

## World electricity generation, nuclear power, and oil markets

*Energy analysts report that nuclear energy has supplied nearly one-third of all new electricity worldwide since 1973*

*Striking changes have characterized the world's production and use of energy over the past 15 years. Most prominent have been the wide price fluctuations, politicization of world oil prices and supply, along with profound changes in patterns of production and consumption.*

*This report, based on a study by energy analysts at Science Concepts, Inc., in the United States, traces changes in world energy supply since 1973-74 — the time of the first oil "price shocks". In so doing, it identifies important lessons for the future. The study focused in particular on the role of the electric power sector because the growth in fuel use in it has been accomplished without oil. Instead, the growth has directly displaced oil.*

*In the pre-1973 era, the world relied increasingly on oil for many energy applications, including the production of electricity. By 1973, more than one-fourth of the world's electricity was produced by burning oil. By 1987, however, despite a large increase in electric demand, the use of oil was reigned back to generating less than 10% of the world's electricity. Nuclear power played a major role in this turnaround. From 1973-87, analysts at Science Concepts found, nuclear power displaced the burning of 11.7 billion barrels of oil worldwide and avoided US \$323 billion in oil purchases.*

**T**he rising importance of electricity is evident in the fact that 28% of the world's primary energy was devoted to making electricity in 1987 compared to 24% in 1973.

While electricity use in the world has risen by 56% since 1973, all non-electric energy use has grown much more slowly by a total of 24%; in the industrialized countries non-electric energy use *has decreased* by 9% while the use of electricity *has grown* by 50%. The increased use of electricity has made a remarkable difference in the world's pattern of energy use. Since 1979, the Organization of Petroleum Exporting Countries (OPEC) has lost 12 million barrels per day of oil markets, even while the world use of energy has risen by the equivalent of 16 million barrels of oil per day.\* OPEC not only lost a portion of its share of existing markets, it made no penetration into new energy markets created by economic growth. Clearly, other energy sources besides OPEC oil have increased to power economic growth and displace oil.

Between 1973-87, world energy use increased by 39%. By 1987 the world was consuming 38 million barrels per day more of oil-equivalent energy than in 1973. Annual increases in energy use were interrupted only briefly by the oil price increases in 1973-74 and 1979. Since 1983, worldwide energy use has been growing at a rate of 3% per year.\*\* The annual increase of 3% represents new energy which must be produced and delivered each year: The increase in 1987 alone represents an additional demand for energy equivalent to the use of 4 million barrels of oil per day.

Simultaneous with rising worldwide energy use, OPEC oil sales have fallen by 12 million barrels per day, which equals almost 40% of OPEC's peak production level in 1979. It is this loss of oil markets which has

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This report is based on a study by Science Concepts, Inc. prepared for the US Council for Energy Awareness, a non-governmental organization in Washington DC. Copies of the full study are available from USCEA, 1776 Eye St. NW, Suite 400, Washington, DC 20006, USA.

\* BP Statistical Review of World Energy (June 1988).

\*\* In 1982, electricity use in the World Outside Communist Areas (WOCA) was 5625 trillion kilowatt-hours, and in 1987 it was 6778 trillion kilowatt-hours; the increase was at an annual compound growth rate of 3.8%.

completely changed the economics of energy production worldwide. In 1979, OPEC was in control of the world oil markets; oil prices were rising, causing other energy prices to rise as well, and inflation in many parts of the industrial world reached post-war highs. Since then, OPEC has lost a large degree of its ability to control oil prices and dominate the oil market. Energy prices are at their lowest point in many years, and there is no energy-induced price inflation in the industrialized world. The reason for this turnaround has been the tremendous expansion in other fuels which has met the world's growing need for energy and, at the same time, displaced OPEC oil.

Looking behind the figures, however, shows the importance of the electric sector. Most coal, significant amounts of natural gas, and all nuclear power and hydro power are used to make electricity. Nuclear and hydro used to make electricity are, overall, lower in environmental impact, typically indigenous and secure resources, and have significant room for expansion. The remaining supply of new energy was dominated by increased non-OPEC oil production, which is now in decline (e.g. North Sea and Alaska).

Nuclear power has provided 31% of all new electricity in the world since 1973.

### Electricity and growth

Given the substantial role of fuels used in the electric sector, it is not surprising that worldwide electricity use has increased by more than 50% since 1973, equivalent to the output of 345 power plants of 1000-megawatt size.\* Meanwhile, non-electrical energy (or direct energy use) rose by only 24%.

In the industrial world, the trend towards electrification is even stronger. In the 24 countries of the Organisation for Economic Co-operation and Development (OECD), direct energy use has actually fallen 9% since 1973. This is a remarkable achievement: a 50% increase in economic output has been accomplished with a smaller amount of direct energy use than 15 years earlier. This increase in the efficient use of energy can be attributed, in part, to the application of electrical energy to processes which previously used fuels directly. It is also attributable to the fact that new electrical processes are far more efficient than their fuel-driven predecessors.\*\* The increased use of electricity and declining consumption of non-electrical energy in the marketplace is evident in industrial nations.

This trend towards increased use of electricity also indicates some important differences between the

Western industrial world and Eastern European countries, as well as between the industrialized West and the developing regions of the world. The trend suggests that as countries of Eastern Europe and the countries of the Third World continue to develop, it is reasonable to assume that the need for electricity will show the same pattern as in the Western world by tracking economic growth and outstripping the growth in other forms of energy.

Another way to examine this important trend is the amount of fuel, or electricity, required per unit of economic output. It is clear that the growing energy efficiency of the industrial world has been achieved through displacing the direct use of energy while increasing the use of electricity.

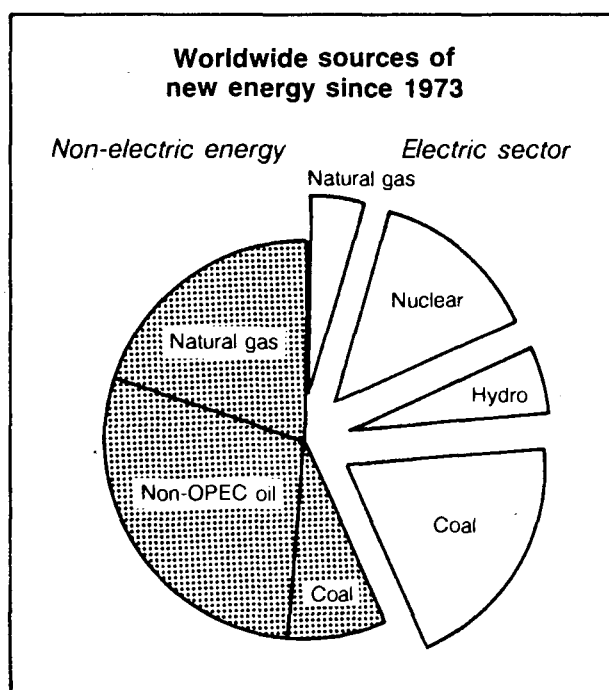
This trend has important economic and environmental implications:

- Continuing improvements in overall energy efficiency are likely to be accomplished with electric and economic growth continuing in parallel.

- Increased use of electricity and decreased use of combustible fuels in the marketplace will improve air quality.

- Since electricity can be generated by many different fuels, countries can select the generation sources which are cheapest, most secure, and most environmentally sound over the long run.

Countries with reductions in non-electric energy consumption also have high growth in the use of electricity. By electrifying, they have imported less fossil fuels while encouraging economic growth and minimizing environmental impacts. It is no coincidence that these same countries also have made the most pronounced use of nuclear power. And, it is no coincidence that the use of imported oil to make electricity has declined as the use of nuclear power has grown.



\* Increased output in OECD countries is 2118.7 billion kilowatt hours. A 1000-megawatt plant at 70% capacity produces 6.1 billion kilowatt-hours per year. Nuclear and hydro power have produced virtually all the new power and replaced fossil-fuelled power.

\*\* *Heating Homes: A Comparison of the Energy Efficiency and Economic Competitiveness of Natural Gas and Electricity*, Calvin C. Burwell (January 1988).

**Country analyses**

*Following are some points from Science Concepts' country-by-country analyses covering the 1973-87 time period:*

**BELGIUM:** Nuclear electricity generation displaced about 200 000 barrels of oil per day and 88 billion cubic feet of natural gas in 1987. Oil use for electricity generation has fallen to nearly zero.

**CANADA:** Without nuclear power, it is estimated that Canada would have used an extra 73 million barrels of oil annually. Nuclear power has also displaced gas-fired generation; the estimated amount of natural gas spared totals more than 800 billion cubic feet since 1973.

**FEDERAL REPUBLIC OF GERMANY:** In 1987, nuclear power offset an estimated 16 million short tons of coal, which accounts for about 55% of total electric power generation compared to nuclear power's share of about 30%. Gas-fired electricity now represents only about 6% of power generation, compared to nearly 20% in 1979. Oil use for electricity generation has fallen from almost 200 000 barrels per day in 1973 to only 28 000 barrels per day in 1987.

**FINLAND:** Nuclear power has allowed electricity use to rise by almost 70% while oil consumption for the generation of electricity has fallen by 60%.

**FRANCE:** Now generating more than 70% of its electrical power with nuclear plants, France is estimated to have avoided the importation of more than 2.2 billion barrels of oil since 1973. France alone accounts for almost one-quarter of worldwide oil displacement through the use of nuclear power.

**ITALY:** The country's three nuclear stations produced 4% of all electricity in 1987, displacing the need for importing 37 000 barrels of oil per day.

**JAPAN:** Japan consumed 23% less oil in 1987 than it did in 1973. An important element has been the shift of generating capacity from largely oil-based (73% of all generation in 1973, 26% in 1987) to one increasingly based upon nuclear power and natural gas.

**NETHERLANDS:** The country's nuclear power stations displaced 1000 barrels of oil per day and 38 billion cubic feet of natural gas per year.

**SPAIN:** Nuclear power generation in Spain has tripled since 1983, with virtually all of the nuclear capacity displacing oil.

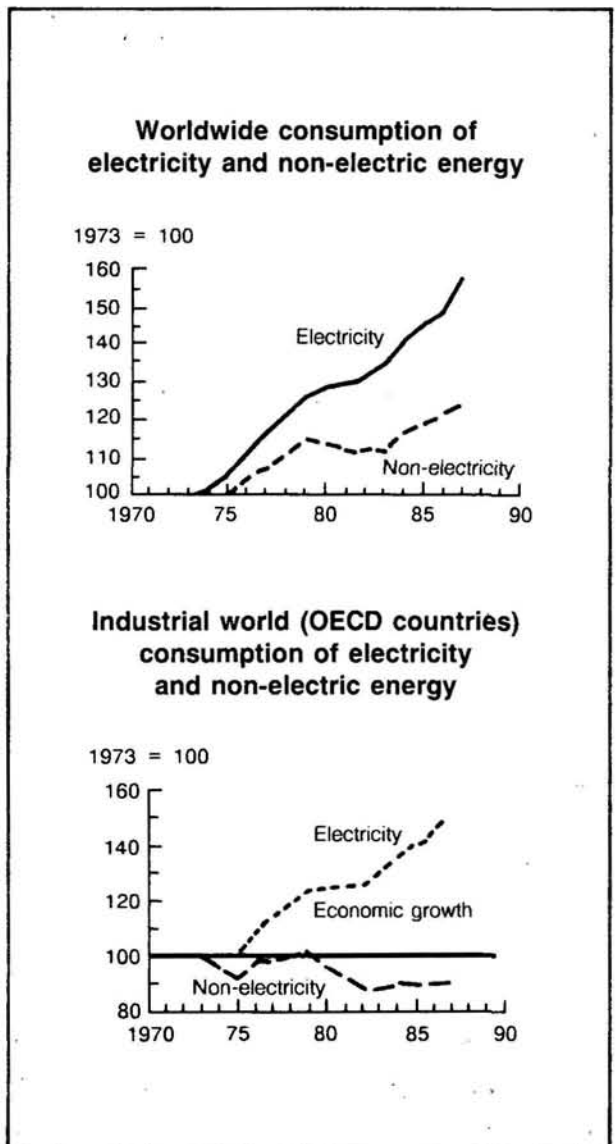
**SWEDEN:** The country's 12 nuclear power plants — which generated about half of all electricity there — saved some 300 000 barrels of oil per day in 1987; more than 700 million barrels of oil have been saved in Sweden since 1973. Oil-fired generation stood at less than 2% of total production in 1987, down sharply from 20% in 1973.

**SWITZERLAND:** Nuclear power — which produces more than 40% of the country's electricity— displaces more than 120 000 barrels of oil per day and has enabled reduction of oil consumption for electricity generation to less than 1000 barrels per day.

**UNITED KINGDOM:** Nuclear power produced more than 20% of the electricity generated in the UK in 1987 and displaced almost 80 000 barrels of oil per day and about 70 billion cubic feet of natural gas. Oil saved by nuclear power in the UK since 1973 is estimated to represent about 4% of British oil exports and oil earnings of US \$500 million per year.

**UNITED STATES:** The world's largest producer of nuclear-generated power, the USA accounted for about 30% of nuclear electricity production worldwide in 1987. That year, nuclear power in the USA displaced 260 million barrels of oil, 1200 billion cubic feet of natural gas, and 90 million tons of coal.

**OTHERS (USSR and Eastern Europe):** Between 1973-87, nuclear power plants in Bulgaria, Czechoslovakia, German Democratic Republic, Hungary, Yugoslavia, and USSR displaced about one billion barrels of oil, more than four trillion cubic feet of natural gas, and 212 million tons of coal.

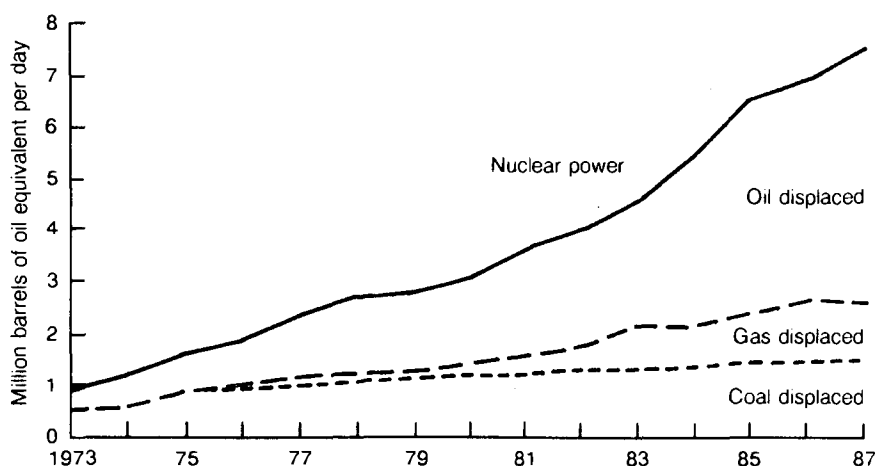


## Special reports

### Fuel displaced by nuclear power: Historical overview

WORLDWIDE					
		Displacement, 1987	Value	Displacement, 1973-87	Value
Oil	5 million barrels per day		US \$32.0 billion	11.7 billion barrels	US \$323 billion
Gas	3 trillion cubic feet		US \$ 9.0 billion	15 trillion cubic feet	US \$ 96 billion
Coal	185 million tons		US \$ 9.3 billion	1500 million tons	US \$ 75 billion
REGIONAL					
North America			Western Europe		
		Fuel displacement			
		1987	1973-87	1987	1973-87
Oil	1 million barrels per day		4 billion barrels	Oil	2.2 million barrels per day
Gas	1280 billion cubic feet		3.2 trillion cubic feet	Gas	817 billion cubic feet
Coal	97 million tons		750 million tons	Coal	26 million tons
					4.7 billion barrels
					5.3 trillion cubic feet
					273 million tons
USSR & Eastern Europe			Other regions		
		Fuel displacement			
		1987	1973-87	1987	1973-87
Oil	400 000 barrels per day		1 billion barrels	Oil	1.3 million barrels per day
Gas	995 billion cubic feet		4.4 trillion cubic feet	Gas	11 billion cubic feet
Coal	18 million tons		212 million tons	Coal	44 million tons
					2 billion barrels
					2.1 trillion cubic feet
					265 million tons
SELECTED COUNTRIES					
United States			France		
		Fuel displacement			
		1987	1973-87	1987	1973-87
Oil	800 000 barrels per day		3.5 billion barrels	Oil	1 million barrels per day
Gas	1200 billion cubic feet		3.9 trillion cubic feet	Gas	91 billion cubic feet
Coal	90 million tons		800 million tons	Coal	2 million tons
					2.2 billion barrels
					0.7 trillion cubic feet
					12 million tons
Japan			Federal Republic of Germany		
		Fuel displacement			
		1987	1973-87	1987	1973-87
Oil	800 000 barrels per day		2.0 billion barrels	Oil	200 000 barrels per day
				Gas	484 billion cubic feet
				Coal	14 million tons
					0.3 billion barrels
					2.6 trillion cubic feet
					160 million tons
Oil displaced and oil purchases avoided by nuclear power, 1973-87					
		Oil displaced	Purchases avoided		
		Oil displaced	Purchases avoided		
North America	4.0 billion barrels		US \$114 billion	USSR	1.0 billion barrels
Western Europe	4.7 billion barrels		US \$150 billion	Other regions	2.0 billion barrels
					US \$36 billion
					US \$23 billion
<b>World</b>				11.7 billion barrels	US \$323 billion
Notes: Billion = 10 <sup>9</sup> ; trillion = 10 <sup>12</sup> ; one cubic foot = 0.028 cubic metres. All values are expressed in 1987 US dollars.					

Fuels displaced by nuclear power: Worldwide, 1973-87



### Analysis of nuclear power's fuel displacement

Analysts at Science Concepts conducted a detailed, year-by-year and country-by-country analysis based on a computer model of world electric supply. Results revealed that cumulatively since 1973, nuclear power has displaced 11.7 billion barrels of oil, over 15 trillion cubic feet of natural gas, and over 1.5 billion tons of coal.

The computer model enabled a country-by-country estimate of the fuels displaced by looking at electric generating capacity in place each year, considering the amount of nuclear power added and the changes in availability of other fuels. The fuel displacement figures answer the question: what would have been burned had nuclear power not been available?

The procedure for developing the computer model involved studying each country's energy picture on a year-by-year basis, assuming in each case that electricity that had been generated with nuclear power had, instead, been generated by other existing power plants. To do this, top priority was given to coal-fired power. This was done because coal is generally favoured in those countries where it is used, either because of its low cost (North America) or because coal production is a favoured domestic industry (United Kingdom, Federal Republic of Germany). It was assumed that coal-fired generating capacity would have been used to the maximum extent possible. This maximum amount of generation was achieved by assuming that all coal-fired plants would have operated at peak record capacity and that all coal-fired plants that had been planned but not built

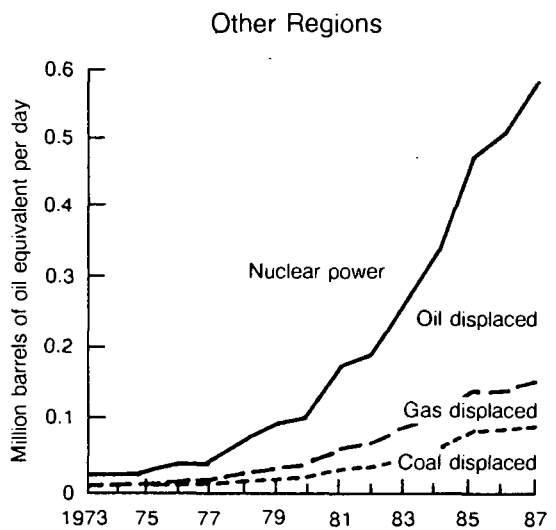
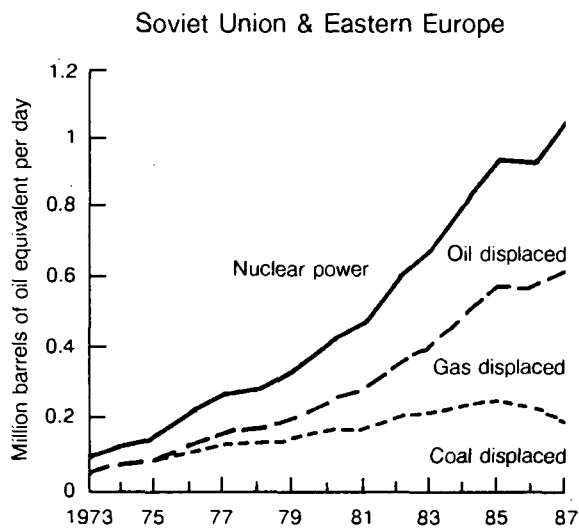
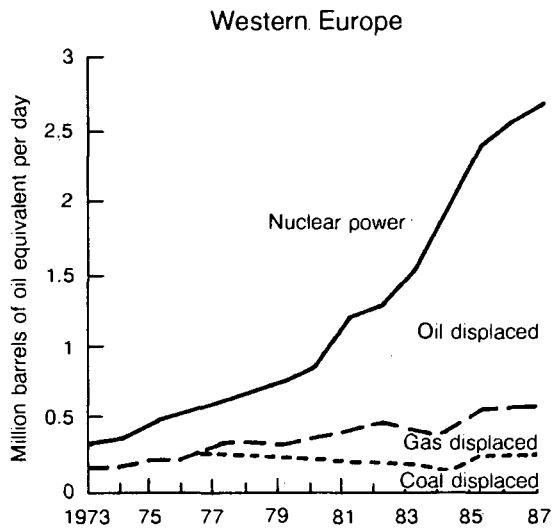
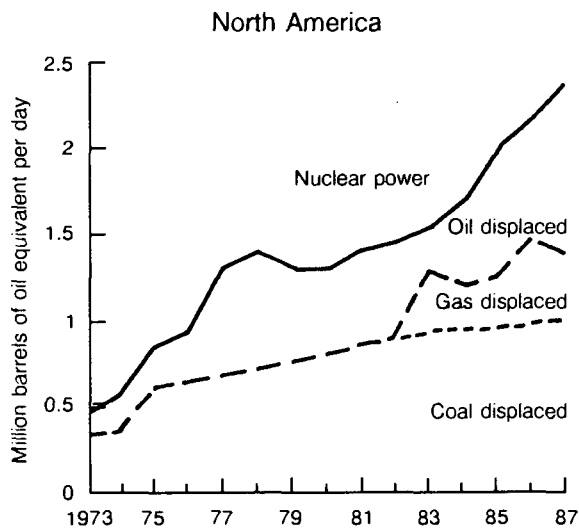
would have actually been built under the conditions of the study. Also assumed was a factor for increasing the coal supplies for each country to the maximum credible amount for each year.

After using coal to its maximum potential, the next fuel choice was natural gas. Its use was increased to the maximum feasible level using similar procedures. Natural gas for electrical generation has been falling off in all countries of this survey except Japan. Without nuclear electricity, it was assumed that this decrease in natural gas consumption for electrical generation would not have occurred. The model was further qualified to allow the peak use levels of natural gas consumption for electrical generation to be used for continual electrical generation. The difference between this "continual peak level" use of natural gas during each year of the period 1973-87 and the actual quantity of natural gas used was assumed to be the amount of natural gas saved by nuclear generation for that year.

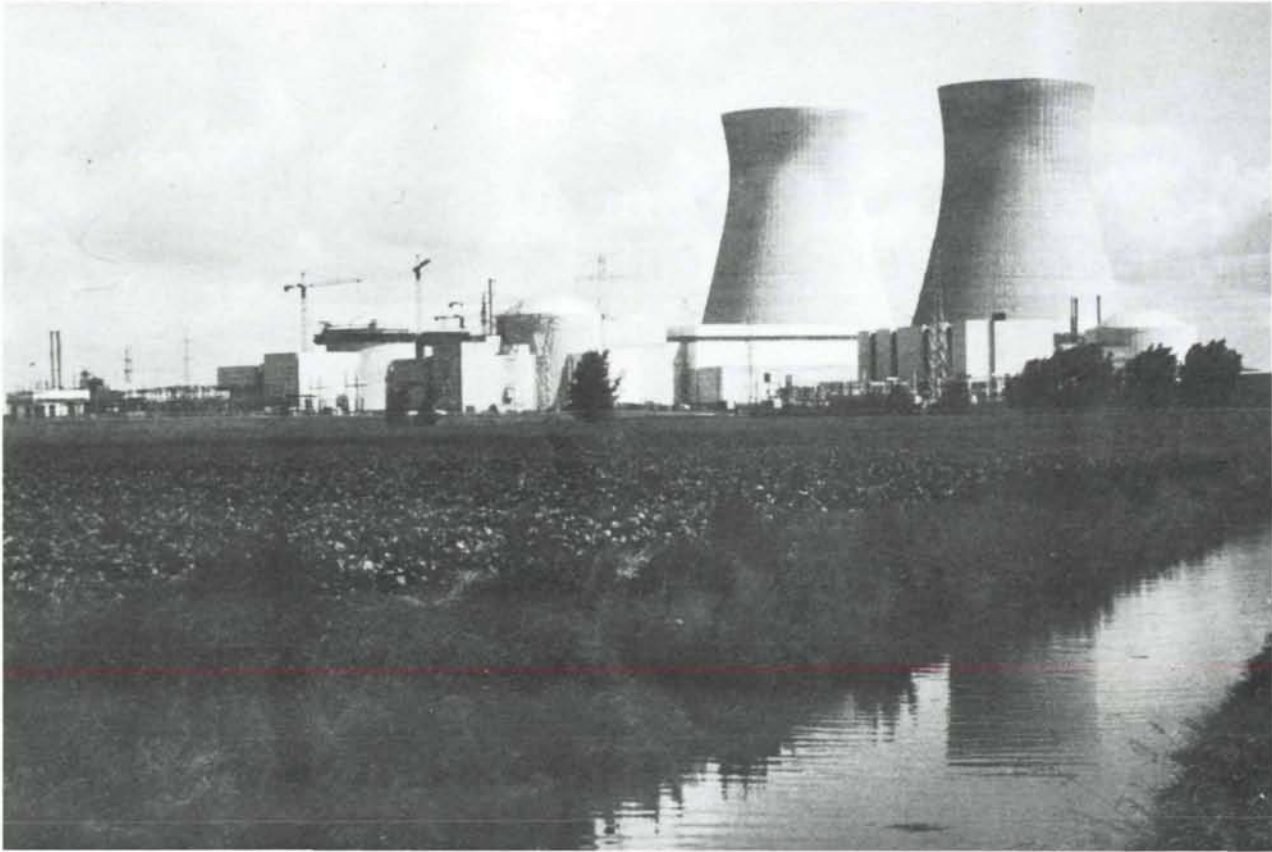
Finally, the model used oil as the fuel of last resort for producing electricity. This assumption, in fact, reflects the practice of most nations. It was assumed that the oil for generating electricity would have been imported only if the amount of oil required exceeded the amount which could have been produced domestically.

The result is a year-by-year compilation of the estimated fuels displaced by nuclear power. Since this is an estimate of what would have happened without nuclear power, it remains an estimate and not a precise figure. However, since it is based on existing capacity, capacity planning, as well as the history of fuel use in each specific country, Science Concepts analysts believe it represents an accurate estimate of fuel displacement.

Fuels displaced by nuclear power: Regional overview



Cumulatively between 1973 and 1987, nuclear electricity plants have displaced the use of fossil fuels valued at nearly US \$500 billion, analysts in the United States have estimated.



Doel nuclear power plant in Belgium, where more than 60% of all electricity is produced by nuclear power plants.

**Fuels displaced by nuclear power in 1987**

	Net nuclear generation (billions of kilowatt-hours)	Oil displaced (millions of barrels)	Coal displaced (millions of tons)	Natural gas displaced (billions of cubic feet)	OPEC purchases avoided (billion 1987 US \$)
United States	455.0	294	90	1200	5.2
France	251.3	387	2	91	6.8
Japan	188.5	291	0	0	5.1
Federal Republic of Germany	123.2	69	14	484	1.2
Canada	72.9	73	7	80	0.0
Sweden	69.4	102	0	0	1.8
United Kingdom	48.9	50	6	73	0.9
Belgium	39.6	49	0	99	0.0
Spain	39.5	57	0	39	1.0
Switzerland	21.7	46	0	0	0.8
Finland	18.5	12	4	0	0.2
Netherlands	3.4	0	0	31	0.0
Italy	0.1	13	0	0	0.2
<b>TOTAL</b>	<b>1332.0</b>	<b>1443</b>	<b>163</b>	<b>2097</b>	<b>23.2</b>
Eastern Europe	244.1	160	18	995	0.0
Others	84.7	187	44	11	7.5
<b>WORLD TOTAL</b>	<b>1660.8</b>	<b>1790</b>	<b>185</b>	<b>3103</b>	<b>30.7</b>

Notes: Under "Eastern Europe", Science Concepts analysts included USSR, Czechoslovakia, Bulgaria, German Democratic Republic, Hungary, and Yugoslavia. Under "Others", the analysts included Argentina, Brazil, India, Pakistan, the Republic of Korea, South Africa, and Taiwan, China. Net nuclear generation is from the *World Industry Handbook 1989*. Billion = 10<sup>9</sup>; one cubic foot = 0.028 cubic metres.