Nuclear Energy's Clean Air Benefits

A LEGACY OF GREENHOUSE GAS REDUCTIONS AND FOSSIL FUEL CONSERVATION IN AMERICA

October 1997

NUCLEAR ENERGY INSTITUTE

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ACKNOWLEDGEMENTS

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FOREWORD

Nuclear power plants provide one-fifth of U.S. electricity supply. They are the nation's second-largest power source, helping to sustain the nation's economic growth and quality of life. The environmental benefits of nuclear energy are no less significant. Nuclear energy has done more to prevent atmospheric emissions—carbon dioxide, sulfur dioxide, and nitrogen oxides—than any other form of electricity generation.

Because nuclear power plants produce electricity without burning fuel, they do not emit greenhouse gases. Nuclear plants, providing 40 percent of the increase in electricity generation since 1973, substituted for fossil-fueled generating plants that would otherwise have been built. This report estimates the amounts of fossil fuel that were conserved because of the use of nuclear power plants from 1973-96. It quantifies the emissions avoided by the use of nuclear energy in each of seven regions of the United States. It also provides important historical perspective on changes in U.S. electricity supply since 1973—and the resulting effects on the environment.

These facts have profound implications for the nation's energy future. The challenge of the coming decades is to meet rising electricity demand while fulfilling the nation's commitments to reduce the emission of pollutants into the atmosphere. These include the 1990 Clean Air Act Amendments targets for sulfur dioxide and nitrogen oxide reductions, and the administration's pledge to reduce emissions of carbon dioxide—a principal greenhouse gas—to 1990 levels by the year 2000.

These commitments cannot be met without a diverse energy mix including large-scale, emission-free nuclear power plants. This report clearly demonstrates the importance of nuclear power plants—including extending the operating licenses of today's plants, as well as preparing for new orders—so nuclear energy can continue to pay energy and environmental dividends for decades to come.

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EXECUTIVE SUMMARY

Over the past several decades, the U. S. government has committed to improve the nation's air quality by reducing the emission of atmospheric pollutants. The nation's electric utilities are taking a leading role in fulfilling these commitments. The challenge is to supply America's growing demand for electricity while protecting the environment and maintaining a stable, diverse energy mix.

Utilities can use a variety of electricity-generating fuels: fossil fuels (coal, gas and oil), nuclear energy, hydropower, and, to a much lesser extent, renewables (solar, wind, biomass). Of these, only nuclear energy and hydropower are large-scale and emission-free. Although some renewables also are non-polluting, they do not supply significant amounts of electricity—less than one percent. Hydropower produces 10 percent of U.S. electricity. Nuclear energy supplies one-fifth—the nation's second-largest source.

Nuclear power plants account for 40 percent of the increase in electricity generation since 1973. If they had never been built, that electricity would have been generated by fossil fuel-burning plants. This substitution of nuclear energy for fossil-fueled electricity has paid enormous environmental dividends—particularly in reducing emissions of carbon dioxide, the principal greenhouse gas. To generate one million kilowatt-hours of electricity from coal releases 230 metric tons of carbon into the atmosphere, 190 metric tons from oil, and 150 metric tons from natural gas. But a nuclear power plant generates those kilowatts entirely carbon-free. Clearly, the use of nuclear energy has avoided significant atmospheric emissions from the use of fossil fuels.

This report is an overview of the electricity fuel sources—and resulting emissions—that were conserved in the United States by the use of nuclear energy from 1973-96. Its findings are based on Department of Energy state-by-state data on historic fuel availability and use. For evaluation purposes, the report divides the nation into seven geographic regions.

To help the reader understand these emissions savings in the context of U.S. environmental policy, they will sometimes be compared with the emission reduction goals established by the Clean Air Act Amendments of 1990 and the administration's Global Climate Action Plan to reduce greenhouse gases to 1990 levels by 2000.

Nuclear Energy Reduced Utility Emissions by 25 Percent in 1996

In 1996, electric utilities' emissions of carbon dioxide, sulfur oxide and nitrogen oxide were 25 percent lower than they would have been if fossil fuels had been used instead of nuclear energy.

Since 1973, nuclear energy has been by far the most important factor in preventing electric utility carbon dioxide[1] emissions:

- From 1973-96, nuclear energy enabled utilities to prevent the cumulative emission of two billion metric tons of carbon.

- In 1996, utilities' use of nuclear energy prevented the emission of 147.3 million metric tons of carbon dioxide. (This is the additional amount that fossil-fueled plants would have emitted if there had been no nuclear plants.)

- Improved efficiency, additions to capacity, and completion of new nuclear plants since 1989[2] have prevented additional emissions of 38.8 million metric tons of carbon annually. (The more efficiently nuclear plants operate, the more emission-free electricity they produce to substitute for fossil-fueled power.)

U.S. nuclear power plants also have prevented sulfur dioxide and nitrogen oxide emissions:

- In 1996, utilities' use of nuclear energy prevented the emission of 5.3 million tons of sulfur dioxide from fossil-fueled plants. (This amount is equivalent to more than half of the reduction target established in the Clean Air Act Amendments of 1990.)

- In 1996, nuclear plants prevented the discharge of 2.5 million tons of nitrogen oxides. (This amount is greater than the two-million-ton annual reduction required in the 1990 law.)

- From 1973-96, nuclear plants prevented the emission of 80.2 million tons of sulfur dioxide and 34.6 million tons of nitrogen oxides.

Nuclear Energy Prevented Consumption of Coal, Natural Gas and Oil

From 1973-96, nuclear energy substituted for enormous quantities of fossil fuels that otherwise would have been burned to generate electricity:

- 3.4 billion tons of coal,
- 12 trillion cubic feet of natural gas, and
- 2.3 billion barrels of oil.

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[1] All values of carbon dioxide emissions in this report are expressed in metric tons of carbon weight — the measurement unit used by the Clinton administration to quantify reduction in the nation's greenhouse gas emissions between 1900 and 2000. If expressed in terms of (short) tons of carbon dioxide (i.e., molecular weight), the carbon dioxide emissions values in this report would be about four times greater.
[2] In the Energy Policy Act of 1992, the years from 1987-89 are used as a base period against which atmospheric emissions improvements can be calculated.

Without nuclear energy, 22 percent more coal, 32 percent more oil and 17 percent more natural gas would have been consumed by electric utilities between 1973 and 1996.

In 1996, nuclear energy prevented the burning of the following amounts of fossil fuels:

- 268 million tons of coal,
- 983 billion cubic feet of natural gas, and
- 62 million barrels of oil.

A look at today's U.S. electricity fuel requirements puts these numbers in perspective: These substitutions equal 31 percent of the coal burned by utilities in 1996, 36 percent of their natural gas usage, and 54 percent of their oil consumption.

As the above data clearly shows, nuclear energy has produced major environmental benefits for the nation in the past quarter of a century. As the nation strives to further control its atmospheric emissions in the years ahead, nuclear energy—more than ever—must be an essential part of any realistic, long-term solution.

SCOPE OF THIS REPORT

This report provides an overview of electricity fuel sources that were "conserved" due to the use of nuclear energy plants during 1973-1996.[3] The fuel sources that would have been used to generate electricity had nuclear power plants not come on line are identified for seven U.S. regions. These results are used to calculate key atmospheric emissions that were avoided through the operation of nuclear energy plants.

"Replacement" fuels had nuclear energy plants not been built were estimated for each state, on the basis of historical fuel availability and use for electricity generation. Department of Energy state information was used because it provided a meaningful level of detail in accounting for critical variances, such as local fuel resources, existing or planned fuel transportation infrastructure (railway lines, pipelines, etc.), and fuel delivery prices.[4] The state information was then aggregated into the following seven regions (for the continental United States):

(1) New England: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont.

(2) Middle Atlantic: Delaware, District of Columbia, Maryland, New Jersey, New York, Pennsylvania.

(3) Southeast: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, West Virginia.

(4) Midwest: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, Ohio, Wisconsin.

(5) Southwest: Arizona, New Mexico, Oklahoma, Texas.

(6) Mountain: Colorado, Idaho, Montana, Nevada, North Dakota, South Dakota, Utah, Wyoming.

(7) West Coast: California, Oregon, Washington.

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[3]The first commercial nuclear power plants came on line in the late 1950s, but most of the growth in nuclear capacity began in the early 1970s. U.S. nuclear power plants generated only 83 billion kilowatt-hours in 1973, as compared with 675 billion kilowatt-hours in 1996.

[4]Utility-specific data would have been perhaps even more appropriate but was not used for lack of a consistent, centralized database of historical data over the 1973-1996 study period.

The analysis was conducted on an annual basis to account for historic changes in actual fuel dispatch and planning priorities affected by fluctuations in fossil fuel prices, environmental requirements and costs, or other events and measures that changed the competitive advantage and availability of electricity sources. This report's estimates are based solely on historical data. This is an important feature of this analysis: It does not attempt to create scenarios through the use of complex econometric or statistical simulation models. (For more information, refer to "Notes on the Estimation Methodology" in the Appendices section.)

The atmospheric emissions included in the analysis are:

- Carbon emissions from carbon dioxide. The Clinton Administration's *Climate Change Action Plan* outlines measures and recommendations to achieve nationwide reductions in carbon dioxide emissions to fulfill the United States' commitment to lower greenhouse gas emissions to 1990 levels by 2000.

- Sulfur dioxide and nitrogen oxide emissions. Both gases are regulated under Title IV of the Clean Air Act Amendments of 1990; caps on the total emissions of these gases are established in the act.[5]

[5]NOx emissions are also indirectly impacted under Title I of the Clean Air Act Amendments, targeted at reducing ozone and other air pollutants, since ozone formation is related to the presence of NOx in the air.

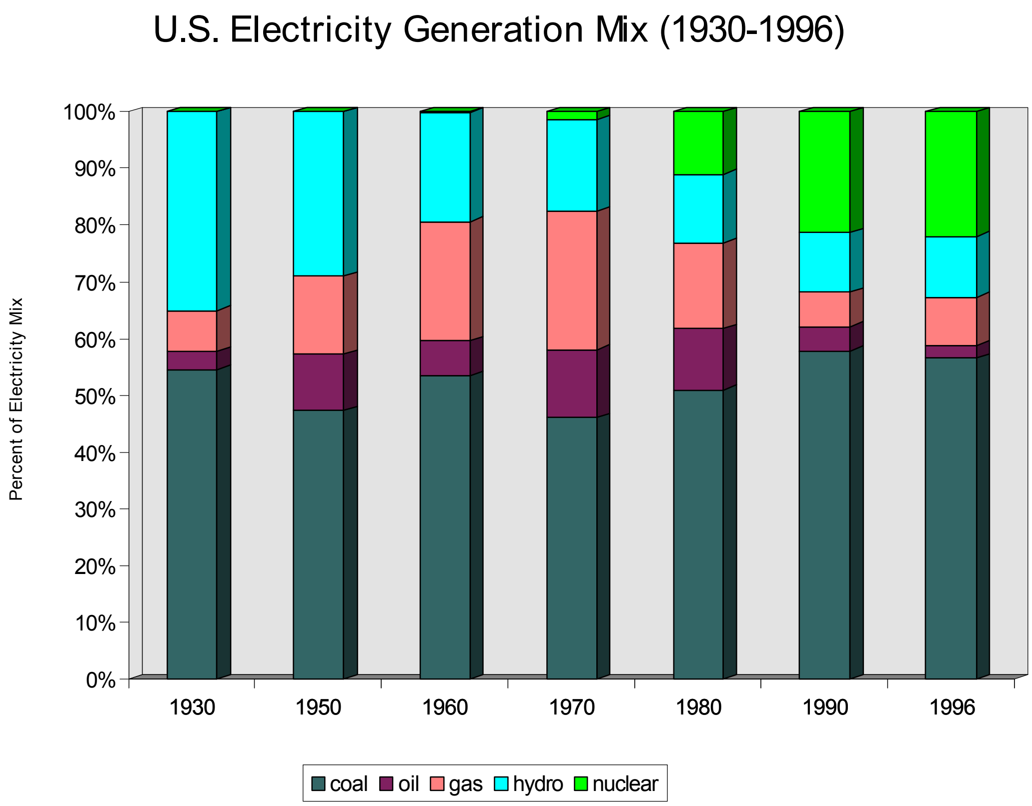
NUCLEAR GENERATION IN THE UNITED STATES

Historical Perspective

During the first half of this century, coal and hydroelectricity provided the vast majority of the electricity generated in the United States[6]. While coal continues to supply more than half of the nation's electricity needs, hydroelectricity generation peaked in the early 1970s.

Other sources of electricity contributed to a more diversified U.S. electric supply system during the second half of the century. Gas- and oil-fired plants generated increasing amounts of electricity until the mid-1970s. The OPEC oil embargo in 1973, and the resultant supply disruptions and price hikes for both oil and natural gas during the 1970s, prompted utilities to reduce their reliance on these fuels.

By the early 1970s, nuclear energy had become a fast-growing source of electricity and it played an important role in substituting for declining or stagnant oil and gas-fired electricity supply.

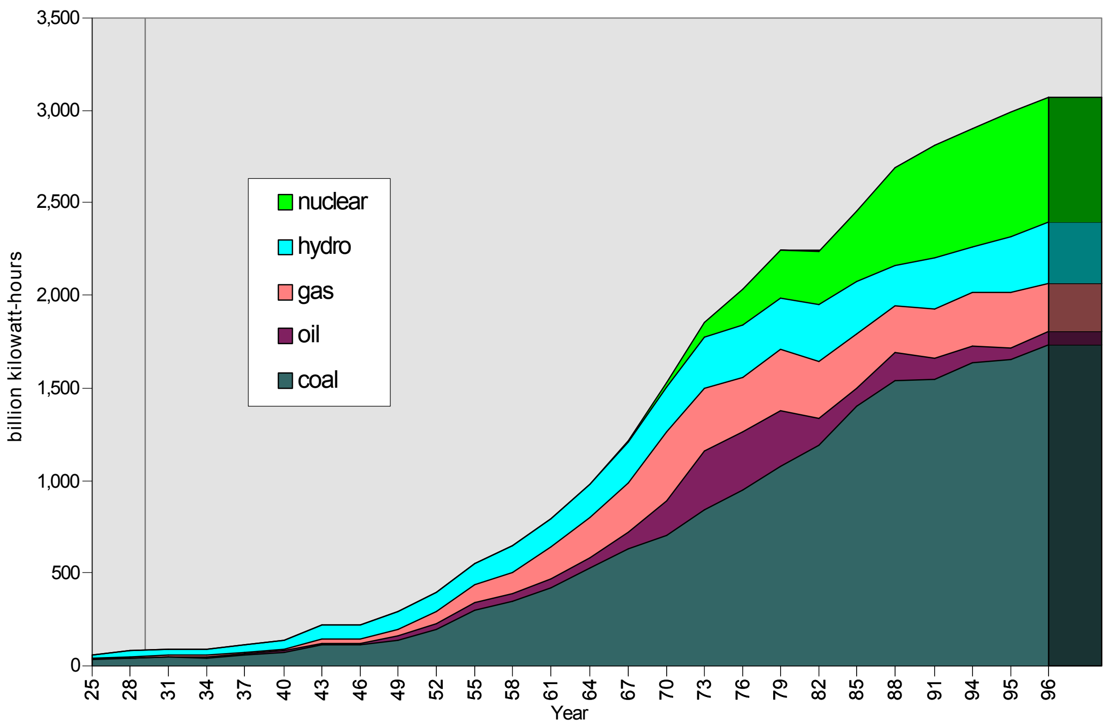


[6]During this period, large industrial users of electricity produced between one-quarter and one-third of the nation's electricity on their industrial sites, through cogeneration.

The U.S. electricity supply system gradually evolved from two resources — coal and hydro — to today's more diversified mix. While coal has consistently produced about half of the U.S. electricity supply, the share of hydroelectricity gradually declined from about 40 percent in 1930 to 11 percent in 1996. The growing role of natural gas, oil and nuclear energy transformed the U.S. electricity fuel makeup to a more diversified electricity fuel mix.

Oil- and natural gas-fired electricity generation expanded from about 10 percent of the nation's production in 1930 to more than one-third in the early 1970s. In 25 years, nuclear energy has grown from 1 percent to one-fifth of the nation's electricity. In 1996, nuclear power plants generated more electricity than the entire nation consumed in 1955.[7]

U.S. Electric Utility Generation Since 1925



Nuclear Energy and U.S. Electricity Supply Since 1973

Only two electricity sources — nuclear energy and coal — have grown significantly since 1973. All other sources have stagnated or decreased. Between 1973 and 1996, nuclear generation increased more than seven-fold, and coal-fired generation more than doubled.

Hydroelectric generation increased by 14 percent. Generation from all other sources decreased: oil by 81 percent, and natural gas by 24 percent.

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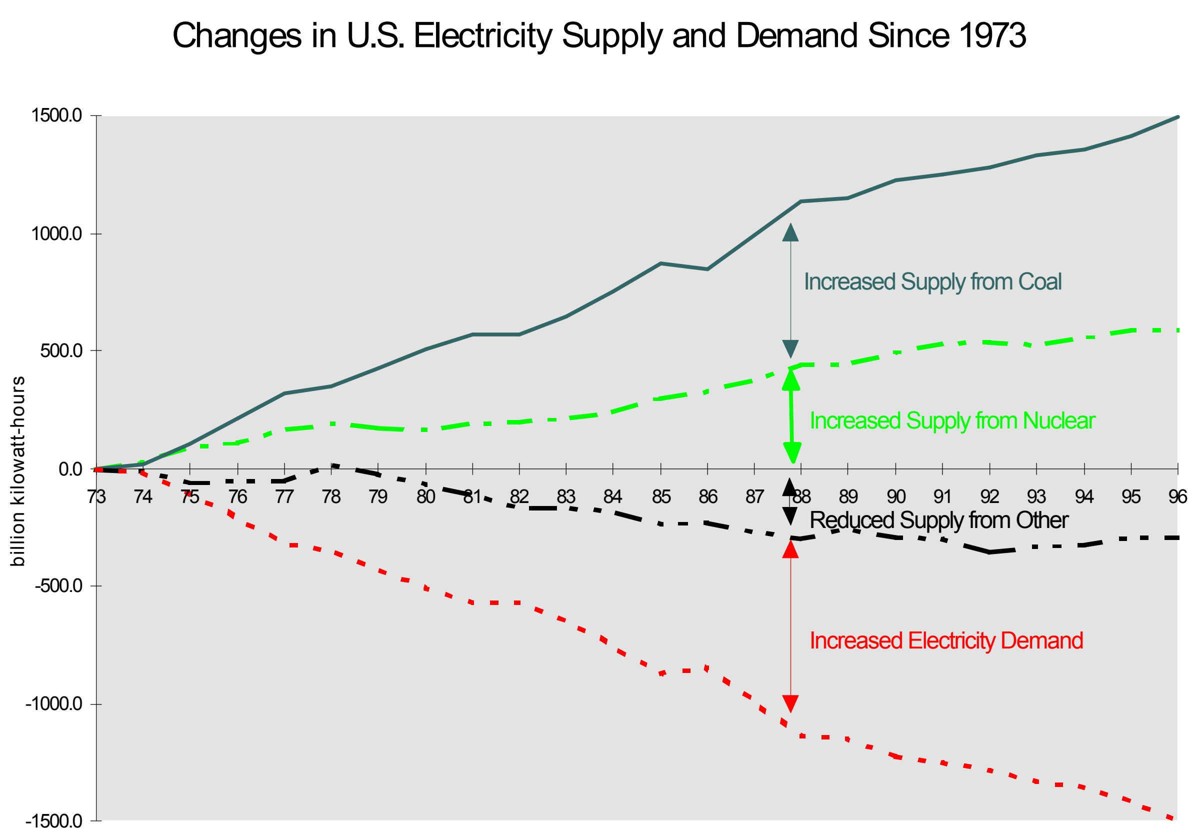
[7]1955 was the year the first commercial nuclear power plant began construction and the first full year after passage of Atomic Energy Act Amendments of 1954.

In absolute terms, changes in electricity generation (1973-1996) by source, in kilowatt hours (kWh), are:

- Coal + 903.8 billion kWh
- Nuclear + 591.1 billion kWh
- Hydro + 46.3 billion kWh
- Oil - 258.5 billion kWh
- Natural Gas - 81 billion kWh

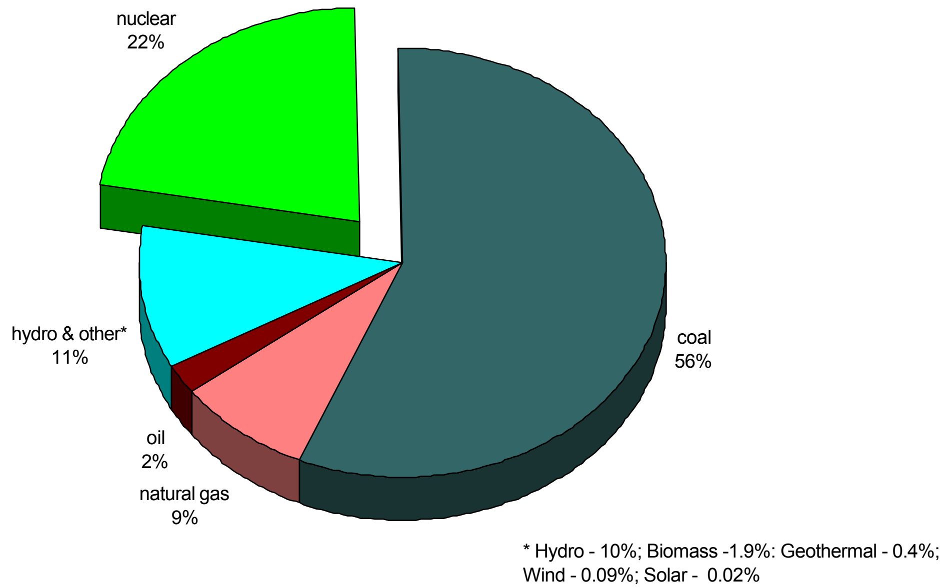
Nuclear energy accounts for 40 percent of the increase in electricity generation over the period 1973-1996 and coal for the remaining 60 percent. This increase in generation met continuing growth in the nation's electricity demand and substituted for reduced supply from other sources.

The increase in nuclear and coal-fired electricity supply is shown below as the mirror image of the new electricity requirements due to increased electricity demand and supply "shortfalls" from other generating sources.



In 1996, the nation's 110 nuclear plants generated 674.8 billion kilowatt-hours, or 20 percent, of the nation's electricity[8].

U.S. Electricity Generation Mix, 1996



U.S. Fossil Fuel Displacement Since 1973

In most regions, coal is the fossil fuel of choice for baseload generation. This widespread reliance on coal for bulk electricity production explains why nearly three-quarters of the electricity produced by nuclear energy since 1973 would otherwise have been produced by coal plants.

Oil generation displacements occur primarily along the Northeast coastal regions and represent 15 percent of total displacements. Natural gas offsets are centered on the West Coast and, to a lesser degree, in the Southwest. They account for 12 percent of total fuel displacements.

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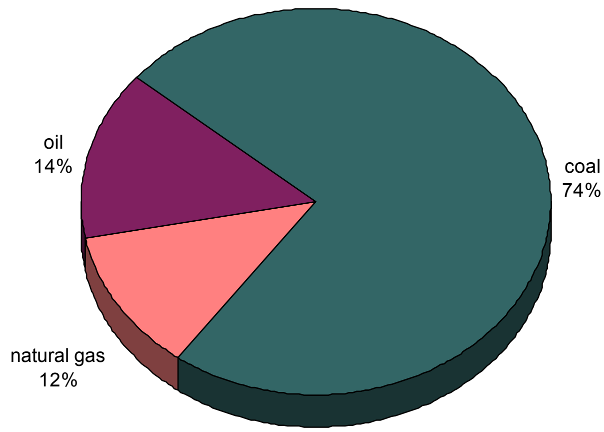
[8]Nuclear energy represented 22% of U.S. electric utility generation in 1996. Total U.S. generation includes non-utility generators such as industrial cogenerators and independent power producers; nuclear energy's share of total generation was 20%. The statistics throughout this report represent percentages of utility generation.

Fossil-Generated Electricity Displaced by Nuclear Power Plants (1973-1996)



In terms of physical quantities of fuels, these displacements reflect very large amounts of natural resources conserved because of the operation of nuclear energy plants. These "savings" are summarized below for 1996 and cumulatively for 1973-1996.

During 1996, the 110 U.S. nuclear energy plants displaced approximately:

- 268 million tons of coal,
- 983 billion cubic feet of gas,
- 62 million barrels of oil.

Between 1973-1996, nuclear energy avoided the burning of fossil fuels by about:

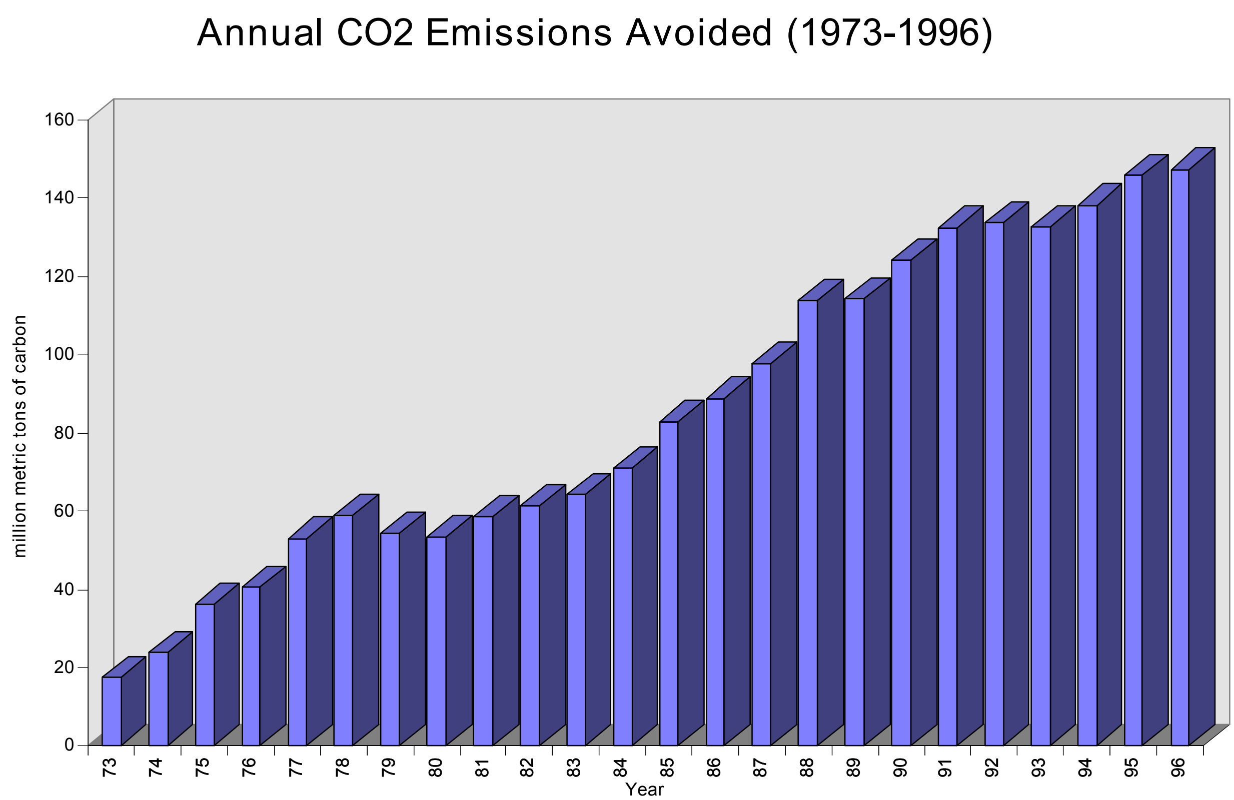
- 3.4 billion tons of coal,
- 12 trillion cubic feet of gas,
- 2.3 billion barrels of oil.

Nuclear — The Clean Air Energy

Emission displacements achieved through the operation of nuclear energy plants are derived by using typical emission rates of today's fossil-fueled units — on the basis of Department of Energy generation and emission data. For example, the typical coal-fired plant emits about 230 tons of carbon per million kilowatt-hours of electricity. Natural gas- and oil-fired plants emit about 190 tons and 150 tons of carbon per million kilowatt-hours, respectively.[9]

If nuclear energy plants had not been operating, U.S. carbon dioxide emissions from electricity generation would have been 32.6 percent higher in 1996, and 22.5 percent higher since 1973.[10]

On the basis of the fossil fuel generation avoided to date, emission offsets are quantified for carbon dioxide, sulfur dioxide and nitrogen oxide emissions.



In 1996, America's 110 nuclear energy plants avoided the discharge of approximately:

- 147.3 million metric tons of carbon dioxide,
- 5.3 million tons of sulfur dioxide,
- 2.5 million tons of nitrogen oxides.

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[9]One million kilowatt-hours is the amount of electricity generated by a large baseload plant for one hour. It also corresponds to the average electricity consumed in the U.S. every 10 seconds. This data is based on U.S. average fossil plant emissions per million kilowatt-hours.
[10]This estimate is based on utility fuel mix for 1996.

A perspective on the magnitude of these benefits is provided by a comparison with current major U.S. policy objectives regarding atmospheric emissions.

The Administration's 1997 *Climate Change Action Plan*, designed to achieve the President's pledge of stabilizing U.S. greenhouse gas emissions at 1990 levels by 2000, projects that carbon dioxide emissions in 2000 will exceed that target by 198 million metric tons.

Title IV of the Clean Air Act (as amended in 1990) regulates emissions believed to cause "acid rain" and requires halving U.S. emissions of sulfur dioxide and nitrogen oxide from 1980 levels by the year 2000. These Clean Air Act objectives represent annual emission reductions of 10 million tons of sulfur dioxide and 2 million tons of nitrogen oxide.

Nuclear energy's clean air benefits exceed our national goals to reduce carbon dioxide and nitrogen oxide, and represent half our committed sulfur dioxide reductions. Over the period 1973-1996, nuclear energy offset the following emissions:

- 2.0 billion metric tons of carbon dioxide,
- 80.2 million tons of sulfur dioxide,
- 34.6 million tons of nitrogen oxide.

Finally, utilities are enhancing these environmental contributions through improvements in operating efficiency and recent construction of new nuclear plants. Since the baseline period of 1987-1989[11], efficiency improvements — the equivalent of building 11 new large nuclear plants — and the operation of new units have reduced greenhouse gas emissions by 39 million metric tons of carbon dioxide.

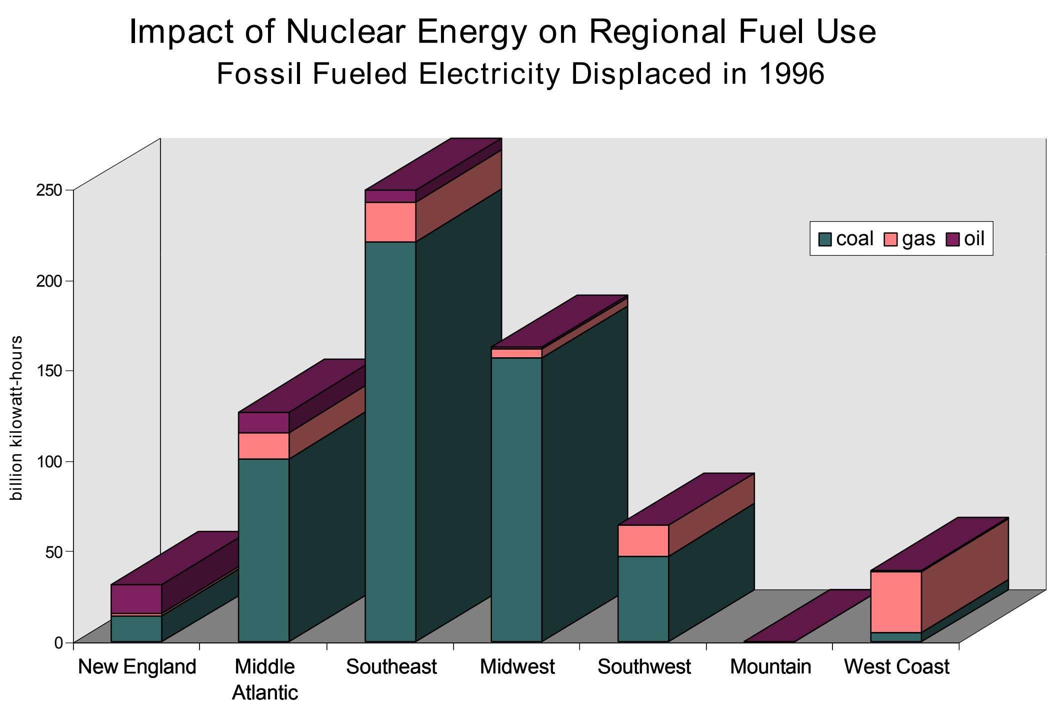
[11] Base period used in the Energy Policy Act of 1992.

U.S. NUCLEAR GENERATION BY REGION

Because of the diverse nature of U.S. energy supply, nuclear energy has had varying impacts in different regions of the United States. The magnitude of these impacts has also varied, depending on (1) the number of nuclear power plants operating in each region and (2) on the importance of nuclear energy relative to each region's electricity use. These geographical variations in fuel mix and nuclear energy distribution make it necessary to analyze the impacts of nuclear plant operation on a regional basis.

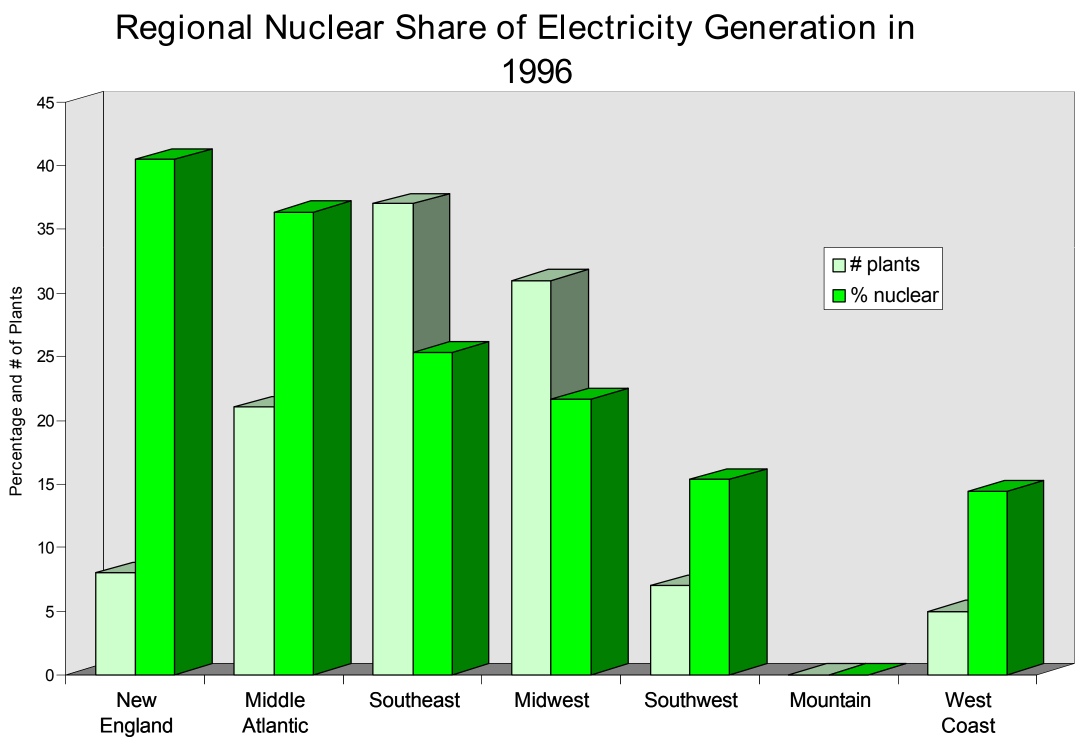
Results in this report are presented for seven regions comprising the lower 48 states: New England, the Middle Atlantic area, the Southeast, the Midwest, the Southwest, the Mountain region, and the West Coast. (For a detailed description of each regional group, see the list of states on page 9 or the U.S. map at the end of the report.)

Obviously, nuclear energy has the largest overall impact in regions where the most nuclear plants are operating: 37 nuclear plants are located in the Southeast, 31 in the Midwest, 21 in the Middle Atlantic region, eight in New England, seven in the Southwest region, and five on the West Coast. There are no nuclear plants in the Mountain region.



In most regions, nuclear energy has replaced coal, which is relatively abundant and low cost. Exceptions are New England, where heavy oil remains an important fuel to generate electricity, and the West Coast, where natural gas is the fuel of choice.

Although New England does not have the largest number of nuclear plants, it is the region where nuclear energy plays the most dominant role in electricity supply. Today, nuclear energy represents 40 percent of electric utility supply in New England, more than 35 percent in the Middle Atlantic region, more than 20 percent in the Midwest and the Southeast areas, 15 percent for the Southwest, and 14 percent for the West Coast



Detailed regional information is presented in the following seven chapters.

New England

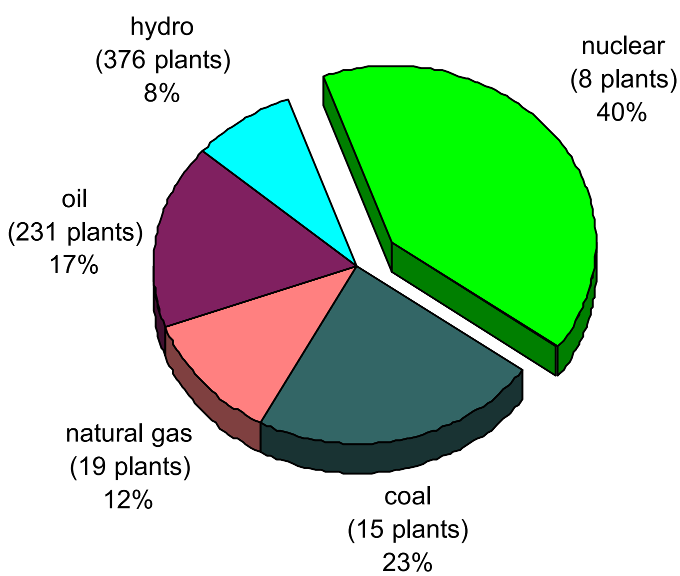
New England Electricity Supply Since 1973

- There are eight nuclear energy plants in operation in the following New England states.[12]

	Unit name	Capacity	Commercial operation date	Cumulative generation (million kWh)
Connecticut	Connecticut Yankee	582 MW	Jan-68	104,515
	Millstone 1	660 MW	Dec-70	101,043
	Millstone 2	870 MW	Dec-75	94,641
	Millstone 3	1154 MW	Apr-86	71,296
Maine	Maine Yankee	870 MW	Dec-72	119,543
Massachusetts	Pilgrim	655 MW	Dec-72	75,768
New Hampshire	Seabrook	1148 MW	Aug-90	52,252
Vermont	Vermont Yankee	522 MW	Nov-72	81,816
		6,461 MW		700,874

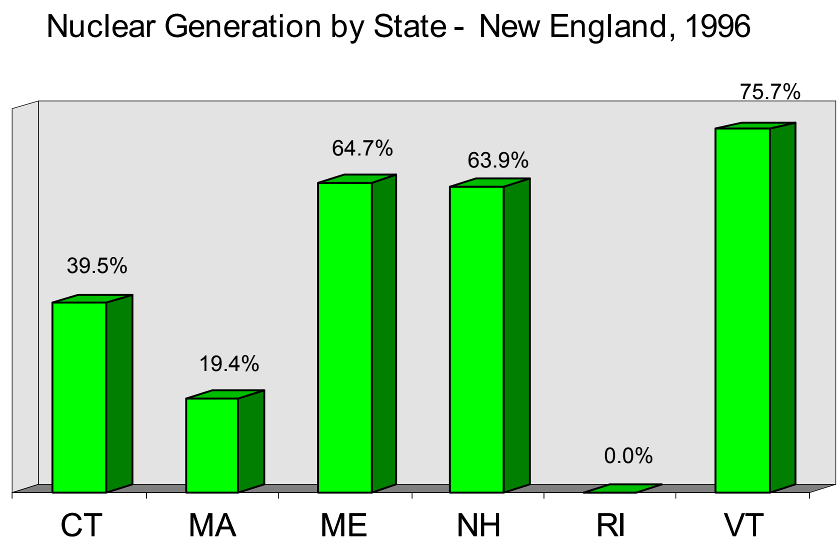
- New England's eight nuclear plants generated 30 billion kilowatt-hours in 1996, representing 40 percent of the region's electricity.

New England Electricity Mix, 1996

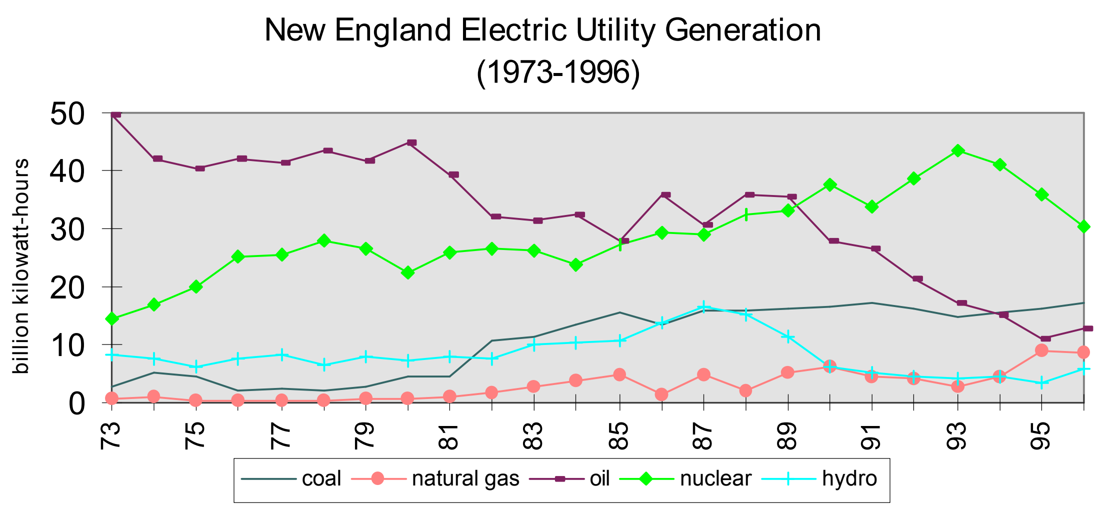


[12] The owners of Connecticut Yankee and Maine Yankee have announced a permanent shutdown of the plants. They are included, however, because they generated electricity during 1996.

- On a state-by-state basis, New England's nuclear power plants supplied the following shares of electricity in 1996[13].



- Nuclear energy grew from supplying 20 percent of New England's electricity in 1973 to more than 40 percent of the region's electricity in 1996.



New England Fuel and Emission Displacements

- In addition to nuclear energy, New England traditionally has relied largely on fuel oil, and secondarily on coal for its baseload electricity generation needs. The region's nuclear plants historically have displaced residual fuel oil, with coal gaining in importance over time.

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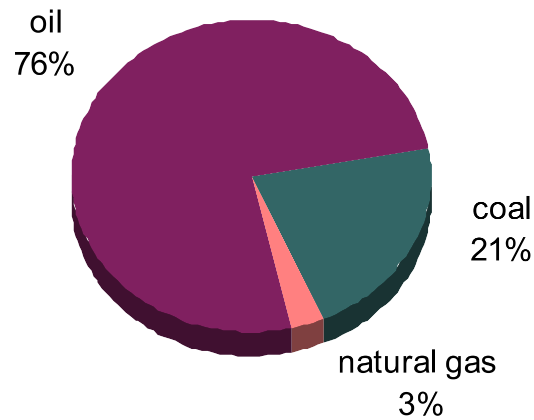
[13]This chart shows the percent of electricity generated in each state by nuclear plants located within the state. Percentages do not necessarily relate to how much electricity demand was met by nuclear energy in a particular state.

Fossil-Generated Electricity Displaced by Nuclear Power Plants in New England (1973-1996)



- During 1996, New England's eight nuclear power plants displaced approximately:

  7 million tons of coal,
  19 billion cubic feet of natural gas,
  26 million barrels of oil.

- Over the period 1973-1996, nuclear energy in New England reduced the burning of fossil fuels by about:

  72 million tons of coal,
  220 billion cubic feet of natural gas,
  900 million barrels of oil.

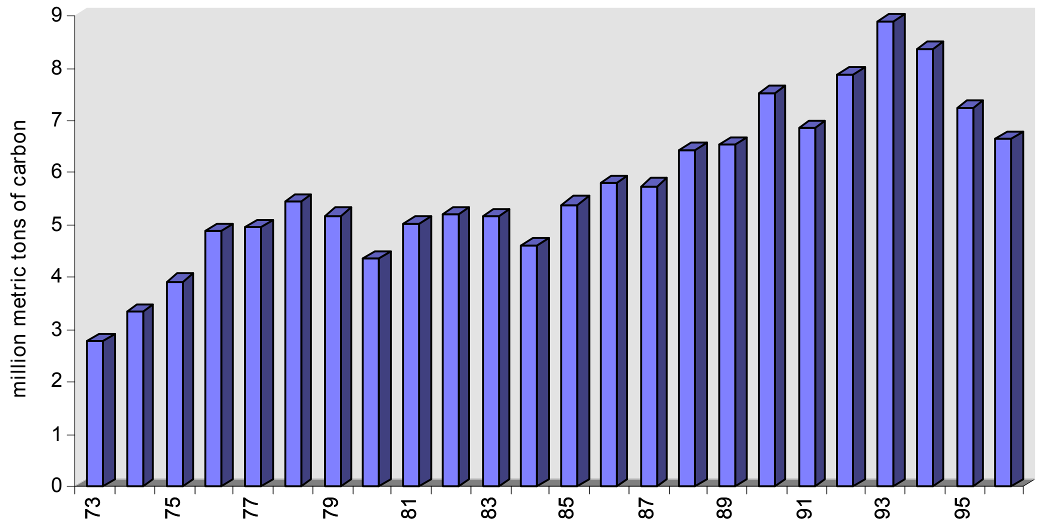
- New England's nuclear power plants reduced the region's carbon dioxide emissions (expressed in carbon, not molecular, weight) by:

  7 million metric tons of carbon dioxide in 1996, and

  138 million metric tons cumulatively since 1973.

- Electric utilities in New England would have emitted 86 percent more carbon dioxide in 1996 without their nuclear generating capacity.

New England Annual CO2 Emissions Avoided
(1973-1996)



- During 1996, New England's eight nuclear power plants avoided the emission of approximately:

  220,000 tons of sulfur dioxide,
  90,000 tons of nitrogen oxide.

- Over the period 1973-1996, nuclear energy in New England reduced sulfur dioxide and nitrogen oxide emissions by about:

  4.2 million tons of sulfur dioxide,
  1.6 million tons of nitrogen oxide.

- New England electric utility sulfur dioxide and nitrogen oxide emissions would have been 96 percent and 82 percent greater in 1996, respectively, in the absence of nuclear energy.

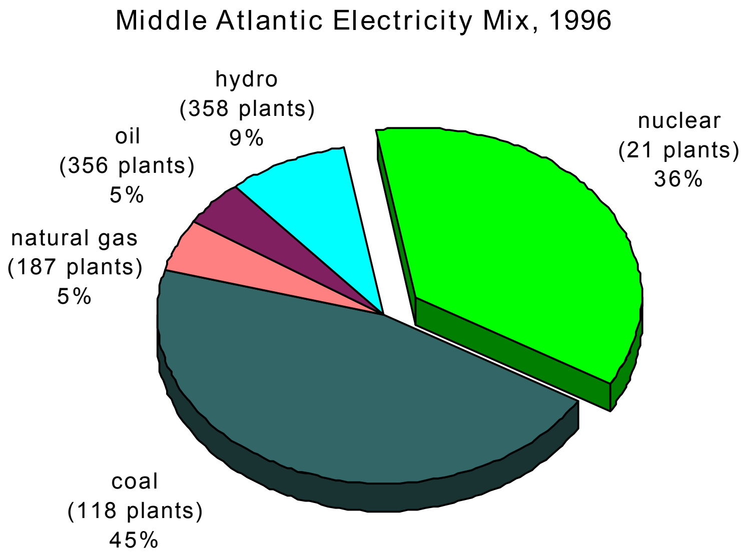
Middle Atlantic

Middle Atlantic Electricity Supply Since 1973

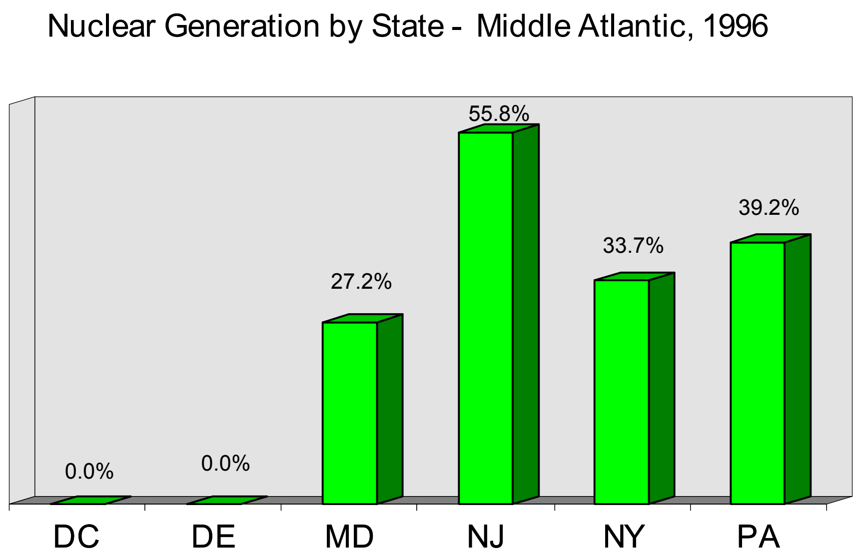
- There are 21 nuclear power units in operation in the following Middle Atlantic states.

	Unit name	Capacity	Commercial operation date	Cumulative generation (million kWh)
Maryland	Calvert Cliffs 1	845 MW	May-75	108,248
	Calvert Cliffs 2	845 MW	Apr-77	103,977
New York	Fitzpatrick	816 MW	Jul-75	93,107
	Ginna	470 MW	Jul-70	83,646
	Indian Point 2	986 MW	Aug-73	114,494
	Indian Point 3	965 MW	Aug-76	83,701
	Nine Mile Point 1	613 MW	Dec-69	86,862
	Nine Mile Point 2	1143 MW	Apr-88	54,231
New Jersey	Hope Creek	1067 MW	Dec-86	73,472
	Oyster Creek	650 MW	Dec-69	88,209
	Salem 1	1115 MW	Jun-77	100,175
	Salem 2	1115 MW	Oct-81	74,702
Pennsylvania	Beaver Valley 1	835 MW	Oct-76	86,862
	Beaver Valley 2	836 MW	Nov-87	51,489
	Limerick 1	1105 MW	Feb-86	76,933
	Limerick 2	1115 MW	Jan-90	56,305
	Peach Bottom 2	1119 MW	Jul-74	120,466
	Peach Bottom 3	1119 MW	Dec-74	119,439
	Susquehanna 1	1100 MW	Jun-83	92,155
	Susquehanna 2	1100 MW	Feb-85	88,721
	Three Mile Island 1	819 MW	Sep-74	91,144
		19,778 MW		1,848,438

▶ The Middle Atlantic's 21 nuclear plants generated 127 billion kilowatt-hours in 1996, representing 36 percent of the region's electricity.

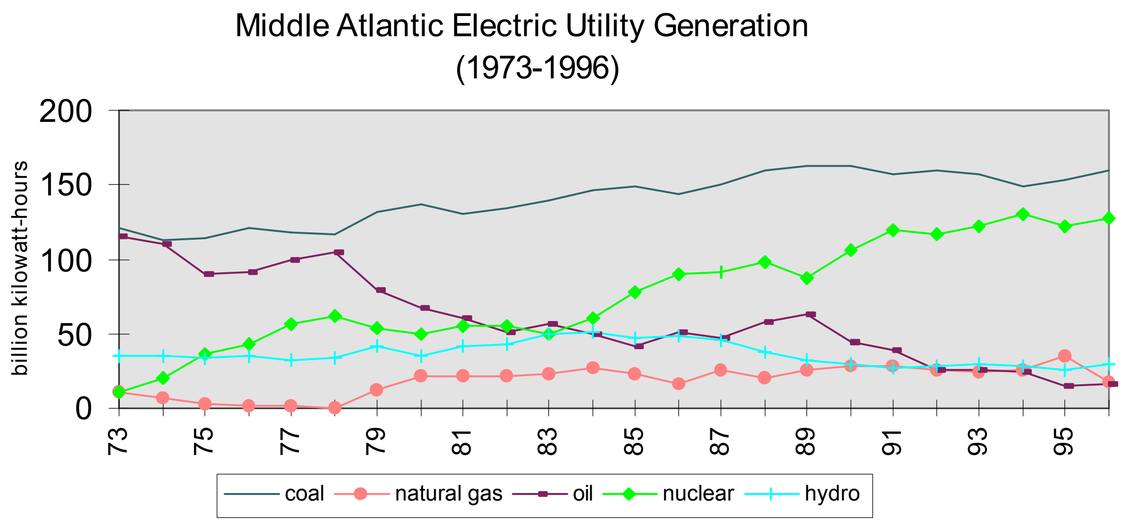


▶ On a state-by-state basis, the Middle Atlantic's nuclear power plants supplied the following shares of electricity in 1996.[14]



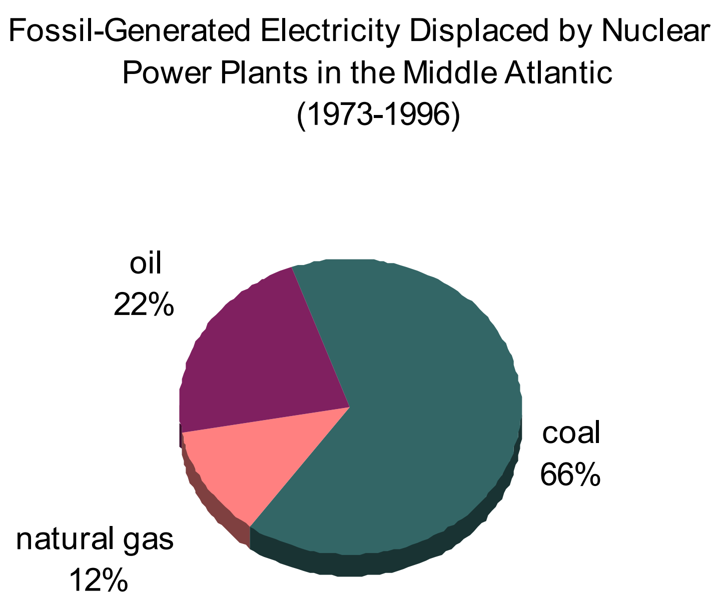
[14]This chart shows the percent of electricity generated in each state by nuclear plants located within the state. Percentages do not necessarily relate to how much electricity demand was met by nuclear energy in a particular state.

▶ Nuclear energy grew from supplying 4 percent of the Middle Atlantic's electricity in 1973 to 36 percent of the region's electricity supply in 1996.



Middle Atlantic Fuel and Emission Displacements

▶ In addition to nuclear energy, the Middle Atlantic region has relied for a large part on coal and to a lesser degree oil for baseload generation. Sixty-six percent of the electricity generated today by nuclear energy would have instead been generated at coal-fired plants, 22 percent at oil-fired plants.



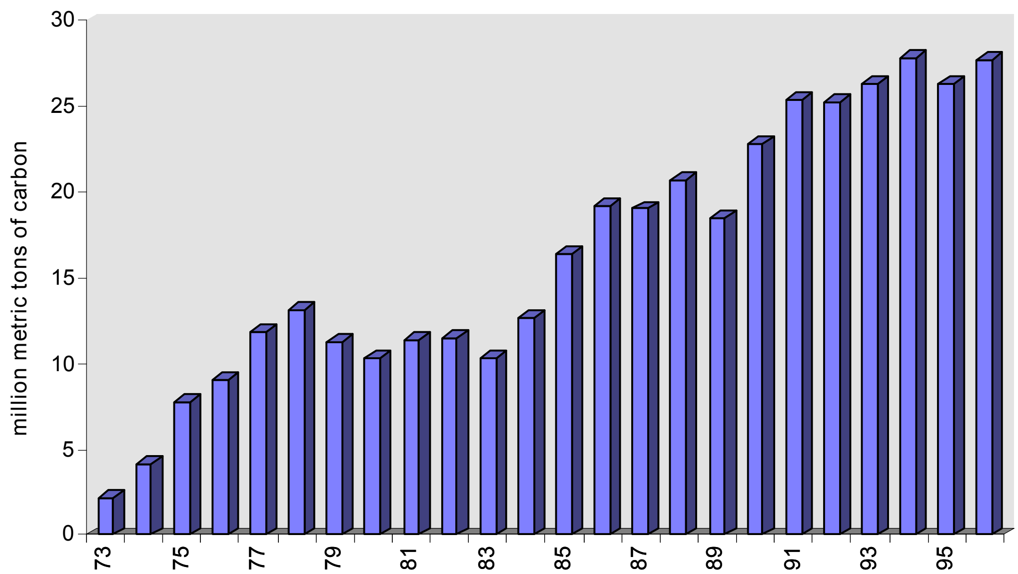
▶ During 1996, the Middle Atlantic's 21 nuclear power plants displaced approximately:

50 million tons of coal,
154 billion cubic feet of natural gas,
19 million barrels of oil.

▶ Over the period 1973-1996, nuclear energy in the Middle Atlantic reduced the burning of fossil fuels by about:

591 million tons of coal,
2.3 trillion cubic feet of natural gas,
703 million barrels of oil.

Middle Atlantic Annual CO2 Emissions Avoided
(1973-1996)



▶ The Middle Atlantic's nuclear power plants reduced the region's carbon dioxide emissions (expressed in carbon, not molecular, weight) by:

28 million metric tons of carbon dioxide in 1996, and
391 million metric tons cumulatively since 1973.

▶ Between 1990 and 1996, improved efficiency at nuclear energy plants avoided greenhouse gas emissions in the Middle Atlantic by an additional:

4.9 million metric tons of carbon dioxide.

- Electric utilities in the Middle Atlantic would have emitted 66 percent more carbon dioxide in 1996 without their nuclear energy plants.

- During 1996, the Middle Atlantic's 21 nuclear power plants avoided the discharge of approximately:

  1 million tons of sulfur dioxide
  470,000 tons of nitrogen oxide

- Over the period 1973-1996, nuclear energy in the Middle Atlantic reduced sulfur dioxide and nitrogen oxide emissions by about:

  14.7 million tons of sulfur dioxide
  6.3 million tons of nitrogen oxide

- Middle Atlantic electric utility sulfur dioxide and nitrogen oxide emissions would have been 64 percent and 65 percent greater, respectively in 1996 without nuclear energy.

Southeast

Southeast Electricity Supply Since 1973

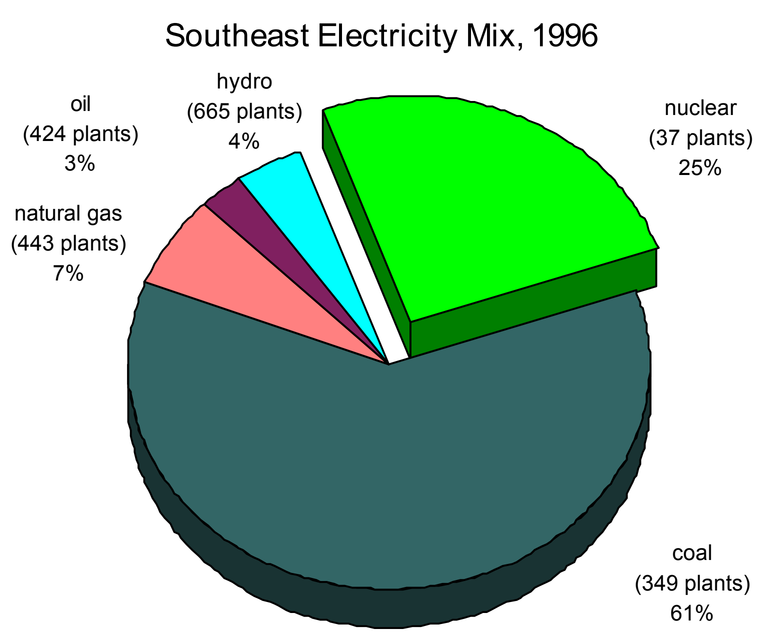
▶ There are 38 nuclear power units in operation in the following Southeast states.

	Unit name	Capacity	Commercial operation date	Cumulative generation (million kWh)
Alabama	Browns Ferry 1	1065 MW	Aug-74	53,796
	Browns Ferry 2	1065 MW	Mar-75	91,833
	Browns Ferry 3	1065 MW	Mar-77	51,682
	Farley 1	829 MW	Dec-77	104,882
	Farley 2	829 MW	Jul-81	90,550
Arkansas	Arkansas Nuclear One 1	850 MW	Dec-74	105,148
	Arkansas Nuclear One 2	912 MW	Mar-80	94,945
Florida	Crystal River 3	825 MW	Mar-77	87,402
	St. Lucie 1	830 MW	Dec-76	109,167
	St. Lucie 2	830 MW	Aug-83	79,767
	Turkey Point 3	720 MW	Dec-72	91,160
	Turkey Point 4	720 MW	Sep-73	88,054
Georgia	Hatch 1	776 MW	Dec-75	95,083
	Hatch 2	784 MW	Sep-79	80,779
	Vogtle 1	1169 MW	Jun-87	79,192
	Vogtle 2	1169 MW	May-89	65,276
Louisiana	River Bend	936 MW	Jun-86	60,067
	Waterford 3	1104 MW	Sep-85	87,933
Mississippi	Grand Gulf	1250 MW	Jul-85	93,224
North Carolina	Brunswick 1	821 MW	Mar-77	75,085
	Brunswick 2	821 MW	Nov-75	77,237
	Harris	900 MW	May-87	58,625
	McGuire 1	1180 MW	Dec-81	98,726
	McGuire 2	1180 MW	Mar-84	95,768

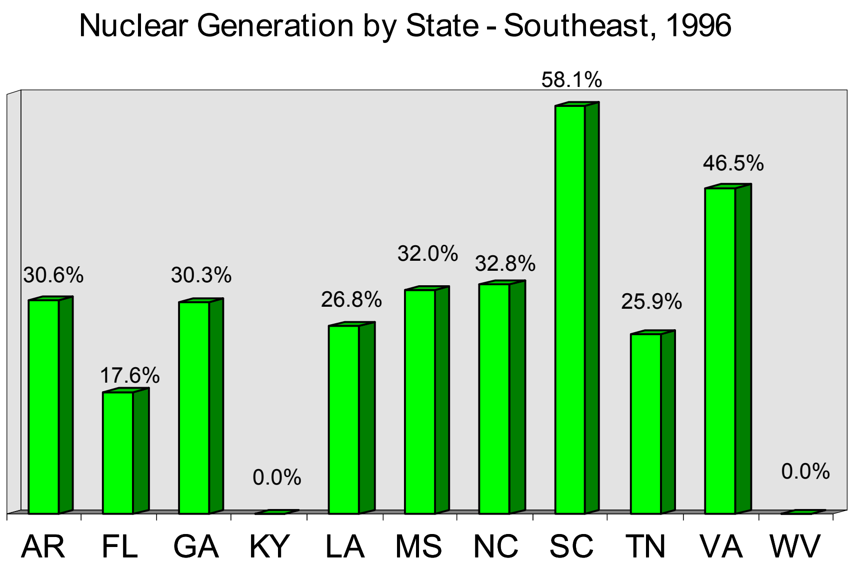
(Continued)

	Unit name	Capacity	Commercial operation date	Cumulative generation (million kWh)
South Carolina	Catawba 1	1145 MW	Jun-85	83,355
	Catawba 2	1145 MW	Aug-86	77,146
	Oconee 1	886 MW	Jul-73	127,610
	Oconee 2	886 MW	Sep-74	122,154
	Oconee 3	886 MW	Dec-74	121,665
	Robinson	700 MW	Mar-71	101,192
	Summer	954 MW	Jan-84	76,322
Tennessee	Sequoyah 1	1148 MW	Jul-81	80,378
	Sequoyah 2	1148 MW	Jun-82	80,680
	Watts Bar 1	1160 MW	May-97	5,141
Virginia	North Anna 1	907 MW	Jun-78	101,987
	North Anna 2	907 MW	Dec-80	98,693
	Surry 1	788 MW	Dec-72	105,594
	Surry 2	788 MW	May-73	103,192
		36,078 MW		3,300,690

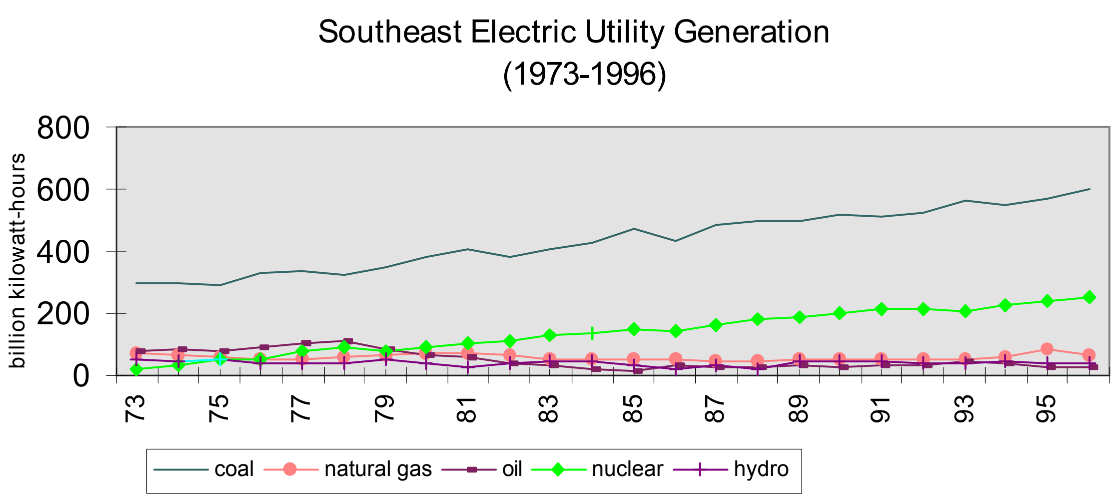
- The Southeast's 38 nuclear plants generated 250 billion kilowatt-hours in 1996, representing 25 percent of the region's electricity.



▶ On a state-by-state basis, the Southeast's nuclear power plants supplied the following shares of electricity in 1996[15].



▶ Nuclear energy grew from supplying 4 percent of the Southeast's electricity in 1973 to 25 percent of the region's electricity supply in 1996.

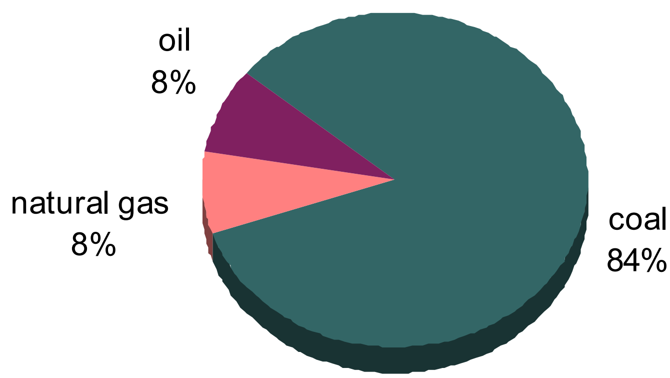


[15]This chart shows the percent of electricity generated in each state by nuclear plants located within the state. Percentages do not necessarily relate to how much electricity demand was met by nuclear energy in a particular state.

Southeast Fuel and Emission Displacements

- In addition to nuclear energy, the Southeast has relied principally on coal for baseload generation purposes. Eighty-four percent of the electricity generated today by nuclear energy would have instead been generated at coal-fired plants, eight percent each at oil- and natural gas-fired plants.

Fossil-Generated Electricity Displaced by Nuclear Power Plants in the Southeast (1973-1996)



- During 1996, the Southeast's 38 nuclear power plants displaced approximately:

  109 million tons of coal,
  227 billion cubic feet of natural gas,
  12 million barrels of oil.

- Over the period 1973-1996, nuclear energy in the Southeast reduced the burning of fossil fuels by about:

  1.4 billion tons of coal,
  2.8 trillion cubic feet of natural gas,
  476 million barrels of oil.

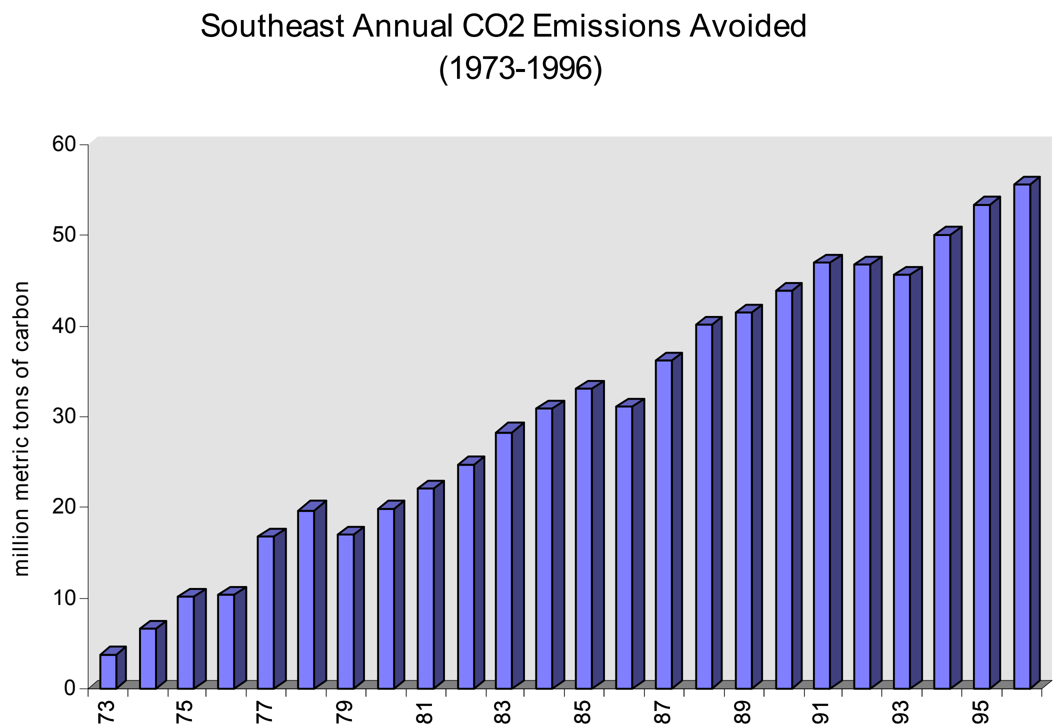
- The Southeast's nuclear power plants reduced the region's carbon dioxide emissions (expressed in carbon, not molecular, weight) by:

  56 million metric tons of carbon dioxide in 1996, and
  735 million metric tons cumulatively since 1973.

▶ Between 1990and 1996, improved efficiency at existing nuclear energy plants and operation of new plants avoided greenhouse gas emissions in the Southeast by an additional:

11.7 million metric tons of carbon dioxide.

▶ Electric utilities in the Southeast would have emitted 36 percent more carbondioxide in 1996 without their nuclear energy plants.



▶ During 1996, the Southeast's 38 nuclear power plants avoided the discharge of approximately:

2 million tons of sulfur dioxide
970,000 tons of nitrogen oxide

▶ Over the period 1973-1996, nuclear energy in the Southeast reduced sulfur dioxide and nitrogen oxide emissions by about:

30.3 million tons of sulfur dioxide
12.9 million tons of nitrogen oxide

▶ Southeast electric utility sulfur dioxide and nitrogen oxide emissions would have been 36 percent greater in 1996 without nuclear energy.

<u>Midwest</u>

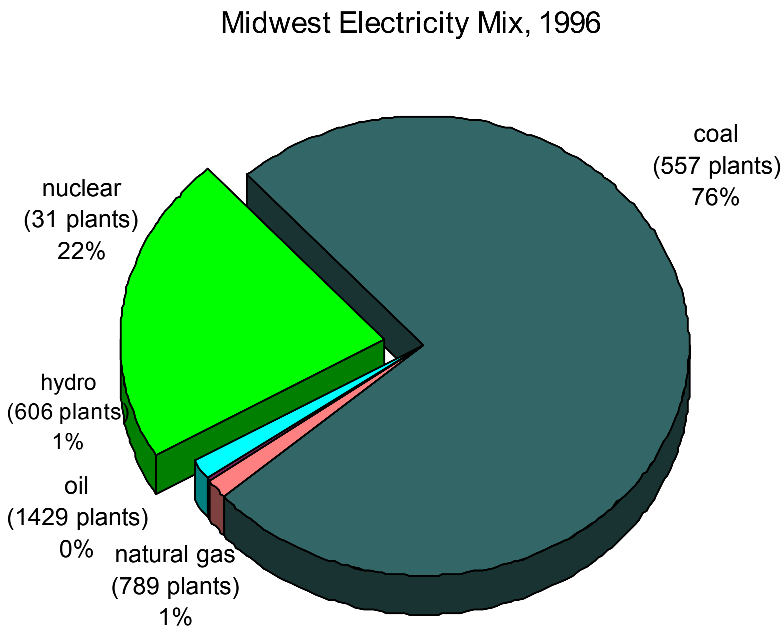
Midwest Electricity Supply Since 1973

▶ There are 31 nuclear power units in operation in the following Midwest states.

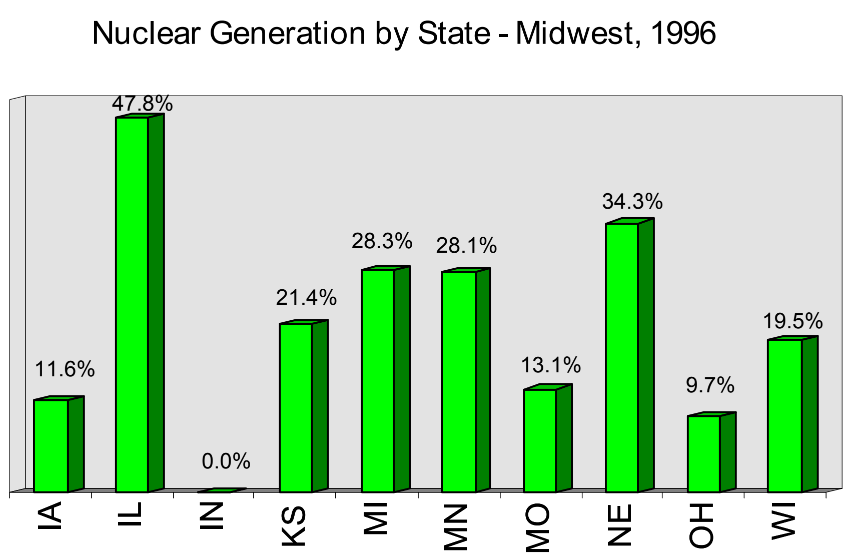
	Unit name	Capacity	Commercial operation date	Cumulative generation (million kWh)
Illinois	Braidwood 1	1120 MW	Jul-88	58,061
	Braidwood 2	1120 MW	Oct-88	61,638
	Byron 1	1120 MW	Sep-85	79,905
	Byron 2	1120 MW	Aug-87	69,291
	Clinton	933 MW	Nov-87	48,697
	Dresden 2	794 MW	Aug-70	100,102
	Dresden 3	794 MW	Oct-71	94,083
	Lasalle 1	1078 MW	Jan-84	73,669
	Lasalle 2	1078 MW	Oct-84	73,974
	Quad Cities 1	789 MW	Aug-72	106,155
	Quad Cities 2	789 MW	Oct-72	103,320
	Zion 1	1040 MW	Dec-73	122,492
	Zion 2	1040 MW	Sep-74	124,095
Iowa	Duane Arnold	538 MW	Feb-75	63,416
Kansas	Wolf Creek	1170 MW	Sep-85	89,642
Michigan	Big Rock Point[16]	72 MW	Nov-65	12,381
	Cook 1	1020 MW	Aug-75	133,051
	Cook 2	1090 MW	Jul-78	108,383
	Fermi 2	1116 MW	Jan-88	48,155
	Palisades	805 MW	Dec-71	81,268
Minnesota	Monticello	545 MW	Jun-71	90,604
	Prairie Island 1	530 MW	Dec-73	84,712
	Prairie Island 2	530 MW	Dec-74	83,811
Missouri	Callaway	1171 MW	Dec-84	100,714
Nebraska	Cooper	778 MW	Jul-74	95,565
	Fort Calhoun 1	478 MW	Sep-73	66,986
Ohio	Davis-Besse	906 MW	Nov-77	83,043
	Perry	1191 MW	Nov-87	61,270
Wisconsin	Kewaunee	535 MW	Jun-74	83,418
	Point Beach 1	497 MW	Dec-70	86,856
	Point Beach 2	497 MW	Oct-72	85,412
		26,284 MW		2,574,169

[16] Big Rock Point permanently ceased operations in August, 1997.

▶ The Midwest's 31 nuclear plants generated 163 billion kilowatt-hours in 1996, representing 22 percent of the region's electricity.

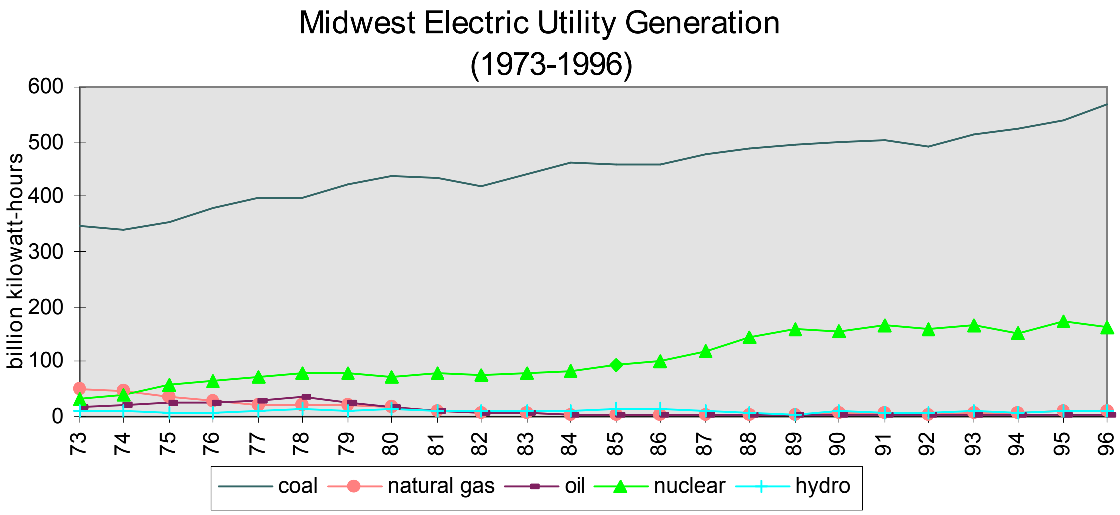


▶ On a state-by-state basis, the Midwest's nuclear power plants supplied the following shares of electricity in 1996.[17]



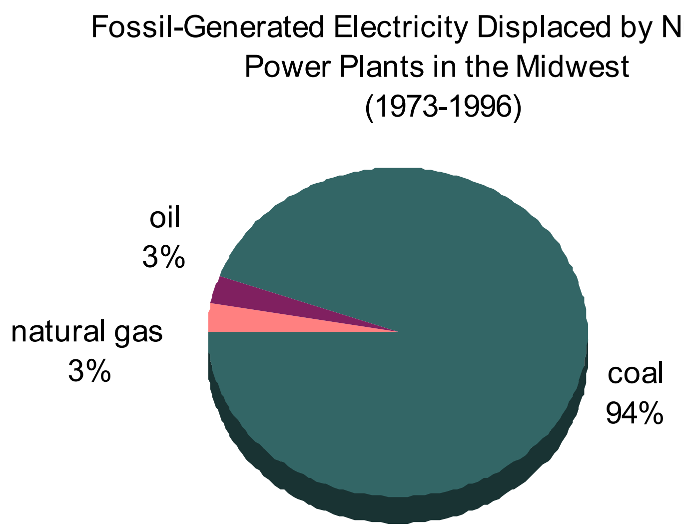
[17] This chart shows the percent of electricity generated in each state by nuclear plants located within the state. Percentages do not necessarily relate to how much electricity demand was met by nuclear energy in a particular state.

▶ Nuclear energy grew from supplying 7 percent of the Midwest's electricity in 1973 to 22 percent of the region's electricity supply in 1996.



Midwest Fuel and Emission Displacements

▶ In addition to nuclear energy, the Midwest region has relied almost entirely on coal for its electricity generation needs. Almost all of the electricity generated since 1973 by nuclear energy would have instead been generated at coal-fired plants.



▶ During 1996, the Midwest's 31 nuclear power plants displaced approximately:

77 million tons of coal,
51 billion cubic feet of natural gas,
2.4 million barrels of oil.

- Over the period 1973-1996, nuclear energy in the Midwest reduced the burning of fossil fuels by about:

  1.2 billion tons of coal,
  735 billion cubic feet of natural gas,
  123 million barrels of oil.

- The Midwest's nuclear power plants reduced the region's carbon dioxide emissions (expressed in carbon, not molecular, weight) by:

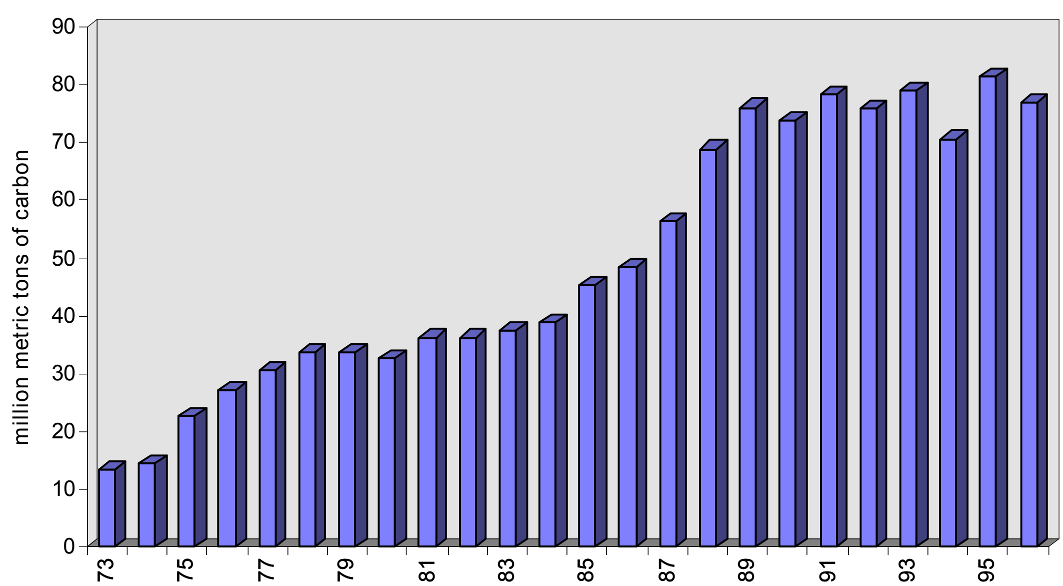
  37 million metric tons of carbon dioxide in 1996, and
  583 million metric tons cumulatively since 1973

- Between 1990 and 1996, improved efficiency at nuclear energy plants avoided greenhouse gas emissions in the Midwest by an additional:

  1.9 million metric tons of carbon dioxide.

- Electric utilities in the Midwest would have emitted 28 percent more carbon dioxide in 1996 without their nuclear energy plants.

Midwest Annual CO2 Emissions Avoided (1973-1996)



- During 1996, the Midwest's thirty-one nuclear power plants avoided the discharge of approximately:

  1.5 million tons of sulfur dioxide,
  660,000 tons of nitrogen oxide.

- Over the period 1973-1996, nuclear energy in the Midwest reduced sulfur dioxide and nitrogen oxide emissions by about:

  27 million tons of sulfur dioxide,
  11 million tons of nitrogen oxide.

- Midwest electric utility sulfur dioxide and nitrogen oxide emissions would have been 27 percent greater in 1996 without nuclear energy.

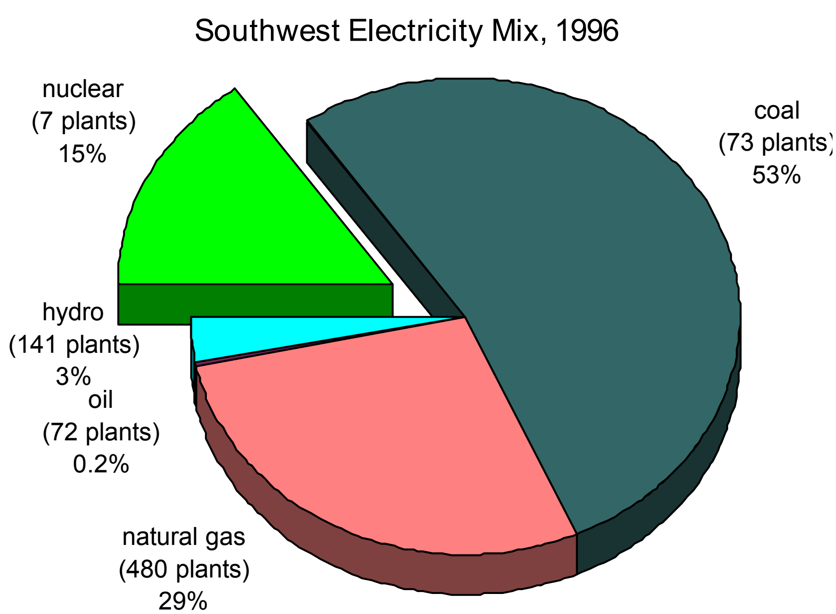
Southwest

Southwest Electricity Supply Since 1973

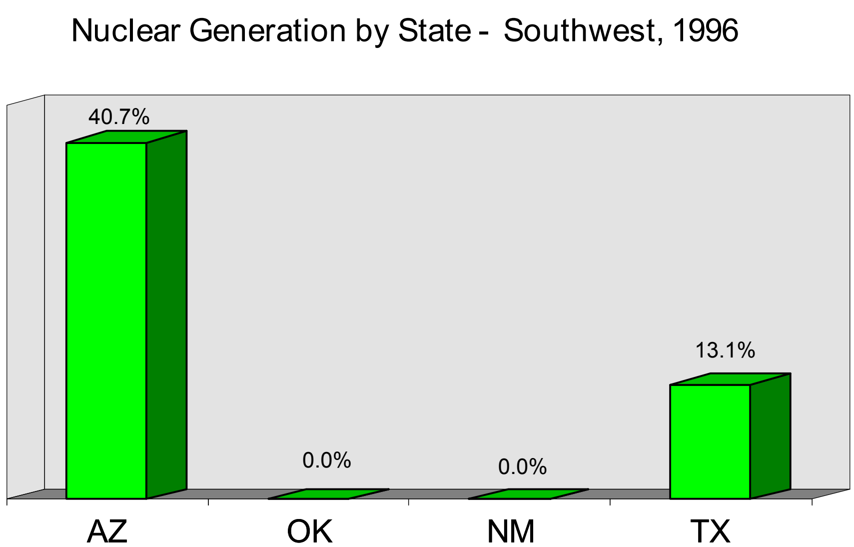
- There are seven nuclear power units in operation in the following Southwest states.

	Unit name	Capacity	Commercial operation date	Cumulative generation (million kWh)
Arizona	Palo Verde 1	1249 MW	Jan-86	75,471
	Palo Verde 2	1249 MW	Sep-86	77,111
	Palo Verde 3	1253 MW	Jan-88	73,299
Texas	Comanche Peak 1	1150 MW	Aug-90	46,923
	Comanche Peak 2	1150 MW	Aug-93	25,229
	South Texas Project 1	1251 MW	Aug-88	58,040
	South Texas Project 2	1251 MW	Jun-89	54,107
		8,553 MW		410,180

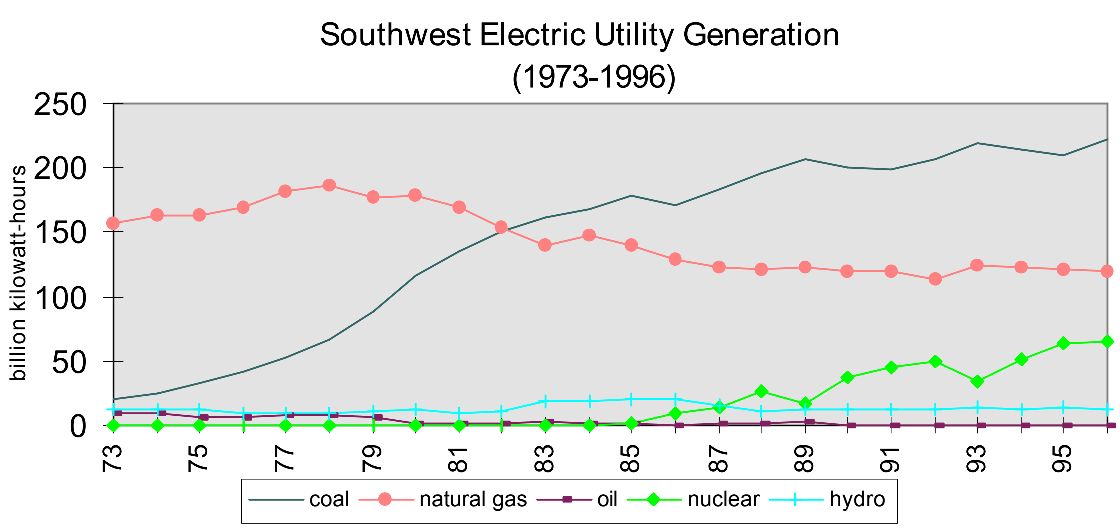
- The Southwest's seven nuclear plants generated 65 billion kilowatt-hours in 1996, representing 15 percent of the region's electricity.



▶ On a state-by-state basis, the Southwest's nuclear power plants supplied the following shares of electricity in 1996[18].



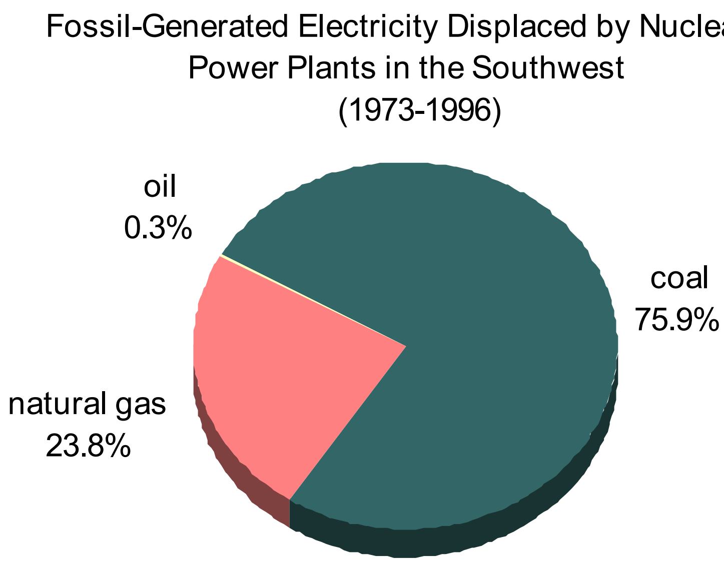
▶ Nuclear energy grew from supplying none of the Southwest's electricity in 1985 to 15 percent of the region's electricity supply in 1996.



[18]This chart shows the percent of electricity generated in each state by nuclear plants located within the state. Percentages do not necessarily relate to how much electricity demand was met by nuclear energy in a particular state.

Southwest Fuel and Emission Displacements

- Apart from nuclear energy, the Southwest has relied for a large part on coal and natural gas for its electricity generation purposes. Seventy-five percent of the electricity generated today by nuclear energy would have instead been generated at coal-fired plants, almost all of the remaining 25 percent at natural-gas fired plants.



- During 1996, the Southwest's seven nuclear power plants displaced approximately:

    23 million tons of coal,
    178 billion cubic feet of natural gas,
    240,000 barrels of oil.

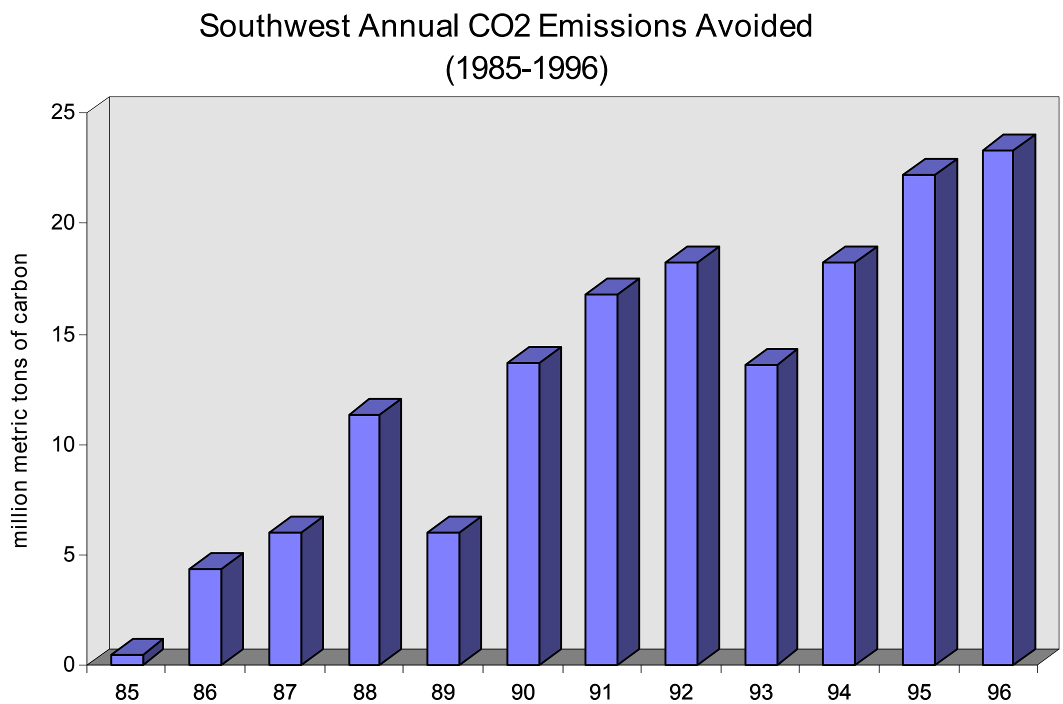
- Over the period 1973-1996, nuclear energy in the Southwest reduced the burning of fossil fuels by about:

    154 million tons of coal,
    1,035 billion cubic feet of natural gas,
    1.9 million barrels of oil.

▶ The Southwest's nuclear power plants reduced the region's carbon dioxide emissions (expressed in carbon, not molecular, weight) by:

14 million metric tons of carbon dioxide in 1996, and
88 million metric tons cumulatively since 1973

▶ Electric utilities in the Southwest would have emitted 19 percent more carbon dioxide in 1996 without their nuclear energy plants.



▶ During 1996, the Southwest's seven nuclear power plants avoided the discharge of approximately:

440,000 tons of sulfur dioxide
230,000 tons of nitrogen oxide

▶ Over the period 1985-1996, nuclear energy in the Southwest reduced sulfur dioxide and nitrogen oxide emissions by about:

2.9 million tons of sulfur dioxide
1.5 million tons of nitrogen oxide

▶ Southwest electric utilitysulfur dioxide and nitrogen oxide emissions would have been 21 percent and 20 percent greater in 1996, respectively, without nuclear energy.

Mountain

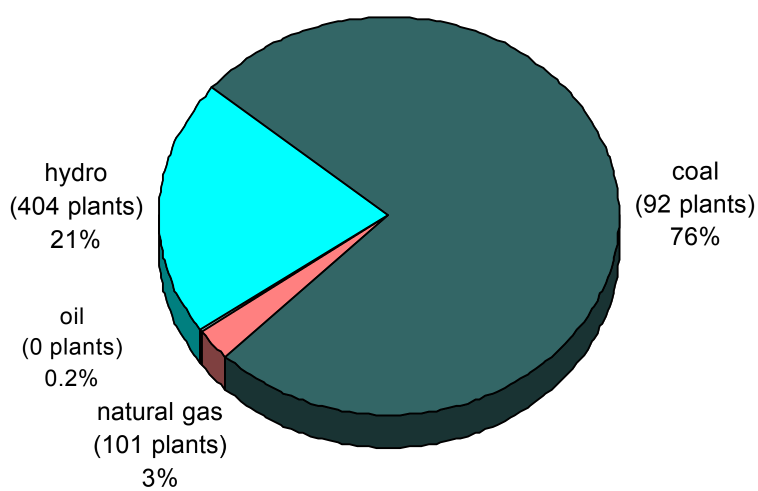
Mountain Region Electricity Supply Since 1973

- Only one commercial nuclear power plant operated in the Mountain region between 1977 and 1989, with the following characteristics:

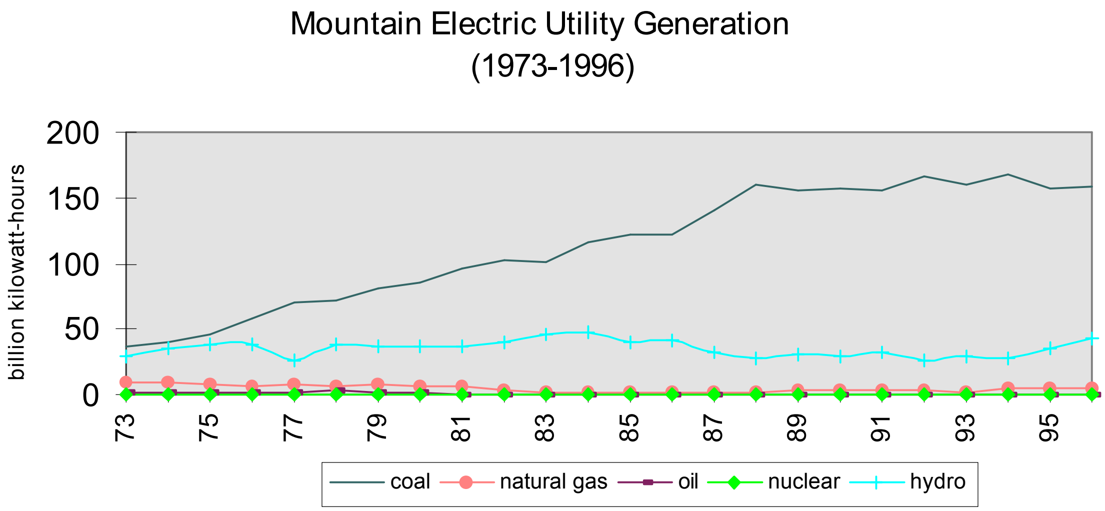
	Unit name	Capacity	Commercial operation date	Cumulative generation (million kWh)
Colorado	Fort St. Vrain	330 MW	Jul-79	4,224

- There are no nuclear energy plants currently in operation in the Mountain region.

Mountain Electricity Mix, 1996

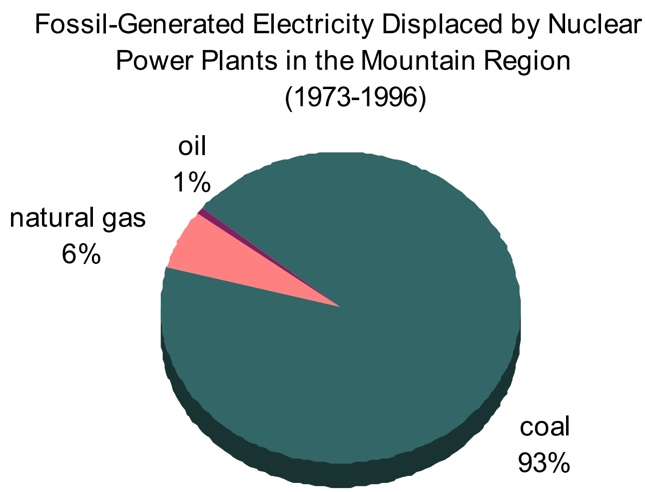


▶ Nuclear energy played a very limited role in the Mountain region's electricity supply.



Mountain Region Fuel and Emission Displacements

▶ The Mountain region has traditionally relied on coal for baseload generation purposes and almost all electricity generated at the region's nuclear energy plant would otherwise have been generated at coal-fired plants.

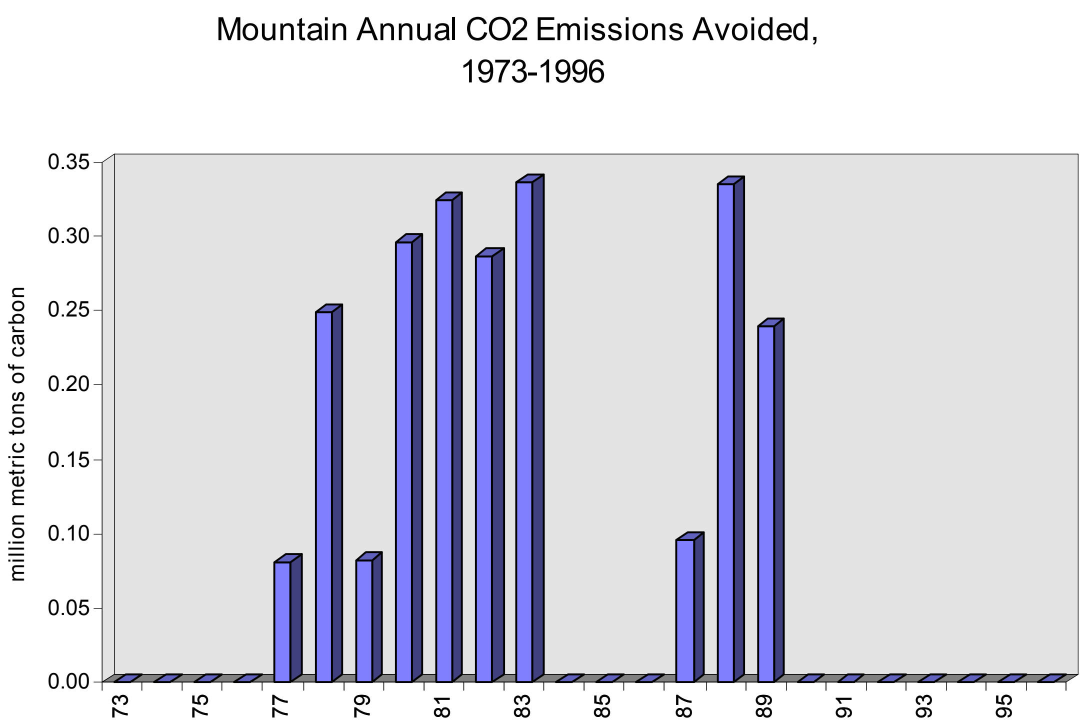


- Over the period 1977-1989, nuclear energy in the Mountain region reduced the burning of fossil fuels by about:

  2.3 million tons of coal,
  3.4 billion cubic feet of natural gas,
  60,000 barrels of oil.

- During its period of operation, the Mountain region's nuclear power plant reduced the region's carbon dioxide emissions (expressed in carbon, not molecular, weight) by:

  1.1 million metric tons of carbon dioxide



- Over the period 1977-1989, nuclear energy in the Mountain region reduced sulfur dioxide emissions by about:

  60,000 tons of sulfur dioxide,
  22,000 tons of nitrogen oxide.

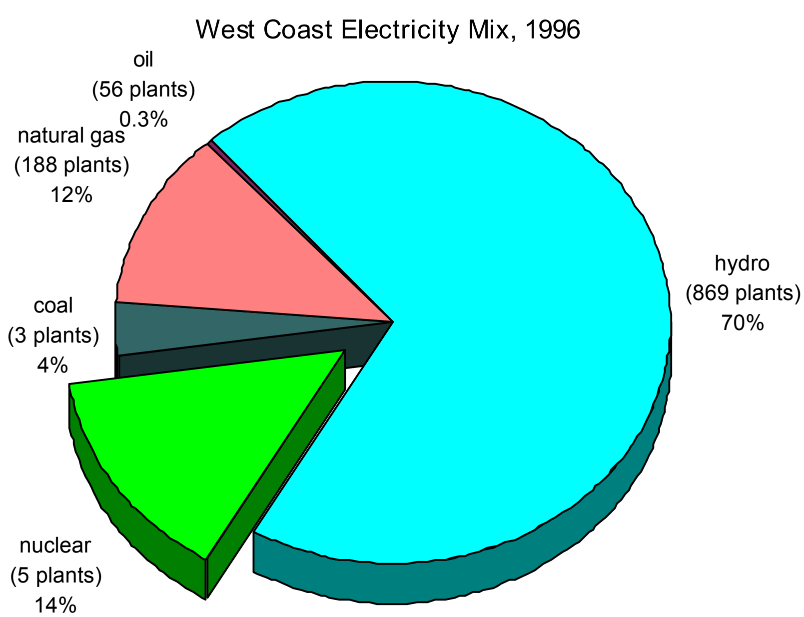
West Coast

West Coast Electricity Supply Since 1973

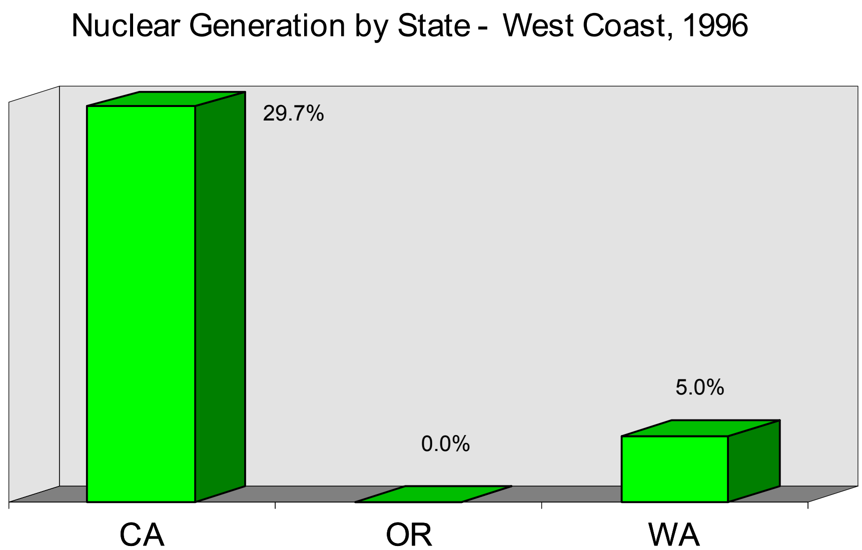
- There are five nuclear power units currently operating in the following West Coast states.

	Unit name	Capacity	Commercial operation date	Cumulative generation (million kWh)
California	Diablo Canyon 1	1086 MW	May-85	87,420
	Diablo Canyon 2	1119 MW	Mar-86	84,072
	San Onofre 2	1070 MW	Aug-83	94,591
	San Onofre 3	1080 MW	Apr-84	91,778
Washington	WNP 2	1153 MW	Dec-84	70,308
		5,508 MW		428,169

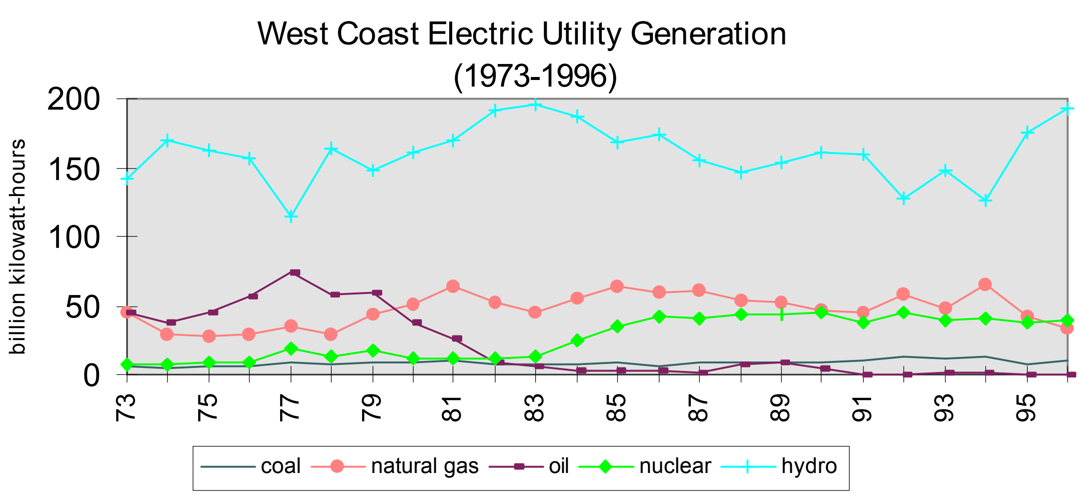
- The West Coast's five nuclear plants generated 40 billion kilowatt-hours in 1996, representing 14 percent of the region's electricity.



▶ On a state-by-state basis, the West Coast's nuclear power plants supplied the following shares of electricity in 1996[19].



▶ Nuclear energy grew from supplying 3 percent of the West Coast's electricity in 1973 to 14 percent of the region's electricity supply in 1996.

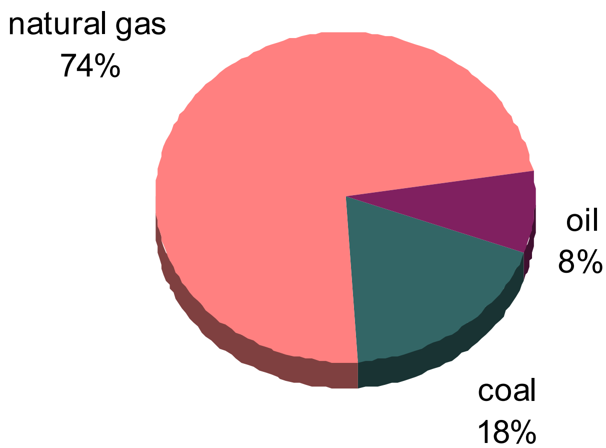


[19]This chart shows the percent of electricity generated in each state by nuclear plants located within the state. Percentages do not necessarily relate to how much electricity demand was met by nuclear energy in a particular state.

West Coast Fuel and Emission Displacements

- The West Coast relies heavily on electricity generated by hydro plants, but it is unlikely that electricity from this source would have been used to replace nuclear generation. Hydroelectricity capacity is generally employed before all other types of generation due to its very low lifetime generation costs. There would not have been additional hydroelectric capacity, not already operating, to replace nuclear-generated electricity had the nuclear energy plants not been used. Other than hydro and nuclear energy, the West Coast historically has relied on natural gas for most of its electricity generation. Seventy-four percent of the electricity generated today by nuclear energy would have instead been generated at natural gas-fired plants, 18 percent at coal-fired plants, and eight percent at oil-fired plants.

Fossil-Generated Electricity Displaced by Nuclear Power Plants in the West Coast (1973-1996)



- During 1996, the West Coast's five nuclear power plants displaced approximately:

  2.6 million tons of coal,
  354 billion cubic feet of natural gas,
  1.3 million barrels of oil.

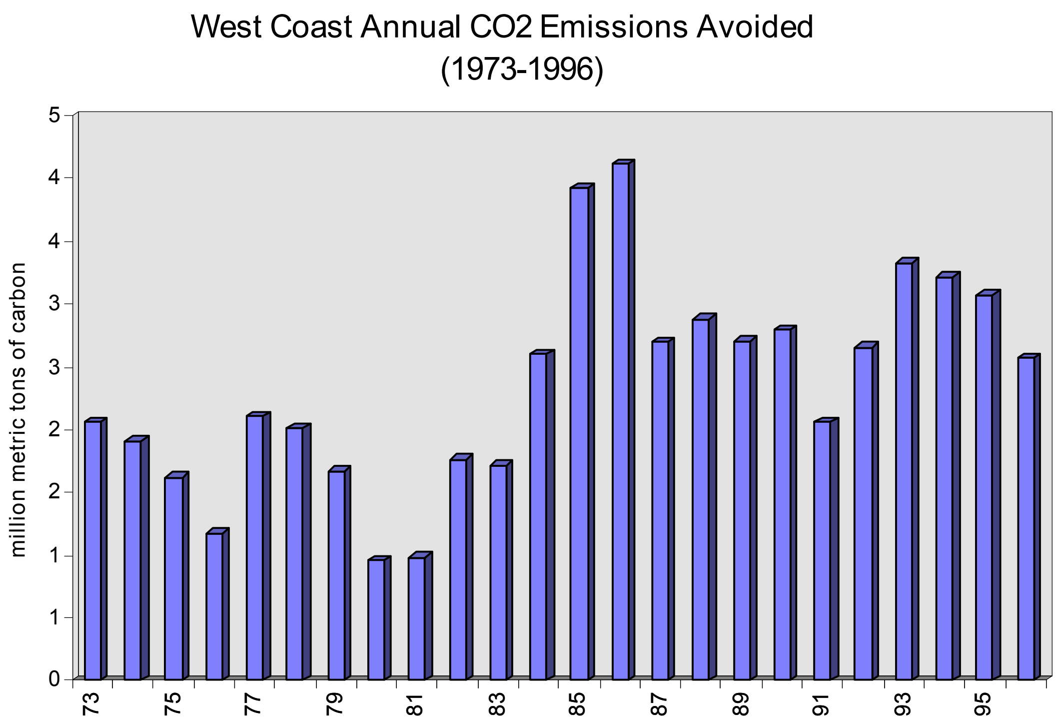
- Over the period 1973-1996, nuclear energy in the West Coast reduced the burning of fossil fuels by about:

  57 million tons of coal,
  4,918 billion cubic feet of natural gas,
  86 million barrels ofoil.

- The West Coast's nuclear power plants reduced the region's carbon dioxide emissions (expressed in carbon, not molecular, weight) by:

  6.5 million metric tons of carbon dioxide in 1996, and
  108 million metric tons cumulatively since 1973

- Electric utilities in the West Coast region would have emitted 88 percent more carbon dioxide in 1996 without their nuclear energy plants.



- During 1996, the West Coast's five nuclear power plants avoided the discharge of approximately:

  50,000 tons of sulfur dioxide,
  90,000 tons of nitrogen oxide.

- Over the period 1973-1996, nuclear energy in the West Coast reduced sulfur dioxide and nitrogen oxide emissions by about:

  1.6 million tons of sulfur dioxide,
  1.6 million tons of nitrogen oxide.

- West Coast electric utility sulfur dioxide and nitrogen oxide emissions would have been 84 percent and 76 percent greater in 1996, respectively, without nuclear energy.

APPENDICES

NOTES ON THE ESTIMATION METHODOLOGY

A few fundamental premises and an overall estimation methodology serve as the basis for quantifying the impact of nuclear energy on utility fuel use and atmospheric emissions. The analysis first identifies the fuels that qualify as potential substitution "candidates" for nuclear energy. A systematic approach is then applied to quantify the additional regional fuel requirements that would have prevailed had nuclear plants not been built. This estimation methodology is largely based on historical state-by-state generation data.

Which Fuels Displaced?

Prior to performing the analyses, the choice between the potential "candidate" replacement sources can be narrowed to three — coal, oil, and natural gas — on the basis of the following criteria:

- Candidates must rely on available generation technologies capable of producing cost-competitive electricity. For example, over the period of time analyzed in this study (1973-1996), fuel cells, photovoltaics, and many other developing technologies were not commercially viable, although they do hold promise for the future.

- Candidates must provide baseload or "around-the-clock" electricity. Baseload plants are large plants which use cheaper fuels. Low cost fuels make baseload plants most economical to run on a 24-hour basis but, because of the large investment required, these plants are not generally economical for non-continuous generation. Peaking or intermittent technologies like combustion turbines or wind power play a complementary role to baseload plants and, at least over the period of time analyzed, could not be substituted for them.

- Candidates must rely on a "fuel" likely to be available. In some regions, gas and oil were not available for lack of a pipeline distribution network.. Hydroelectricity must also be ruled out for the period as a potential replacement on two grounds. First, hydroelectric potential in the U.S had been largely tapped by 1973 — dams generate about the same amount of electricity today as 20 years ago. Second, existing hydroelectric plants generally operate before any other type of generation, since their operating costs are very low. Thus, it is highly unlikely that additional, reserve hydroelectric capacity would have been available to replace nuclear generation.

The operation of nuclear power plants over the past twenty years therefore contributed to reducing the use of the three prevalent utility fuels: coal, natural gas, and oil.

How Much Coal, Natural Gas, Oil ?

From a utility perspective, the answer to this question is the result of a two-step process:

1. On a medium- to long-term basis, utilities must plan for adequate generating capacity and reserve margin. These plans typically include building new facilities, converting fossil plants to a different primary fuel, and repowering "mothballed" generating units. These investment decisions are conditioned by utility-specific factors such as regional fuel availability and deliverability, changes in local fuel prices (that have a lasting impact on the relative competitiveness of a fuel), institutional restrictions placed on the use of any fuel for generation purposes (such as the Industrial and Power Plant Fuel Use Act of 1978[20]); regional electricity demand patterns and economic activity; average annual temperature and weather patterns; etc. In the electricity supply environment prevailing during the period evaluated, factors like non-utility generators, public service commission bidding processes and integrated resource planning implementation were also major contributors to utility decision-making.

2. On a short-term basis, utilities must then decide how to allocate or "dispatch" their electricity production needs throughout their distribution system. Each utility defines a "dispatch order" for its generating units. Baseload plants, which come first, are run "around the clock" to provide the continuous supply of electricity needed at all times in a region. Cycling and peaking plants come next in the sequence and are used for only part of the time. Peaking plants are used for short periods of the day, when electricity demand is highest and cycling plants provide the electricity needed for all intermediate demand levels between the continuous 24-hour needs and the peaking needs. Cycling plants are also useful to accommodate seasonal differences in energy demand as they may be run more extensively during the cold or hot parts of the year.

   A utility's dispatch order is based primarily on short-term operating costs which, in turn, are essentially determined by relative fuel costs on a kilowatt-hour basis. Typically, utilities that operate hydroelectric dams run them first.[21] Nuclear plants also come first in the sequence because of their low fuel price. Fossil plants come next, but their dispatch order varies from one region to another because of different fossil fuel availability and cost characteristics. In most of the United States, coal-fired units are used first, either in a baseload or in a cycling mode, but in New England and the West Coast, natural gas and oil are the dominant fossil fuels.

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[20]The Power Plant and Industrial Fuel Use Act of 1978 enacted as part of the National Energy Act placed restrictions on the use of natural gas and oil as boiler fuels for existing and new generating capacity. These restrictions were partially lifted in 1981 and eliminated (for all practical purposes) in 1987.

[21]In some cases, a portion of a utility's hydro capacity is retained for peaking purposes through "pumped storage." Today, about 6 percent of all hydroelectricity is generated through pumped storage for peaking purposes.

A plant's output is also fine-tuned to adjust for (1) changes in dispatch order prompted by maintenance, refueling and occasional repair work in different parts of the supply system; and (2) changes in load requirements following daily weather conditions, unanticipated changes in demand -- particularly from large industrial customers, etc.

This analysis did not attempt to collect and analyze the very substantial utility-specific information that would be required to attempt to simulate what capacity plans and dispatch decisions would have been forthcoming without the building and operation of today's nuclear energy plants.[22] Instead, this analysis infers the impact of existing nuclear energy plants, and the shifting of load priorities, on the basis of historical generation data. Simply put, the fossil fuels that dominated a region's electricity mix are assumed to represent those which would have still prevailed in substituting for nuclear energy.[23]

Any replacement fuel for a nuclear plant must be largely available and competitive in its region. The running of a large baseload plant calls for highly reliable and continuous delivery of fuel. Any fuel that is not competitively priced is not a good candidate for baseload generation but may be well suited for peaking purposes. Fossil fuels, which would be used to replace electricity generated by nuclear energy, are thus likely to be those already relied upon in their area in fueling at least intermediate or "cycling" plants, and perhaps also baseload plants. Without the existing nuclear capacity, these fuels would have been more fully used for baseload purposes. Conversely, fossil fuels that were used exclusively for peaking purposes are generally inappropriate for baseload generation.[24]

In a broad sense, nuclear power plant additions generally shifted the dispatch order of all fossil plants by one notch, thus producing a sequence of displacements. Fossil plants that had been previously used to supply electricity on a continuous basis now came in second position, and were used more for cycling purposes. In turn, fossil fuel plants that were predominantly used in the cycling mode were shifted to a narrower cycling or a peaking use.[25] It is assumed that the operation of nuclear power plants did not change the relative importance of the three fossil fuels in a given region and that the fuel displacements occurred primarily because of the change in dispatch priorities (with nuclear in first position, or second behind hydro). Nuclear generation is thus assumed to have substituted for fossil-fueled generation roughly proportionally to a region's existing mix of fossil fuels. Again, hydroelectricity generation levels are deemed to have been independent from other fuel plans, and hydro is not included as part of the nuclear fuel displacements.

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[22]Obviously, the amount of data to support even a basic understanding of how regional economic, technical, natural, and political factors would have conditioned U.S. utility planning and generation decisions on a year-by-year basis since 1973 is daunting. The interpretation of such a set of information might be even more problematic.

[23]The state level generation data used in this study is largely based on the Department of Energy's Energy Information Administration (DOE/EIA) survey data.

[24]The new, high efficiency combined cycle turbines (CCTs) are actually suitable for generating electricity for cycling as well as baseload purposes. CCTs will begin to blur somewhat the traditional distinction between cycling turbines and baseload steam turbines — but this does not apply over the 1973-1996 time frame.

[25]This shift implies that some small, old coal units used for cycling purposes were mothballed or retired, because these coal units were not capable of the rapid heat response needed for peaking generation.

Displacement estimates in this study account for any changes in regional electricity fuel mixes on an annual basis. Some of the changes simulated in this model might actually have occurred at a slower pace in a real world situation when planning constraints such as building new capacity, and retiring or converting existing plants, would have created constraints to change. However, it should be noted that: (1) the generation cost of baseload fossil plants is still dominated by the fuel cost, which means that fossil plant investments are by nature more fungible than other generating plants; (2) utilities take advantage of technical switching capabilities depending on the priorities of the moment;[26] (3) the changes that have occurred in fossil fuel electricity shares already integrate many such planning constraints (although admittedly, in some instances, rapid shifts in fossil fuel shares are made possible by the fact that some fossil plants are relatively under-utilized — a situation that would not have occurred to the same degree had nuclear power plants not been built.)

Calculating Emission Displacements

Once fuel displacements are estimated, calculating related emissions is a straightforward exercise. Emission displacements are obtained by multiplying tons of coal, barrels of oil, and cubic feet of gas by each fuel's specific emission factor. The factors used in this report were based on U.S. average fossil plant emission rates as reported by the Department of Energy's Energy Information Administration (DOE/EIA).

Sulfur dioxide and nitrogen oxide emissions have markedly decreased over the past 20 years, due to increased use of scrubbers, low-NOx burners and other pollution control devices, and more efficient fossil generation technologies. The emission rates for these gases were therefore estimated for every year since 1973.[27] Carbon dioxide emission rates have not decreased significantly since 1973, and single conversion factors were used throughout the 1973-1996 period.[28]

[26] Some 29,000 MW of coal capacity was converted to oil in the late 1960s, partly for economic reasons, but also to comply with early air quality requirements. Much of this capacity was re-converted to coal during the early 1970s. Today, over 70 percent of all installed oil capacity is dual-fired, and over 40 percent uses gas as a primary fuel.

[27] Differences in sulfur content of different quality fuels, particularly coal, were not taken into account in this analysis.

[28] Unlike for SO2 and NOx there is no technology capable of "trapping" CO2. As a by-product of the combustion process (C + O2 = CO2 + heat), CO2 cannot be washed out of the fuel. It cannot be filtered or precipitated from the exhaust. In fact, any filtering device would be highly impractical, given the very large quantities of CO2 that would need to be disposed of.

ELECTRICITY FUEL AND EMISSIONS DISPLACED, BY REGION 1996 [29]

	New England	Middle Atlantic	Southeast	Midwest	Southwest	West Coast	U.S. Total[30]
# nuclear units in operation	8	21	37	31	7	5	109
nuclear share of electricity[31]	47%	35%	25%	24%	15%	14%	20%
COAL 10^6 tons	7	50	109	77	23	3	269
NATURALGAS 10^9 cubic feet	19	154	227	51	178	354	983
OIL 10^6 barrels	28	19	12	2	*	1	62
Carbon Dioxide MMt carbon	7	28	58	37	14	7	151
Sulfur dioxide 10^3 tons	218	998	2,088	1,460	440	52	5,256
Nitrogen oxide 10^3 tons	90	466	967	658	230	91	2,502

* = values greater than zero but smaller than 0.5

[29]Note: Emission estimates are based on average U.S. conversion factors.
[30]Totals may not add up exactly due to independent rounding.
[31]Electric utility generation only, industrial cogenerators and other independent power producers are not accounted for.

ELECTRICITY FUEL AND EMISSION DISPLACED, BY REGION 1973-1996

	New England	Middle Atlantic	Southeast	Midwest	Southwest	Mountain	West Coast	U.S. Total
COAL 10^6 tons	72	591	1,362	1,188	154	2	57	3,426
NATURAL GAS 10^9 cubic feet	220	2,340	2,817	735	1,035	3	4,918	12,068
OIL 10^6 barrels	900	703	478	123	2	*	86	2,292
Carbon dioxide MMt carbon	138	391	735	583	88	1	108	2,044
Sulfur dioxide 10^6 tons	4.2	14.7	30.3	26.5	2.9	*	1.6	80.2
Nitrogen oxide 10^6 tons	1.6	6.3	12.9	10.7	1.5	*	1.6	34.6

* = values greater than zero but smaller than 0.1

STATE ELECTRICITY FUEL AND EMISSIONS DISPLACEMENT DATA, 1996[32]

	Displacements					
States	Coal Displacemen (in million tons)	Gas Displacements (ir billion cubic feet)	Oil Displacements (in million barrels)	CO2 Displacements (in MMt of Carbon)	SO2 Displacements (in million short tons)	NOx Displacements (in million short tons)
AL	14.42	2.31	0.11	6.83	0.27	0.12
AR	5.79	15.70	0.08	2.96	0.11	0.05
AZ	13.36	15.93	0.10	6.53	0.25	0.12
CA	0.00	350.34	1.25	5.27	0.00	0.07
CO	0.00	0.00	0.00	0.00	0.00	0.00
CT	0.84	7.30	6.52	1.23	0.04	0.02
DC	0.00	0.00	0.00	0.00	0.00	0.00
DE	0.00	0.00	0.00	0.00	0.00	0.00
FL	6.85	69.17	8.38	5.17	0.16	0.08
GA	14.52	1.69	0.23	6.88	0.28	0.12
IA	1.88	0.77	0.02	0.90	0.04	0.02
ID	0.00	0.00	0.00	0.00	0.00	0.00
IL	32.14	36.21	1.25	15.78	0.61	0.28
IN	0.00	0.00	0.00	0.00	0.00	0.00
KS	3.97	0.60	0.07	1.88	0.08	0.03
KY	0.00	0.00	0.00	0.00	0.00	0.00
LA	3.34	92.89	0.17	2.95	0.06	0.05
MA	1.37	11.37	2.46	1.09	0.03	0.02
MD	5.52	2.76	0.97	2.74	0.11	0.05
ME	0.00	0.00	8.66	0.97	0.03	0.01
MI	12.95	1.57	0.45	6.16	0.25	0.11
MN	5.45	7.50	0.44	2.72	0.10	0.05
MO	4.31	0.76	0.03	2.04	0.08	0.04
MS	2.77	31.77	0.94	1.87	0.06	0.03
MT	0.00	0.00	0.00	0.00	0.00	0.00
NC	16.41	1.07	0.23	7.76	0.31	0.14
ND	0.00	0.00	0.00	0.00	0.00	0.00
NE	4.51	2.44	0.02	2.16	0.09	0.04
NH	3.85	0.00	3.40	2.19	0.08	0.04
NJ	3.56	31.97	1.30	2.29	0.07	0.04
NM	0.00	0.00	0.00	0.00	0.00	0.00
NV	0.00	0.00	0.00	0.00	0.00	0.00
NY	8.18	114.58	13.02	6.99	0.20	0.10
OH	6.77	0.87	0.05	3.20	0.13	0.06
OK	0.00	0.00	0.00	0.00	0.00	0.00
OR	0.00	0.00	0.00	0.00	0.00	0.00
PA	32.41	4.41	3.60	15.71	0.62	0.28
RI	0.00	0.00	0.00	0.00	0.00	0.00
SC	21.20	1.43	0.30	10.02	0.40	0.18
SD	0.00	0.00	0.00	0.00	0.00	0.00
TN	11.17	0.26	0.18	5.28	0.21	0.09
TX	9.90	162.48	0.14	7.05	0.19	0.11
UT	0.00	0.00	0.00	0.00	0.00	0.00
VA	12.10	10.35	1.03	5.96	0.23	0.10
VT	0.93	0.00	6.50	1.17	0.04	0.01
WA	2.57	3.62	0.01	1.26	0.05	0.02
WI	4.92	0.52	0.06	2.33	0.09	0.04
WV	0.00	0.00	0.00	0.00	0.00	0.00
WY	0.00	0.00	0.00	0.00	0.00	0.00

[32] Emission estimates are based on average U.S. conversion factors.

Totals may not add up exactly due to independent rounding.
Electric utility generation only. Industrial cogenerators and other independent power producers are not accounted for.

STATE ELECTRICITY FUEL AND EMISSIONS DISPLACEMENT DATA, 1973-1996[33]

States	Displacements Coal Displacemen (in million tons)	Gas Displacements (in billion cubic feet)	Oil Displacements (in million barrels	CO2 Displacements (in MMt of Carbon)	SO2 Displacements (in million short tons)	NOx Displacements (in million short tons)
AL	193.9	27.7	2.3	91.8	4.5	1.8
AR	74.1	336.6	31.6	43.3	1.6	0.7
AZ	103.7	161.1	1.2	51.2	2.0	0.9
CA	0.0	4118.4	85.3	69.8	0.2	0.9
CO	2.3	3.4	0.1	1.1	0.1	0.0
CT	23.4	123.2	490.2	67.8	1.9	0.7
DC	0.0	0.0	0.0	0.0	0.0	0.0
DE	0.0	0.0	0.0	0.0	0.0	0.0
FL	102.1	952.4	263.8	91.5	2.9	1.4
GA	156.6	16.6	4.8	74.4	3.2	1.4
IA	30.0	26.8	0.9	14.6	0.7	0.3
ID	0.0	0.0	0.0	0.0	0.0	0.0
IL	514.6	272.9	71.1	254.0	11.5	4.6
IN	0.0	0.0	0.0	0.0	0.0	0.0
KS	41.5	60.3	0.6	20.5	0.8	0.4
KY	0.0	0.0	0.0	0.0	0.0	0.0
LA	30.3	895.3	2.3	27.6	0.6	0.4
MA	11.3	90.2	109.4	18.9	0.6	0.2
MD	80.7	49.1	76.5	47.3	2.0	0.8
ME	0.0	0.0	203.3	22.8	0.6	0.2
MI	174.3	67.6	26.9	86.0	3.9	1.6
MN	117.8	82.4	9.3	57.7	2.8	1.1
MO	49.0	7.6	0.9	23.2	1.0	0.4
MS	28.5	314.6	8.6	19.0	0.6	0.3
MT	0.0	0.0	0.0	0.0	0.0	0.0
NC	200.1	12.1	3.2	94.6	4.1	1.7
ND	0.0	0.0	0.0	0.0	0.0	0.0
NE	70.2	147.8	6.5	35.9	1.6	0.7
NH	17.8	7.0	24.5	11.2	0.4	0.2
NJ	71.2	1056.8	141.4	64.8	1.9	1.0
NM	0.0	0.0	0.0	0.0	0.0	0.0
NV	0.0	0.0	0.0	0.0	0.0	0.0
NY	77.0	1190.3	400.7	98.6	2.9	1.3
OH	71.8	3.3	1.1	33.9	1.4	0.6
OK	0.0	0.0	0.0	0.0	0.0	0.0
OR	0.0	773.9	0.0	11.3	0.0	0.2
PA	361.9	43.5	84.5	180.3	7.9	3.2
RI	0.0	0.0	0.0	0.0	0.0	0.0
SC	329.6	136.5	40.7	161.5	7.3	2.9
SD	0.0	0.0	0.0	0.0	0.0	0.0
TN	83.5	1.1	1.1	39.4	1.7	0.7
TX	50.4	873.9	0.7	36.6	1.0	0.6
UT	0.0	0.0	0.0	0.0	0.0	0.0
VA	163.1	124.3	117.4	91.7	3.8	1.6
VT	19.9	0.0	72.7	17.5	0.7	0.3
WA	56.6	25.8	0.7	27.0	1.3	0.5
WI	118.6	66.1	5.4	57.3	2.8	1.1
WV	0.0	0.0	0.0	0.0	0.0	0.0
WY	0.0	0.0	0.0	0.0	0.0	0.0

[33] Emission estimates are based on average U.S. conversion factors.

Totals may not add up exactly due to independent rounding.
Electric utility generation only. Industrial cogenerators and other independent power producers are not accounted for.

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