving oil a share equal to its historical peak. This generation level is implausible, but indicative of the large reserve oil-fired generation potential available in multifuel power plants.

Mothballed Oil-Fired Plants

There is an estimated 18 GWe mothballed oil-fired power plants in selected OECD countries accounting for over 90% of active oil-fired capacity (Table 10). Mothballed

Table 9

Potential Generation from 65% Utilisation of Oil-Fired Plants

Country	Potential Oil-Fired TWh	Fraction of 1994 TWh	Potential Incr. Oil Mt
United States	147	4%	41
Japan	103	11%	20
Spain	34	21%	8
France	46	10%	7
United Kingdom	28	9%	6
Canada	26	5%	5
Germany	23	4%	5
Sweden	22	15%	4
Mexico	15	10%	4
Portugal	7	24%	2
Turkey	5	7%	2
Greece	4	10%	1
Switzerland	4	7%	1
Australia	4	2%	1
Finland	4	5%	1
Belgium	2	3%	1
Denmark	2	4%	0
Ireland	1	7%	0
Iceland	1	18%	0
Netherlands	0	0%	0
Luxembourg	0	4%	0
New Zealand	2	5%	0
Norway	1	1%	0
Italy	0	0%	0
Austria	0	n.a.	n.a.
OECD Total	**480**	**6.1%**	**108**
OECD Pacific	**108**	**9.3%**	**21**
OECD North America	**188**	**4.5%**	**50**
OECD Europe	**184**	**7.3%**	**37**

Source: IEA and Secretariat estimates.
Notes: n.a. means current capacity factors were not estimated.
Current capacity factor of oil-fired plants in Italy is greater than 65%

Table 10

Mothballed Oil-Fired Capacity Among OECD Countries with Largest Oil-Fired Generation, MWe

United Kingdom	7628
United States	5808
France	3625
Canada	1100
Denmark	10
Germany	0
Italy	0
Japan	0
Mexico	0
Norway	0
Portugal	0
Sweden	0
Total	**18171**

Source: Major electric utilities, national trade organisations.
Note: Plants available within six months are included in figures.

capacity thus amounts to approximately one tenth of the total active oil-fired capacity. Four countries account for the most of this: the United Kingdom, the United States, France, and Canada. Of the roughly 100 GWe of oil-fired capacity withdrawn from service since 1974, less than 20% was mothballed. Most was converted to use other fuels or, to a lesser extent, retired.

If all mothballed capacity were used at 65% capacity factor, an estimated 100 TWh could be generated. This is about 15% of 1994 oil-fired generation and 1.3% of total OECD electricity generation.

Summary of Estimates

Table 11 presents a summary of the potential annual generation obtainable from existing oil-capable power plants. The OECD as a whole could, in principle, generate roughly 3000 TWh using oil in existing plants, while consuming 730 Mt of oil (13 million bbl/day). This would amount to almost five times 1994 oil-fired generation and five times 1993 oil use for power. As a fraction of total 1994 electricity generation this could reach 40%, higher even than the oil's share of power generation at its historical peak. The technical ability of oil-capable plants to attain the levels of generation suggested would depend upon many factors, among them:

- the accuracy of statistical data on true multifuel capacities;
- actual demand profile of plant called into service using oil;
- fuel transportation logistics to power plants;
- availability of adequate supplies of fuel in the proper grade.

As oil is the marginal fuel in most national electricity supply systems due to its cost, the potential generation estimated in Table 11 is illustrative only should a need or changed economic condition arise. It does show a large reserve of backup oil-fired capacity available within six months.

Table 11

Potential Generation from Existing OECD Oil-Capable Power Plants

	1994 Generation	Increased Utilisation	Multifuel Plants	Mothballed Plants	Total
			Annual Oil-Fired Generation, TWh		
OECD Pacific	260	108	198	0	567
OECD North America	217	188	1079	39	1524
OECD Europe	200	184	606	64	1054
OECD Total	**677**	**480**	**1883**	**103**	**3144**
			Annual Oil Use, Mt/yr		
OECD Pacific	50	21	43	0	114
OECD North America	57	50	275	10	392
OECD Europe	43	37	139	13	232
OECD Total, Mt/yr	**151**	**108**	**457**	**22**	**735**
OECD Total, bbl/day	2.6	1.9	8.0	0.4	13.0

Source: IEA and Secretariat estimates.
Notes: Estimates based upon 65% capacity factor.
Constant national efficiencies assumed.
Calculations are illustrative only and do not take into account detailed logistical, technical, or environmental constraints.

OIL PRODUCT MIX AND RELATION WITH REFINING

There has not been a marked change in the fuel mix demanded for power generation, as heavy fuel oil still is the primary fuel. The power industry consumes over half of all inland use fuel oil in the OECD and provides an important outlet for residual products from the refining industry. In considering future trends in oil use in power plants, the trends in the refining sector must be considered.

There have been relatively minor shifts in power plant use of petroleum products other than fuel oil. There are no apparent pressures likely to change this quickly, but there could be changes in the quantities of crude oil, Orimulsion, and other heavy products, particularly refinery residues, used in power generation.

Heavy Refinery Products

The tendency towards lighter products implies that refiners will either need to invest in upgrade capacity to transform heavier products into lighter products, or excess residual fuels will be available on the supply side, at least for periods where the price differential is not sufficient to encourage investment in upgrade capacity. This need to provide outlets for refinery heavy products, combined with liberalising electricity markets, is likely to have some effect upon the use of residual refinery products in power generation. An increased availability of heavy products could lead to lower prices for certain specific products, or increased incentive for refiners to provide their own outlet for heavy products in integrated refining/power production operations.

Utilities will seek the fuels of lowest cost technically compatible with their existing plant, and if a low-cost residual fuel is available it will be used. The increased use of petcoke in the United States and Japan, although small in absolute terms, may offer an example of this. In the United States, the average delivered cost of petcoke for power stations greater than 50 MWe was 21 US$/tonne in 1994 (EIA, 1995a: p. 116), or roughly 30% of the cost of fuel oil on a thermal basis and 50% of the cost of US coal. The nominal price of petcoke has dropped by over 35% since 1987, while its use has seen a rapid increase as a co-fired fuel in coal power plants. This demonstrates the sensitivity of the power generation market to residual product prices, even those with a high sulphur content (4.8% for US petcoke). Should prices decrease relative to other fuels for residual products, such as high-sulphur fuel oil, bitumen, or tar, a similar interest in the power generation sector could be expected.

The way low-cost residual fuels might be used in central stations depends upon their physical characteristics and their price. Petcoke is limited to co-firing because of its low reactivity, and its use is favoured in plants having flue gas desulphurisation equipment because of its high sulphur content. If a steady supply of residual product with a price approaching that of coal were available, a new baseload power plant using that fuel could be economically feasible.

Refiners might also choose to use the residual products themselves for power generation to assure a steady outlet for them. This would be equivalent to adding upgrade capacity to produce electricity rather than lighter products. Depending upon specific project conditions, the combination of a refinery and tar/heavy oil gasification plants could offer economic benefits not possible in separate electricity and refinery plants. Apart from the economic merit to an individual plant of electricity produced in this way, oil gasification plants could also supply hydrogen needed for refinery operations. For example, Shell's Pernis refinery in the Netherlands is installing a residue gasification co-generation system to supply 115 MWe and hydrogen for a hydrocracking unit. Texaco has installed a 40 MWe petcoke gasification unit at its El Dorado refinery in the United States. Additional examples of residue gasification combined cycles plants may be seen in Italy, where three refinery tar gasification plants are under development, albeit with a 50 lire/kWh price subsidy out of selling price of 130 lire/kWh related to their perceived environmental value (Tabarelli, 1995). The possession of gasification technology by certain petrochemical companies (Texaco, Shell, and Dow) may also provide a natural incentive to move towards such an arrangement.

Crude Oil

Japan is currently the only user of crude oil for power generation within the OECD. Although there is a continued incentive to increase crude oil use because of restrictions on SO_2 emissions in Japan, a changing situation regarding importation of petroleum products may tend to reduce crude oil consumption for power generation. Import regulations are being loosened to allow firms other than refiners to import refined products. This may in time lead to a decrease in the cost of fuel oil relative to crude oil, braking the growth of crude oil use. A long term factor may also be the decreasing reserves of Indonesian crudes, from which over two thirds of Japanese power generation needs are drawn, and the increasing domestic needs of Indonesia. These tendencies may work in parallel with to decrease fuel oil price relative to crude oil and slow the growth in or reduce crude oil use in Japan.

The value of very-low-sulphur crude oil in power generation for meeting SO_2 emissions restrictions could lead to increased crude use in other OECD regions. In particular, the emphasis on decreasing fuel sulphur levels in Italy could tighten markets for 0.25% sulphur fuel oil and make crude oil burning an economic choice under certain conditions.

Potential Market for Orimulsion

It is likely that the use of Orimulsion in power generation will continue to grow, although at a relatively slow pace. Bitor's present production capacity is 5.8 Mt/yr, and the company has an expansion project underway which will provide an additional production capacity of 5.9 Mt/yr by 1998 (PON, 1995).

Currently Orimulsion is estimated to provide up to 2% of the OECD's total oil-fired energy input. Assuming that an additional production capacity of 3.3 Mt/yr were developed (to a total of 15 Mt/yr), and that total oil product use for power generation remained near 150 Mt/yr, Orimulsion could conceivably supply up to 7.5% of the OECD's total oil-fired energy input by the year 2000. Bitor's projections of Orimulsion growth suggest a use of 20 Mt/yr by 2001, but these seem rather optimistic. The rate of growth of Orimulsion is likely to be less than either figure because of a number of factors inhibiting rapid introduction of the fuel. These are investment requirements, public acceptance due to environmental concerns, and lack of supply diversity.

Investment costs for development of Orimulsion production facilities are on the order of 100 US$/kWe. Flue gas desulphurisation systems and special ash handling facilities costing 200 to 400 US$/kWe are normally required for power plants using Orimulsion, which Bitor is prepared to finance, if necessary, as an incentive to use the fuel. These costs imply large investment expenditures by Bitor to increase Orimulsion's share of the power generation market: on the order of US$ three billion to attain the 7.5% share cited above. Bitor's ability to finance such an expansion will place a limit on growth and is the reason why the company hopes to attract third-party financing for at least part of their intended growth.

Another factor inhibiting growth may be concerns over the public acceptance of power plants using the fuel. The Pembroke plant in the UK is awaiting planning permission but is facing considerable public opposition. The proposed conversion of the Manatee plant in Florida, USA from fuel oil to Orimulsion was initially approved by various state planning and environmental agencies, but was ultimately blocked in 1996 by the Florida governor's office due to concerns about the plant's environmental performance. This plant was to have installed flue gas desulphurisation equipment to reduce sulphur dioxide emissions, but environmental groups cited the use of a phenol compound in the Orimulsion emulsifier and increased emissions of nitrogen oxides as remaining environmental concerns (ICR, 1996). The presence of heavy metals in Orimulsion ash is also a potential problem. Environmental concerns are likely to result in lengthy scrutiny at individual plants where Orimulsion is proposed as a fuel.

Apart from financial factors, growth in use of Orimulsion may be limited by the reluctance of some plant owners to depend on a sole supplier drawing from a single geographic reserve. While other sources of natural bitumen are available in abundance, for example the Albertan tar sands in Canada and deposits in Russia and China, at present there are no facilities to produce an Orimulsion-type fuel from them, and their presence in colder climates means that extraction costs will probably be higher. Bitor's use of supply contracts from 5 to 20 years in length and pricing tied to world coal prices are aimed at reducing risk of supply interruption or large price increases.

In the long term, use of Orimulsion or similar emulsified bitumens could be favoured, in contrast to heavy fuel oil, by the lower price, pricing tied to coal rather than crude oil, and availability of long-term supply contracts. Orimulsion will probably be used primarily as a baseload fuel because of the low fuel cost and heavy investment costs needed for control of sulphur emissions. The introduction of integrated gasification combined cycle power plants may also, in the long term, provide an incentive for the use of Orimulsion because of the higher thermal and sulphur-removal efficiencies of such plants. An early sign of commercial interest in this is Texaco's agreement with Bitor to purchase up to 1.6 Mt/yr of Orimulsion for use in gasification combined cycle plants of Texaco's design.

ENVIRONMENTAL AND TECHNOLOGICAL DEVELOPMENTS

The increasing emphasis on environmental protection in OECD countries will tend to limit increases in oil-fired power production because of the cost of controlling SO_2, NO_x, and particulate emissions. There are few cases today in which it is economically viable to install emissions control equipment on existing oil-fired power plants. Thus, decreasing limits on total emissions of SO_2 mean that there will be increasing pressure to reduce the sulphur level of petroleum products used in existing power plants. In the longer term, the requirement to include emissions control equipment in new oil-fired plants will make their cost of electricity higher than from the previous generation of oil-fired plants. This will in turn tend to decrease the use of oil products in power generation as a whole.

Where alternatives to fuel oil are limited or where alternative fuel prices are relatively high, there will be an economic incentive to use advanced methods of controlling pollutant emissions in new oil-fired power plants. The interest in advanced methods is evident in Italy, where three 600 MWe tar gasification plants are under development. The projects take advantage of heavy subsidies for environmentally advantageous technologies, using heavy oil residues from refineries, exchange heat flows with them, and also provide hydrogen. Gasification of refinery residuals, tar, petcoke, or bitumen (such as Orimulsion) converts the fuel to a gaseous mixture of carbon monoxide, hydrogen, and methane from which residual sulphur species may be removed down to low levels. This gas may be burned in a combined cycle power plant, thus obtaining high efficiency and good environmental performance relative to conventional boiler steam-electric plant technology.

In large central station power plants, it appears today that the level of control on sulphur emissions required is not alone generally sufficient to warrant the investment in gasification technology. That is, gasification combined cycle power plants do not clearly provide electricity at lower final cost, despite their higher thermal efficiency. The absence of commercial (non-subsidised) gasification combined cycle power plants among recent new coal-fired power plants indicates that to be the case for coal. It is likely to be the case for large new oil fired plants as well, although some cost studies indicate that the current economic advantage of conventional boiler technology is small. Thus, unless sulphur emissions limits for new plants are reduced below current levels, or oil prices increase substantially, conventional boiler steam-electric power plants with flue gas desulphurisation yield a lower cost of electricity than gasification combined cycle power plants.

Oil-fired gasification combined cycle power plants could provide a measure of fuel flexibility between oil and natural gas. This type of plant can be switched from synthetic gas to natural gas in a short period, subject to modifications in fuel supply and combustion systems of the gas turbine. Natural gas would replace the synthetic gas provided by the gasification train, although, as with fuel switching in conventional boilers, the efficiency of the power plant is affected by the switch. In the reverse direction, a natural gas-fired combined cycle could be switched to run on synthetic gas, but this would require a large capital investment, two years or more, and a large area to construct the gasification and gas cleaning train. The technical feasibility of fuel switching is evident from a number of coal gasification plants that have been designed for "phased construction". This means that the combined cycle portion of the plant is designed to burn syngas, but operated initially on natural gas. If gas becomes more expensive relative to coal, the gasification train may be added to supply synthetic gas to the combined cycle. The same flexibility is obtainable in oil-fired gasification combined cycle plants.

EFFECT OF DEREGULATION UPON OIL USE IN POWER GENERATION

There is a general tendency in IEA countries towards introduction of competitive markets in electricity generation. This is most advanced in Norway and the United Kingdom. In the United States, the Nordic countries, and the European Union, discussion, debate, and planning for competitive or, at a minimum, restructured electricity systems is well underway. Deregulation will tend to promote the use of the most economic fuel for local conditions while complying with the relevant local constraints, including the costs of meeting environmental standards. Under these circumstances, deregulation would probably have little effect upon existing patterns of fuel oil use. Where used in existing power plants, oil is generally economic only for peaking or intermediate loads because of its high marginal cost. In new power plants, oil is typically economic in plants used for peaking duty only. These economic roles correspond with the current pattern of use in most OECD countries, and so would not change in a newly competitive environment. However, in certain respects the role of oil could be affected by deregulation:

- Price competition for electricity will tend to favour generators who may flexibly take advantage of relatively brief movements in relative fuel prices. This could heighten competition between and the value of fuel switching between gas and fuel oil in existing boilers.

- A pressure to exploit the value of existing generating stock could lead to increased repowering of old or mothballed oil-fired boilers.

- Use of low-value residual petroleum products such as vacuum residue or petcoke could be favoured as refiners seek to maximise value from them.

Regarding the first point, price differentials between natural gas and fuel oil can be exploited if a generator has access to supplies of both and a power plant may consume either. If, for example, there is a seasonal or short term increase in price of natural gas relative to fuel oil, the generator may switch a plant from natural gas to fuel oil to obtain a lower fuel cost. The reverse sequence is equally possible if it is fuel oil that increases in price. Dual firing allows the plant operator to reduce the economic risk of movements in fuel prices.

An additional economic advantage can accrue to owners of dual-fuel plants with firm fuel supply contracts: the ability to profit from a difference between the contract and spot market fuel price. Take again the example of a dual fuelled plant supplied under a non-interruptible natural gas contract. If the spot price rises relative to the contract price, and fuel oil is available from the spot oil market or in utility storage tanks, the utility could switch the plant from natural gas to oil and sell natural gas on the natural gas spot market. The utility will profit when the difference in price between spot and contract gas prices is greater than the extra cost of operation on fuel oil. Price differentials of this sort are normally of short duration because supply contracts are typically indexed to spot market prices with some time lag and averaging calculation. The technical ability to switch rapidly between fuels is therefore key. The ability to realise arbitrage gains of this type depends on competitive gas supply markets. Fuel switching could take on increased importance in a deregulated electricity market as electricity generators come under competitive pressure to improve financial performance in all areas.

The most immediate effect of competitive generation systems will likely be the increased penetration of natural gas in relation to all other generation options, including oil, where natural gas is available. Natural gas-fired gas turbine systems pose almost no environmental problems and are typically more economic over the whole range of load factors. They are expected to be used increasingly for new power plants. Competitive environments are likely to hasten this trend. This has been seen particularly in the United Kingdom in the 1990's following their privatisation of non-nuclear power generation and liberalisation of the electricity market. In the non-utility power industry in the United States, generally a competitive industry, about one half of near-term capacity additions will be fired on natural gas (EIA, 1995b: p. 242).

Market liberalisation will provide economic opportunities to oil refineries to dispose of heavy oil residues through power generation rather than through product upgrade. The sale of electricity to customers outside of the refinery provides a larger outlet for residual products than that provided by internal refinery electrical consumption. Refinery production of electric power has grown strongly in the United States since independent power production was introduced in 1978 legislation, even as oil-fired power generation as a whole has dropped considerably. There were some 80 refinery-based power generation projects in the United States by 1995 (Karp, 1996). In Japan, the results of the 1996 solicitation of capacity bids by independent power producers included 1200 MWe of oil-fired capacity out of a total of 3000 MWe accepted. Of the oil-fired plants, two-thirds (800 MWe) were based upon the use of oil residuals in refineries (Denki, 1996).

Following the oil shocks of the 1970's, all IEA governments adopted policies to discourage oil use in power generation. Certain governments took a very direct role in the choice of fuel mix for power generation, exerting strong control over utility planning processes to substitute other fuels. This was particularly the case in countries with state-owned electric utility monopolies. Such interventions may have brought specific electricity markets to a point where the mix of fuels is not economically optimum. In such cases, liberalisation of the electricity market could result in a gradual readjustment of fuel shares to reach a market optimum. Depending on such specifics as local fuel price, electricity demand profiles, or availability of indigenous energy sources for peaking and intermediate load power generation, regions with a high share of oil-fired power generation could see further declines in oil use, and regions with a low share could see modest rises in oil-fired power generation.

The ability of a government to directly influence fuel choice in a deregulated electricity market becomes more difficult because of the transparency of policy actions. Economic instruments to discourage particular fuels (taxes, subsidies) can be seen as unfair or "anti-competitive" by utilities dependent on the affected fuels or in competition with utilities benefitting from subsidies. Likewise, regulatory actions will tend to cause a loss in commercial value of generating assets using a discouraged fuel, again provoking the public complaints of affected utilities and investors. This is in contrast with non-competitive markets, where the economic effects of government policy actions can often be passed on quietly and diffusely to electricity consumers.

NATIONAL TRENDS

This section briefly describes the trends in oil-fired power generation in the countries accounting for over three quarters of OECD oil-fired generation: Japan, the United States, Italy, Mexico, and the United Kingdom.

In Japan, the policy of the government and 10 major power companies has been to observe the IEA policy discouraging construction of new oil-fired power plants, while maintaining the existing capacity stock. Oil-fired capacity has remained stable at roughly 60 GWe since 1984, although there was a 7% growth in reported oil-fired capacity over 1992 to 1994. Official plans call for oil-fired capacity to decrease to 18% of total by 2002 and oil-fired generation to drop to 10% (CEPC, 1993) of the total. However, as oil-fired plants have aged, pressure has been increasing to allow replacement of oil-fired capacity. A study group of the Electric Utility Industry Council expected that retiring oil-fired power plants would be replaced by new oil-fired plants (Tanaka, 1995) so as to maintain an appropriate fraction of oil-fired power generation in Japan's power generation mix. The progressive introduction of competition in the Japanese electricity supply industry begun in 1996 will also affect fuel choices for power generation, including oil.

In the United States, oil-fired power generation is expected to continue declining as gas-fired and coal-fired power generation captures the bulk of new generation capacity. All recent and planned power stations intended for baseload and intermediate load use gas or coal as primary fuels. In existing boiler steam electric plants, fuel oil and natural gas are competitive in price, which varies by season. The existence of well developed, competitive gas markets and a large installed capacity of natural gas/oil-fired boilers has led to seasonal fuel switching for peaking plants. Natural gas is burned in the summer when less expensive and readily available, and fuel oil is burned in the winter heating season. A similar strategy can be seen in a number of planned gas turbine simple cycle peaking plants in summer-peaking regions. These plants will use natural gas to meet normal summer peaks, and, if an unusual need arises in the winter, may use more expensive distillate fuels (typically fuel oil no. 2). The issue of liability for oil spills appears to be of particular significance in the United States, as potential costs for environmental damage and cleanup are of concern to utilities. This imposes an additional economic disadvantage to the use of oil in power generation.

Italy is planning a major shift to gas fired combined cycle plants and to coal in order to reduce oil's share of total generation from about one half in 1993 to less than 40% by 2002. This follows a concerted government policy to diversify away from oil despite the past history of difficulty in doing so. Should the introduction of new coal plants meet the same resistance as past projects, there is some possibility that Italian oil use for power generation may continue its upward trend. All planned and most existing coal and natural gas steam electric plants in

Italy can also burn heavy fuel oil. The state electricity company ENEL plans to continue its shift towards very-low-sulphur fuel oil (< 0.25% sulphur) in its plants, increasing this grade to 25% of purchases by 1998.

Fuel oil use in power generation accounts for over half of total Mexican generation and increased at an annual growth rate of 5% from 1985 to 1994. This was the result of the relatively low price of fuel oil compared to both natural gas and coal and the close relationship between the state owned refining and power production companies. In 1995, 1020 MWe of oil-fired capacity was added to the Mexican supply system at the Carbon II and Topolobampo II projects. The Federal Electricity Commission projects continued growth in overall electricity generation at annual rates between 3.8 and 5.4% (PILA, 1995). Government policy is to encourage the rapid introduction of natural gas to help reduce the environmental effects of fuel oil use and begin to reduce the share of fuel oil in total generation. This includes converting some oil-fired plants to gas and construction of new combined cycle power plants, as required by environmental regulations coming into effect in 1998. Liberalisation of the electricity sector to allow independent power producers should also encourage the choice of gas over fuel oil (IEA, 1995c: p. 112). If the increased role of gas plays out according to these projections, oil use will continue to grow, but at a reduced rate. However, the relatively low price of fuel oil compared to natural gas may help to maintain fuel oil's contribution to total generation at a higher level than expected.

Oil fired power generation has remained relatively steady in the United Kingdom in recent years at an annual average of about 30 GWh, where it largely plays the role of a peaking supply. The United Kingdom has one of the most competitive electricity generation markets in the OECD, and generators are obliged to pay close attention to the final electricity cost obtainable from the mix of plants and fuel available. No oil-fired stations have flue gas desulphurisation equipment installed, and limits on sulphur emissions do not allow greatly increased oil-fired generation in existing plants. Under these conditions, fuel oil is likely to become increasingly marginal in competition with natural gas and coal. The United Kingdom has a large amount of mothballed capacity (equivalent to 4/5 of active oil-fired capacity) with an average age of 22 years. This capacity could, under competitive conditions, take on a greater value from refurbishment given a low-cost liquid fuel such as Orimulsion.

IV - ENERGY POLICY ISSUES

This section surveys past policy statements on oil-fired power generation in the IEA and in individual IEA Member countries. The role of oil-fired power generation with respect to energy security in IEA Member countries is then addressed. The section concludes with a discussion of the relationship of oil-fired power generation with oil import dependence, energy supply diversity, economic efficiency, flexibility, power plant technology, and refining.

HISTORY OF IEA POLICY STATEMENTS ON THE USE OF OIL IN POWER GENERATION

The use of oil in power generation features prominently in the IEA's 1977 "Principles for Energy Policy" (IEA, 1977). Principle 5 is:

"Progressive replacement of oil in electricity generation, district heating, industries and other sectors by:

- discouraging the construction of new exclusively oil-fired power stations;
- encouraging the conversion of existing oil-fired capacity to more plentiful fuels in electricity, industrial and other sectors;
- encouraging the necessary structural adjustments in the refinery sector in order to avoid an excess of heavy fuel oil; ..."

This policy was re-affirmed and expanded in 1979 in the statement of "Principles for IEA Action on Coal" (IEA, 1979: Principle 19):

"[Member states] will ensure that the use of oil for electricity generation is minimised by national energy policy planning which, with a minimum of exemptions, precludes new or replacement base load oil-fired capacity; progressively confines oil to middle and peak loads; and makes maximum use of fuels other than oil in dual-fired capacity."

Annex I to the Coal Principles cites specific steps to be taken relating to oil-fired power generation. In fact, the first three specific steps cited to increase coal utilisation relate to measures to decrease the amount of oil-fired generation:

"1. Ensure that national energy policy planning precludes, with minimum of exceptions, the construction of new or replacement baseload power plants which are exclusively or mainly oil-fired. Exceptions should be permitted only where they are reasonably covered by the following situations.

- national action has been taken to restructure refinery yield patterns toward light products but has not yet been able to eliminate excess quantities of residual fuel oil which cannot be used for other purposes;

- economic or supply conditions, including remoteness of location, are such that use of fuels other than oil is unreasonably expensive in comparison with oil:

- because of local climatic or demographic conditions it is impossible or unreasonably expensive to use fuels other than oil fuels in an environmentally acceptable way even with advanced technology.

2. Require that existing oil-fired baseload power plants be progressively limited to middle or peak load requirements.

3. Ensure that dual-fired power plants are not fired with oil unless other fuels are unreasonably expensive in comparison with oil or it is temporarily necessary for environmental reasons."

This policy again aims to prohibit new oil-fired capacity, replacement of old oil-fired capacity, or use of dual-fired plants to burn oil. However, it is recognised in point 1 that refinery balances, local fuel supply costs, or environmental considerations could merit exceptions to the prohibition.

The next major IEA policy statement on electricity appears in the 1985 report "Electricity in IEA Countries" (IEA, 1985). The role of oil-fired generation is touched upon only in the context of specific statements on Italy and Netherlands, in which priority is placed upon the substitution of oil in power generation. IEA Energy Ministers agreed in 1987 (IEA, 1987) that

"it was essential for IEA countries to continue to reduce dependence on oil and to diversify the other sources of energy used in [the electricity] sector."

However, the Governing Board also noted that

"each IEA country will have to decide on the mix of fuels used in generating stations best suited to its particular circumstances."

The brief reference to oil-fired power generation and the statement on fuel choice indicate a continued commitment to reducing dependence on oil, while at the same time recognizing the need for flexibility in fuel choice for power generation.

In response to a 1990 note on oil in power generation, the Governing Board (IEA, 1990a; 1990b) improving security of supply in order to stop the proliferation of power stations burning petroleum products. Although there are still a significant number of power stations capable of generating electricity from oil products, today they account for around 10% of electricity production in the EU. The current market situation, technological progress and environmental concerns dictate that now electricity is generated by burning oil products only in regions where there is no alternative.

Under these conditions, if a new crisis were to arise, the Directive would no longer be very useful to remedy the risk to supplies: the situation with regard to fuel supplies on economically favourable terms is completely different from the situation at the time the Directive was adopted.

Repeal of the Directive would offer electricity generators and refiners greater flexibility and facilitate the possible return to operation of certain multi-fuel units (coal/oil, oil/gas or combinations with wood/peat) and help to make refineries more profitable, by creating markets for surplus heavy fuel oil.

The draft authorizations submitted to the Commission by the Member States so far confirm that they are relatively restrictive on the environmental aspects and the downward trend in consumption of oil products in power stations. The Directive's contribution to environmental protection is also extremely marginal, given the small number of power stations covered. Controls on emissions caused by the use of hydrocarbons are a more effective means of attaining the environmental objectives.

The Commission has always endorsed the authorizations granted by the Member States to use oil products in power stations.

For all these reasons, [...] the Commission proposes that this Directive should be repealed."

In effect, the Council affirms the role of the energy market in utility fuel choices, including that of oil products.

In the United States, the Power Plant and Industrial Fuel Use Act of 1978 banned the construction of boiler steam-electric power plants to provide baseload power burning either natural gas or petroleum products as their primary fuels. Exemptions were granted if alternate fuels (i.e. coal) were not available, petroleum fuel would be less expensive than coal, financing for power plants burning other fuels were not obtainable, or environmental restrictions could not be met using another fuel. There were also provisions for limiting oil use in existing multifuel, baseload facilities. In 1987 most of the Act was repealed. At present, there is no limitation on oil use in power generation facilities. Neither Canada nor Mexico had, at any time, a policy against the use of oil in power plants.

In the IEA Pacific countries, only Japan has a policy against the construction of new oil-fired power plants.

POLICY ISSUES RELATED TO OIL USE IN POWER GENERATION

Oil Import Dependence

The use of oil in power generation has been seen as a potential threat to the security of electricity supply since the 1970's and continues to be seen in that light. The experience of two oil price disruptions left both governments and individual utility companies wary of over-reliance upon oil and conservative in projections of cost of electricity based upon petroleum fuels.

A primary policy objective of OECD countries, most of which do not have large indigenous reserves of oil, has been to reduce dependence on imported oil and this remains a fundamental concern. A variety of policy measures were introduced in the wake of the oil shocks to help reduce oil use, including energy-related research and development programmes, promotion of nuclear power and alternative energy sources, energy conservation programmes, and restrictions on certain end-uses of oil. The discouragement of oil use in power stations falls among the latter policy measures. Although power generation accounts for only 7% of total OECD oil consumption, in absolute terms it is nonetheless an important end use, consuming roughly 150 million tonnes of oil products in 1994.

Projections of future world oil use, not just in OECD countries, suggest that, despite these measures, OECD oil import dependence is set to increase in the coming decades. The World Energy Outlook (IEA, 1996) projects that OECD import dependence could reach 60 per cent by 2010, compared with 50 per cent at present. Production from OPEC countries will provide over half of world oil requirements. Thus, the concern about OECD import dependence has not lost its relevance.

Developments in oil consumption outside of the OECD are becoming increasingly important to OECD countries. The OECD's share of world energy consumption will decrease as dynamic non-OECD economies grow rapidly and increase their per capita energy consumption. Asian economies in particular will account for a large proportion of increased demand outside the OECD. Even as the OECD imports a greater fraction of its oil supplies in the future, its demand of oil will grow by only half the amount expected by 2010 in the rest of the world. Any growth in OECD oil demand beyond what past patterns suggest will increase the draw on world oil supplies.

The potential of OECD countries to respond to oil supply disruptions has been historically of concern and remains so. This "emergency response potential" is a main element of the International Energy Program which the IEA implements. As summarised in a 1995 document: "Perhaps the biggest immediate challenge for those involved in emergency response is to translate future threat into present policies on emergency reserves ..." (IEA, 1995d). Although net stock levels of oil in IEA net importing countries is estimated to be roughly 30% more than the minimum of 90 days equivalent, trends in stock levels have been downward for several years.

In summary, various OECD and world patterns in oil product use suggest continued prudence in policies affecting oil import dependence.

The Evolving Role of Oil in OECD Power Generation

Notwithstanding the continued importance of oil import dependence as a concern to many OECD countries, a view of oil in power generation must take into account its evolution since the 1970's. The most important result of the oil shocks was that the cost of power production using oil increased in relation to other fuels. The cost increase has been accentuated by the increased cost of environmental control equipment for oil-fired power plants. Nuclear power displaced oil-fired generation in many OECD countries. This has led to the situation today, described in Section II, in which oil-fired power generation provides roughly 9% of all electricity generated in the OECD, down from over 20% in 1974. In only six of 25 OECD Member countries does the fraction of generation by oil exceed 9%. The role of oil has been greatly diminished through the action of market economics upon fuel choice.

Oil now occupies a fundamentally different role in the electricity production mix compared to the 1970's. In most OECD countries it provides only a small proportion of energy for electricity production. Whereas it was previously a baseload fuel in many countries, it is now largely confined to intermediate and peaking duty, as seen by the steady drop in utilisation rates of oil-fired power plants throughout the OECD. Nuclear energy and natural gas have increased in absolute and relative terms (nuclear only) as alternate energy sources for electricity production.

For certain utilities, regions, and countries, over-dependence on oil for power generation is and will remain a vital concern. On the other hand, the unqualified perception of oil-fired power generation as a security risk in itself may today no longer be valid. Striving for too low a contribution of oil in electricity supply, or eliminating it entirely, would tend to decrease fuel input diversity to energy supply, increase overall power generation costs, and decrease flexibility. These points are examined below. The discussion aims to show that some non-zero level of oil-fired power production, as appropriate to the energy situation of individual countries, can bring energy security benefits. There can be no misunderstanding that these argue in favour of policy actions to increase oil use in power generation, or that other elements of energy security, including reduced dependence on oil imports, are of lesser or diminishing importance.

Diversity

The essence of fuel diversity is to use as many different economic fuel sources as possible to minimise the risk of disruption to the total end use. Entirely eliminating the use of any one fuel on non-economic grounds must be seen as a decrease in diversity, since other fuels would have to provide greater input shares of energy. Today oil contributes to diversity of fuel supply for electricity generation in that it provides a small fraction of total generation in the majority of OECD countries, yet is not zero.

Efficiency

An economically efficient electricity supply industry will tend to minimise electricity cost according to the set of feasible fuel inputs and technologies available to the industry. Since the 1970's, this has resulted in the diminution of oil's share according to economic criteria, constrained by the industrial and political environment of power generation in each country, because of oil's comparatively high cost of electricity. In certain countries with economic alternatives to oil-fired power generation, such as Norway, New Zealand, or Switzerland, oil use in power is nearly zero. But in others, where the use of oil in power generation has been based upon mainly economic criteria, oil is still used. Examples are the United States, the United Kingdom, Canada, and Portugal. Oil use for autoproduction of electricity has been increasing in recent years, clearly suggesting its economic value for oil generation among autoproducers. These patterns of oil use alone suggest that oil does provide an economic power generation fuel in certain countries and industries.

An economic analysis of oil-fired power generation, rather than the simple observations above, equally shows that oil can be economical. When the relative prices of competing fuels and power generation capital costs fall within certain ranges, oil can provide the least expensive alternative to meet a portion of electricity demand. In practice this has been a shrinking portion, but oil is nonetheless the least expensive for that portion.

Therefore, the use of oil in power generation can contribute to a electricity supply system having greater economic efficiency than one which does not use oil. While demonstrably true at the level of certain countries, the conclusion may be extended to OECD countries taken as a whole.

Flexibility

In the context of energy security, flexibility means the ability to switch from one energy source to another when the supply of the first is disrupted. This can be accomplished within a given power plant or across an electricity supply system by increasing the relative output of plants consuming one fuel versus another. Given enough time for technical conversion, any individual power plant fuelled on a given fossil fuel can be modified to use any one of natural gas, oil, or coal, but the costs and timescale will vary greatly according to the original plant technology. The final plant/fuel configuration would not necessarily be economically viable. The following discussion focuses on short-term flexibility, arbitrarily taken to mean that a switch in fuel can be accomplished in 6 months or less.

Since oil is used to satisfy peak load in many systems, it is called upon when other generating sources are at their full capacity and few or no other generation alternatives are available on the electricity supply system. In situations where oil-fired plants are called upon to replace lost system generation, such as from low hydroelectric output, oil-fired power generation is often the "last resort". In this role as swing supplier of electricity, oil is indeed difficult to replace in the short term.

However, the role of oil in power generation is today limited to the point that, in many OECD countries, its contribution to capacity is less than the reserve margin, that is, the excess of system maximum potential output over maximum electrical demand. This means a disruption in oil-fired generation could be attenuated in the short term by increased output from other types of plants, subject to detailed logistical and technical limitations. For example, if all alternative capacity were put into service, maintenance outages delayed, unplanned outages minimised by increased preventative maintenance activities, and other measures taken to maximise the output of non-oil fired generation, the impact of reduced oil-fired output could be mitigated. It is assumed that oil-capable multifuel power plants would not be affected in the event of an oil supply problem because they are currently fired mainly on coal or natural gas. In only Italy, Japan, and Mexico is the contribution from oil-fired generation greater than the reserve margin (Portuguese data not available), which is generally between 25 and 40% throughout the OECD. The most difficult situations due to an oil supply disruption would be found in those countries with the largest fraction of power generated by oil. However, in many systems reduced output from oil-fired power plants could be replaced in the short term by increased output from other plants. The technical flexibility to withstand an oil supply disruption in the electricity supply industry exists today in many IEA countries.

An abrupt increase in price of oil supply to power generation would cause an economic problem more than a technical one. This arises not only from the increased price of the overall fuel mix, but the lost value in capital stock used for the transformation of that fuel into electricity and the need for investment to convert these plants or build new capacity using a different fuel source. This was certainly observed following the oil price rises of the 1970's.

In fact, the potential decrease in heavy fuel oil supplied to OECD power plants in the event of an oil supply disruption would be moderated by the structure of the refining industry and the demand for light petroleum products. Heavy fuel oil is a residual product of refining. In the short term, the level of fuel oil production depends upon the refinery output of lighter products for use in transportation and other sectors. Yet the demand for light petroleum products cannot change dramatically in the short term because of their use in areas for which there are no or few substitutes. Fuel oil production would therefore only slowly decrease in the event of an crude oil supply problem. In the short term, reducing use of fuel oil in electricity production, which accounts for about one half of total OECD fuel oil consumption, would provide little benefit to the overall petroleum product supply situation. In the long term, as conversion capacity could be added to refineries and substitutes for lighter petroleum products found, a reduction in fuel oil use in power generation would be useful. In summary, the value of short term flexibility to switch to other fuels in oil-fired power generation is today limited by:

- a demand for light petroleum products that is inelastic in the short term;
- the source of heavy fuel oil as a residual product of oil refining;
- a high share of heavy fuel oil in oil-fired power generation, and
- the existence of few other direct uses for heavy fuel oil apart from power generation and steam raising in industry.

Oil's contribution to flexibility in power generation supply is today probably of greater value in the opposite sense - that of a disruption in supplies of fuel other than oil. Oil undoubtedly provides a measure of flexibility to OECD electricity supply systems in several ways if non-oil-fired plants experience a supply problem:

- existing oil plants are underutilised and could provide almost double their electricity generation, on average across the OECD, if used at higher utilisation rates;
- dual- or multifuel plants currently using coal or natural gas could be switched to oil;
- mothballed oil-fired power plants could be drawn into service, many within six months.

Underutilised and mothballed oil-fired power plants represent significant generation assets whose long-term amortisation was undermined by the oil price rises of the 1970's. A substantial portion of their value has been maintained and could provide backup generation if needed. Examples of this are provided by the United Kingdom during the coal strike there in 1985-1986, the Netherlands during a period of reduced gas availability for power generation from 1978 to 1981, and Ireland during a disruption in gas supplies in 1986-1987. Plants that are dual- or multifuel whose fuel supplies were interrupted could rapidly switch to oil as their primary fuel. Although unambiguous figures on the potential for oil-fired generation in multifuel plants are not available, it is clear that it is substantial and, in the best-case limit, could provide up to a quarter of total generation.

This potential for oil to replace lost gas-fired power generation was examined for the recent IEA Natural Gas Security Study (IEA, 1995b), which considered the possible effects of a disruption in either Russian or Algerian gas supplies to OECD Europe. Incremental demand of fuel oil in the power sector was estimated as 12 Mt/yr for a Russian disruption and 8.5 Mt/yr increment for Algerian disruption. Given a nominal European power industry fuel oil demand of about 50 Mt/yr, these disruptions imply increases of less than one quarter and one fifth in demand. These would be well within the capability of oil-fired plants alone to absorb, on average. Multifuel oil-capable plants could also meet this increase in output alone. It must be emphasised in any discussion on supply disruptions that the situation varies greatly by country. The ability of any country's electricity supply system to respond to a disruption in fuel supply depends on the relative contributions of each fuel, types of power plants, fuel distribution systems, and other factors.

The technical ability to switch fuels does not guarantee that the plants will be able to function in the same role within an electricity supply system. Since a fuel switch would be made based upon an effective increase in price or unavailability of the principal fuel, the use of the alternate fuel will tend to increase the marginal cost of power from the plant and make it economic to meet a smaller portion of the total electrical demand. For example, a simple cycle gas turbine switched from natural gas to distillate could see its use change from several thousand hours per year to several hundred. This is exactly analogous to what happened in the 1980's as formerly baseloaded oil-fired plants were used increasingly for intermediate and peak load.

Apart from the ability to quickly supplement or displace non-oil generation, oil-fired generation provides a certain inherent flexibility because of the current flexibility of oil supplies. To a greater extent than coal or natural gas, oil products are sold on world markets, are widely available in standard grades, are available from many individual suppliers, and are often transportable to a given destination by many routes. To the extent that the fraction of oil supply affected by a disruption is limited, power plants and other oil consumers can turn to well developed oil markets to quickly obtain replacement oil from many potential suppliers and via many potential routes. This situation is in contrast to that of 25 years ago.

Once again, the above discussion of the value of flexibility provided by oil-fired power generation should not be interpreted as suggesting oil-fired power generation should be encouraged or increased. Neither should it be interpreted as implying a change in the IEA's policy on oil-fired power generation (see Section IV, "History of IEA Policy Statements on the Use of Oil in Power Generation"). Rather it is to point out the benefit of existing oil-capable power plants in providing this flexibility.

Issues Related to Power Plant Technology

The flexibility of a power plant using a given fuel to switch to another depends most simply on the power plant technology, regardless of fuel availability, cost, or other matters. The plant must be technically capable of burning the alternate fuel. Implicit in the generation technology is the equipment needed to control pollutant emissions to legally required levels. Currently most fossil-fuelled plants use steam boilers that can, in principle, be converted to a different fossil fuel. In the future the flexibility to switch quickly between fuels or to convert plants to use a different fuel will be reduced as natural gas-fired power plants based upon gas turbines become more common.

At present approximately 90% of the installed base of OECD oil-fired generation uses conventional steam boilers. This figure is derived from the fraction of OECD oil-fired generation that is based upon fuel oil or crude oil. Steam boilers are the most flexible of fossil fuel combustion devices and can be made to burn many different liquid, gaseous, or solid fuels by changing, within the boiler itself, the burner type and ash handling systems in the case of solid fuels. The most difficult conversion is from oil or natural gas to coal because of the need for new solids handling systems. This conversion can take over two years to complete. Control of SO_2 emissions is by relatively expensive post-combustion flue gas desulphurisation. Control of NO_x emissions is by burner design and, if necessary, post-combustion systems. Following the oil price increases of the 1970's, many oil-fired boilers were converted to burn coal or natural gas or were converted to burn more than one fuel.

The technical flexibility to switch an oil-fired boiler quickly to coal could be improved by temporary exceptions to environmental restrictions. Such policy flexibility would allow the operation of the plant without the normally required level of SO_2 or NO_x control, thereby saving the time needed to fit the plant with the emissions control systems.

The 10% remainder of oil-fired power generation is produced in gas turbines, gas turbine combined cycles, or internal combustion engines. Gas turbines require relatively clean fuels such as distillates or LPG because they have moving parts in contact with products of fuel combustion. Because of this, they cannot be quickly switched to use heavy fuel oil.

Oil-fired power plants using gasification combined cycle technology can provide the flexibility to switch to natural gas in the event of a problem in oil supply. The flexibility, unlike in boiler steam electric plants, will probably be from oil to gas only and not oil to coal, because there are no commercial gasifiers that accept both oil and coal products. Certain fluidised bed gasifiers could potentially offer three-way flexibility, but lag in development compared to single-feedstock gasifiers. Thus, new oil-fired plants using either conventional boiler or gasification technology can be engineered beforehand or fitted after the fact to provide the flexibility to switch to natural gas.

Natural gas-fired gas turbine combined cycles are the fastest growing type of plant technology because of their high efficiency, environmental acceptability, and competitive electricity price. This means that as combined cycles' share of total electricity capacity increases, as it is expected to do, flexibility to switch from gas to heavy fuel oil will decrease. Distillate oil, natural gas liquids, or lighter oil products will be the only short-term, technically feasible alternate fuels, but these are much more expensive fuels than fuel oil.

Summarizing, most of today's oil-fired power plants may in principle be converted to burn other fuels, as was done in the past when oil prices rose, because they use steam boilers. This will remain true for new oil-fired capacity based upon steam boilers. New oil-fired plants using gasification combined cycle technology will be also able to switch to natural gas, but not normally to coal. The increased role of gas turbines fired on natural gas in the power generation mix of many countries will eliminate the short-term ability to switch from clean fuels (natural gas, distillate, etc.) back to heavy fuel oil.

Table 13

Summary of Technical Fuel Flexibility in Power Plants

Plant Type	Primary Fuel	Switchable in Short Term to
steam boiler	gas	oil
	oil	gas
	coal	oil, gas
gas turbine or combined cycle	gas	distillate, LPG, NGL
gasification combined cycle	coal	gas
	heavy oil product	gas

Issues Related to Oil Refining

Oil-Fired Power Generation Provides an Outlet to Refiners

Oil-fired power generation consumes a residual product of the refining industry for which there are few other direct uses. Power generation consistently consumed between 40 and 45% of OECD residual fuel oil from 1980 to 1994, as total consumption declined by nearly one half. Other inland uses of residual fuel oil, including industry, inland waterways, and energy sector, have steadily declined in share and in tonnage. Only international marine bunkers has increased in absolute consumption, due to an increasing volume of international seaborne trade (IEA, 1994). In 1994 its share of total OECD residual fuel oil use was one quarter.

To the extent that the use of oil in power generation continues at some level, it reduces the need for oil refiners to invest in conversion capacity to provide an outlet for residual fuel oil. In the longer term, changes in fuel oil demand in the OECD power industry are linked to the patterns of investment in refinery conversion capacity.

Use of Residual Fuel Oil Could Be Valuable in a Supply Disruption

In a future supply crisis, the supply of fuel oil itself would be unlikely to be a problem relative to lighter products since flexibility can be expected to be available to switch to other fuels such as coal in dual-fired power plants. However, in a crisis, the flexibility to increase residual fuel oil use could be valuable. An unexpected reduction in crude production in one country or region can be expected to lead to higher oil prices and increased production elsewhere. The previously-shut-in production is likely to be lower value heavier crude which, when processed, could lead to fuel oil surpluses if there were little or no spare global residue conversion capacity at the time of the crisis. This problem could, of course, be compounded by a significant loss of refinery conversion capacity as occurred in Kuwait during the Gulf crisis. In such circumstances, the flexibility to increase heavy fuel oil use in existing, underutilised power plants could permit higher refinery crude throughputs than would otherwise be the case, hence enabling demand for lighter products to be met.

Using High-Sulphur Residuals for Power Can be More Economic than Desulphurising Them

A related refinery issue is the most economic way of removing sulphur from residual refining products such as heavy fuel oil or petcoke. To meet environmental emission standards, sulphur must generally be removed from residual refinery products before or after their ultimate use for inland consumption. Two basic options are desulphurising the residual products in the refinery or using the residuals in a power plant equipped with sulphur control systems. The desulphurisation of residuals in refineries appears to be a more expensive approach than using them in large boilers equipped with flue gas desulphurisation systems. Another less expensive approach is possible for some refineries: integrated refinery power and hydrogen production. Residual products may be gasified and then economically cleansed of their sulphur compounds. The resulting clean synthesis gas provides both chemical feedstock for the refinery (hydrogen) as well as a fuel for use in an in-house gas turbine. This option is likely to take on greater importance in the future as the trend towards lighter oil products continues. Whether residual refinery products are used in conventional power plants with flue gas desulphurisation or in gasification power plants with integrated sulphur removal, power production can be a more economic end use for residual products than desulphurising them and using them in other applications.

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