NUCLEAR POWER CHOICES AND THE FUTURE

By

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ABSTRACT

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By

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From the completion of the first commercial nuclear power plant in 1957 to the present, there has been an increasing failure to meet nuclear power goals. This has occurred in spite of substantial efforts to meet the goals through various technological and institutional innovations.

Large investments of both public and private capital have been used in the development of the nuclear power industry. However, the health of the industry is being threatened by the seeming intractibility of several choices surrounding it. Major choices involve the international resource aspects of nuclear power with the accompanying responsibility for sharing the energy wealth of the world, the nuclear weapons proliferation issue, the waste disposal challenge, and the proper degree of governmental control and implementation.

Part of the problem examined is the wide-spread and inadequate perspective of the major choices such that public and private decisions are being made without an adequate knowledge base. Another facet of the problem is how to quantify at least a portion of the emotion-laden issues

in order to facilitate a less emotionally-based decision.

The problem of perspective is first addressed at the international level by demonstrating the interconnectedness of the world energy economy and how nuclear power is an integral energy resource within it. Then the proliferation question is examined, followed by an investigation of alternate waste disposal techniques.

A sociotechnical evaluation of nuclear power is made, together with an analysis of Michigan resident reaction to the growing presence of nuclear power. Finally, an effort was made to help quantify the nuclear choices by determining the relationship between the current nuclear power shortfall and U.S. oil importation.

Research data for this study was obtained through interviews with personnel at major utility companies, the Edison Electric Institute, Michigan Public Services Commission, Michigan Committee for Jobs and Energy, the U.S. Nuclear Regulatory Commission, and appropriate divisions of the U.S. Department of Energy. Unpublished utility company correspondence, load forecasts, fuel cost data, legal proceedings, and a public opinion poll were also used.

The major findings of the study are as follows: nuclear power can have a significant impact on promoting energy self-sufficiency in many countries possessing limited fossil fuels, rapid implementation in either the

industrialized or developing nations will benefit developing nations disproportionately by making international supplies of fossil fuels more affordable, the problem of nuclear weapons proliferation is not likely to be aggravated by increased expansion of the nuclear power industry abroad, and present restrictions on U.S. exportation of nuclear reactors, fuel, and technology may be counterproductive. Also, considering all the various methods for disposing of high-level radioactive wastes, salt-bed storage remains the most viable, and the major social obstacle to the growth of the nuclear power industry in Michigan as well as the nation is either an unwillingness to bear disproportionate risk, or an inability to properly perceive the magnitude of the risk compared to alternate methods of equally large-scale electrical generation, or both.

An additional finding, based on a review of thirteen reputable forecasts from various sources made over the period from 1964 to 1975, is that installed 1980 nuclear capacity fell short of the forecast 119,000 megawatts by 64,000 megawatts. The energy-equivalent of this shortfall was nineteen percent of all 1979 U.S. oil imports, or over 1.5 million barrels of imported oil per day. This corresponds to 23.746 barrels of imported oil per nuclear megawatt per day.

To the memory of my mentor and friend,

Dr. Ronald L. Shelton

ACKNOWLEDGEMENTS

The Lord Jesus Christ said: "I am the vine, you are the branches; he who abides in Me, and I in him, he bears much fruit; for apart from Me you can do nothing" (John 15:5). I have found this to be true for me in both spiritual and secular endeavors, and therefore give Him the credit for any worthwhile accomplishment. Secondly I owe a debt of gratitude to Dr. Eckart Dersch, Committee Chairman, as well as to other members of the Committee. Thanks are expressed to Eleanor Boyles and Ann Silverman for their assistance in the Government Documents section of the Library, and also to numerous persons at the U.S. Department of Energy, U.S. Nuclear Regulatory Commission, Consumers Power Company, Detroit Edison Company, and Lansing Board of Water and Light. My sincere appreciation goes to the Institute of Public Utilities of Michigan State University for their partial funding of this project. Finally, I thank my parents for their constant love and encouragement.

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INTRODUCTION

One of the most relevant issues today is the "energy crisis" . . . a misnomer because the word "crisis" suggests something temporary. However, the phenomena of increasing costs for most forms of energy is not temporary.

The energy shortages and threats of shortages have even resulted in legislation requiring the President to have a standby national gas rationing plan ready for implementation at all times.[1] These increasing costs, shortages, and threats of shortages make up what is commonly called the "energy crisis".

During the recent period of rising costs for energy (which roughly began at the time of the 1973-74 Arab oil embargo), increasing attention has been given to alternate methods of supplying the world's energy needs other than via the traditional fossil fuels of petroleum and natural gas. The reason for this desire to especially decrease dependence on petroleum is due to the fact that most industrialized nations must import a substantial amount of what they use. This dependence on imported oil weakens national security to the extent that the sources could

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[1]Pub. L. 93-159 (27 November 1973), Emergency Petroleum Allocation Act of 1973, 87 Stat. 627.

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become unreliable in time of peace or war.

Because of the increading desire for energy independence, numerous viable technologies have been emphasized. Nuclear power is one technology that has been thought for years to hold the answer to the world's present and future energy problems. However, there have been many complex issues and choices surrounding this industry which have made it controversial to the point of becoming less viable than many people in the early nuclear era anticipated.

The topic of nuclear power can best be discussed in terms of: (1) choices that must be made if it is to remain a viable industry, (2) the anticipated future of nuclear power, and (3) how present choices may impact upon the anticipated future.

Several of the choices affecting the nuclear power industry include whether or not to pursue the nuclear power option or rely on existing fossil-fueled plants and new technologies for electricity generation, how to dispose of nuclear wastes, how and whether to exploit the national and international nuclear power market, how to deal with the nuclear weapons proliferation issue, and whether, in general, to have more or less nuclear power. It should be emphasized that the proper framework for making these choices is contained in the following three questions: (1) Is nuclear power physically and

biologically reasonable and possible?; (2) Is nuclear power feasible from an economic and engineering standpoint?; and (3) Is nuclear power institutionally acceptable?

The future of nuclear power is discussed in terms of projected installations, its contribution to world energy supply, current and future major suppliers of nuclear reactors and fuel, major users of nuclear power in the future, and the potential future favorable impact that nuclear power could have on decreasing oil importation and increasing energy independence.

Of course the current public and private choices that will be made regarding the nuclear power industry will impact heavily on its futute. There is a significant component of the world society that wants to see nuclear power play an increasing role in supplying the world's energy needs. There is another component that believes that the proper course is away from nuclear power and along a decentralized and renewable "soft-energy" path. An ardent spokesman for this component is the well-known author and speaker, Amory B. Lovins, who asserts that "Available renewable sources are not cheap, easy, or instant, but they are cheaper, easier, and faster than the synfuel plants or still costlier power stations."[1]

Both the choices surrounding nuclear power, and

[1]Amory B. Lovins, "How Much Energy Do We Need?", National Geographic, February 1981, p. 73.

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its probable future need to be viewed at the international level, the national level, and the state level. This tri-level examination takes place in varying degrees throughout this study. However, Chapter 5 especially focuses on the choices and the future of nuclear power in Michigan, while Chapters 6 and 7 focus on the U.S. situation.

Since the choice of more or less nuclear power can play a major role in supplying the neergy needs of the world, it is useful to devote part of this study to determining as precisely as possible what the impact has been on the United States. The benchmark selected for this determination is the energy-equivalent impact on U.S. oil importation of the current nuclear power shortfall.

The United States imported 48.4 percent of its petroleum in 1979,[1] and through the first half of 1980 the amount was 43.8 percent.[2] It was demonstrated to the United States during the 1973-74 Arab oil embargo what a small disruption in the flow of imported oil can do to the orderly functioning of a highly energy-intensive society. It is the opinion of many people that such a heavy dependence on imported oil places the United State's national security in a very precarious position. This may be the most serious problem associated with the energy crisis. There was great optimism following World War II

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[1] See appendix 1, pt. a and pt. b for derivations.

[2] Ibid., pt. c.

that the development of nuclear power would avert any such energy crisis. However, nuclear power in 1980 was not developed even to the level of forecasts made in the early 1970's.

In the United States during 1979, nuclear energy accounted for 3.5 percent[1] of the energy inputs to the U.S. economy (see figure 1). This energy input went to the electric utility industry where 9.1 percent[2] of the installed generating capacity was nuclear (see figure 2). The total electricity generated in 1979 was 2,247,372 million kilowatt-hours (kwh).[3] Of this amount, 11.4 percent was generated by nuclear power plants,[4] and 76.0 percent was generated by the burning of coal, petroleum, or natural gas.[5]

However, the 11.4 percent contribution from nuclear sources was considerably less than the amount forecast by various agencies of the Federal government as well as private industry during the preceding fifteen years. Since the shortfall in nuclear power was made up for with increased reliance upon fossil fuels, a very interesting

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[1]See appendix 1, pt. d for derivation.

[2]Ibid., pt. e.

[3]U.S., Department of Energy, Energy Information Administration, Monthly Energy Review, September 1980, p. 62.

[4]See appendix 1, pt. f for derivation.

[5]Ibid., pt. g.

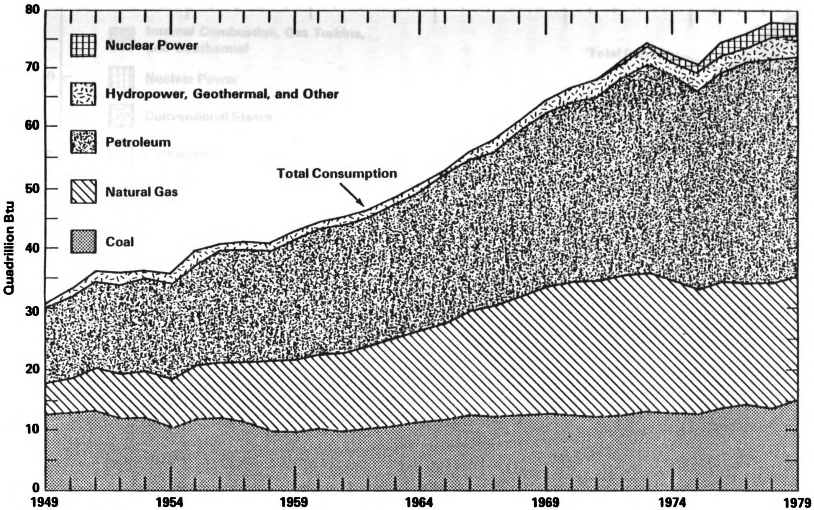
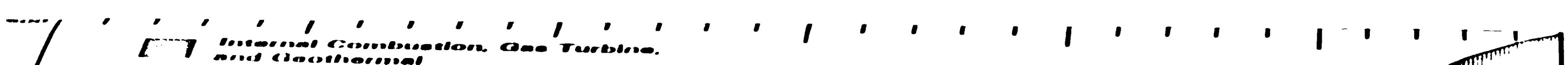


Fig. 1. 1979 total consumption of energy by type

SOURCE: U.S., Department of Energy, Energy Information Administration, Annual Report to Congress 1979, 3 vols., n.d. 2:6.


Internal Combustion, Gas Turbine, and Geothermal

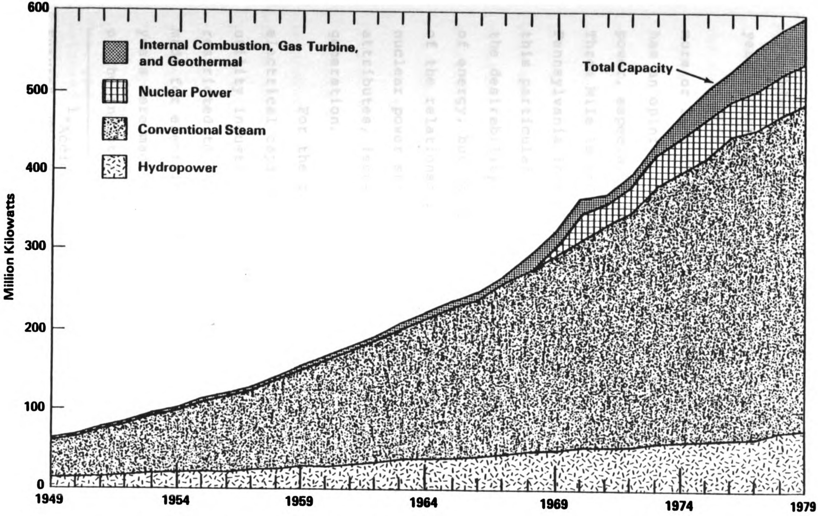


Fig. 2. 1979 generating capacity of the electric utility industry

SOURCE: U.S., Department of Energy, Energy Information Administration, <u>Annual Report to Congress 1979</u>, 3 vols., n.d., 2:138.

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question arises: How much of the 48.4 percent dependence on foreign oil in 1979 was brought about by the failure to achieve the level of nuclear power forecast for that year? Chapters 6 and 7 answer this question.

This paper is not intended to be an argument for more or less development of nuclear power. Almost everyone has an opinion regarding the safety and necessity of nuclear power, especially in the wake of a major event at the Three Mile Island 2 nuclear plant near Harrisburg, Pennsylvania in April 1979.[1] Therefore, the purpose of this particular discussion is not primarily to evaluate the desirability of nuclear energy compared to other forms of energy, but rather to make the aforementioned determination of the relationship between U.S. oil imports and the U.S. nuclear power shortfall, and also consider the major attributes, issues, and choices accompanying nuclear power generation.

For the purposes of this discussion, only the electrical capacities and energy outputs of the electric utility industry will be dealt with. The discussion is being restricted to this source of electricity because the forecasts made for electricity from various types of fuel over past years were made with reference to the public utility sector of the industry, and did not include any references to

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[1]"Accident Triggers Pitched Battle Over Nuclear Future", ENR, McGraw-Hill's Construction Weekly, 5 April 1979, pp. 10-15.

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the private generation of electricity. The total installed generating capacity of the electric utilities at the end of 1979 was 598,298 megawatts (Mw).[1] There was an additional installed capacity of 17,388 Mw at the end of 1979 that was considered privately owned and utilized industrial generating capacity,[2] e.g. General Motors, Dow Chemical, etc.

In order to measure the relationship between the current dependence on imported oil and the shortfall in nuclear power, various forecasts for nuclear power to be installed by 1980 will be analyzed and compared to what was actually installed. The result will be the determination of an average shortfall. This average nuclear shortfall can then be translated into percentage of total oil imports for 1979.

The general outline of this paper will be as follows: Chapter 1 will be a discussion of the international resource aspects of nuclear power and who could (and will) develop it most readily; Chapter 2 will cover the nonproliferation issue that has resulted in severe restriction of U.S. trade in nuclear reactors, fuel enrichment, and reprocessing; Chapter 3 is a discussion of the current technical and institutional mechanisms for dealing with the long-lived

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[1]Melvin E. Johnson, telephone interview, U.S. Department of Energy, Energy Information Administration, Coal and Electric Power Statistical Division, Office of Data and Interpretation (Washington, D.C.), 17 December 1980.

[2]Ibid.

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nuclear wastes; Chapter 4 is an evaluation of the nature and scope of sociotechnical challenges faced by the nuclear power industry; Chapter 5 is an overview of the present and projected roles of nuclear power in the State of Michigan; Chapter 6 will interpret and summarize thirteen U.S. nuclear forecasts for 1980; and Chapter 7 will primarily be a determination of the current level of dependence on imported oil brought about by failure to meet the various nuclear forecasts discussed in Chapter 6.

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CHAPTER 1

NUCLEAR POWER: AN INTERNATIONAL COMMODITY

Why Nuclear Power?

The international market for nuclear power plants is growing. This growth is taking place for reasons which depend greatly on the unique situation of each country. Reasons justifying introduction or expansion of nuclear power in some countries are not sufficient for others.[1]

Some nations lack domestic supplies of coal, oil or natural gas. Hydroelectric power may also be inadequate or unavailable. These countries do not have the benefit of diversified energy sources as the United States or the Soviet Union does. They must therefore either import a substantial proportion of their energy in the form of fossil fuels, or they can install nuclear power plants.

Economic justification is another reason for the building of nuclear power plants around the world. It may not always be economical to pursue a course of nuclear power for the generation of electricity, but this depends on the particular country. For example, some countries

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[1] Mitre Corporation, Nuclear Power Issues and Choices (Cambridge, Mass.: Ballinger Publishing, 1977), pp. 4-7.

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have power grids that are not designed to accommodate the output from the normal size modern nuclear power plants of about 1,000 Mw. At present the capital costs per unit of generating capacity of small nuclear plants that would be appropriate to existing power grids in many countries are high. The costs are high even against the cost of imported fossil fuels.

A major reason for utilizing nuclear power is for freeing up petroleum for other purposes. Since petroleum is used greatly in transportation, it would be a boon to any economy to increase petroleum availability by decreasing its use in oil-fired power plants.

The view also exists that petroleum is too valuable a resource to simply burn for the electricity it can produce - which only utilizes about one third of its energy content in conventional power plants. In the future, as petroleum and natural gas prices rise and the anticipated shift to special processing of coal as a substitute occurs, it may be that nuclear power will be more essential for freeing up coal for the production of synthetic oil and gas.

Some nations have undoubtedly been influenced toward nuclear power by other than economic factors. A major factor is no doubt a desire for increased security in supply of energy. Most nations are no different than the United States in wanting to be at least energy secure,

if not energy self-sufficient. While energy self-sufficiency is an elusive goal for most countries, national security is a minimum goal that generally all countries feel they must attain. Several countries can make progress toward greater energy security by utilizing the uranium within their own borders while lacking any significant deposits of fossil fuels.

Another motive for acquiring nuclear power is prestige. There are no doubt many countries where the economics of nuclear power are highly questionable. However some of them are pursuing nuclear power as the symbol for entrance into twentieth century technology. It tends to "distinguish" them from the class of countries known as "developing nations".

A final significant motive for acquiring nuclear power is to enhance the expertise of the country's scientific community in the field of nuclear technology. A country might have no plans to construct nuclear weapons, yet might want to have the technology available should a perceived need for nuclear weapons arise.

How Much Nuclear Power?

It has been said that any energy problem is the whole world's.[1] This is true in view of the fact that

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[1]Richard Knox, "A Thought for the 1980's", Nuclear Engineering International, January 1980, p. 15.

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energy transactions take place in an international market, and very few countries are self-sufficient. A recent study of the National Academy of Sciences has indicated that worldwide investment in nuclear power between now and the year 2010 could amount to about one trillion dollars.[1] It appears that a substantial portion of this investment will occur in the countries most dependent on imports, the reason being that they will be most affected by increasing costs of imported fuels.

The World Energy Conference suggests a world program for the installation of nuclear capacity by the year 2020 of between 3,200,000 Mw and 5,500,000 Mw.[2] The need for increasing nuclear capacity is simply due to the increasing worldwide demand for energy.[3] In the European community, energy demand will have increased by the year 2000 by between 1½ and 2 times; the anticipated growth rate is similar for the United States and Japan; and in the remaining part of the world, energy demand may increase by two to three times by the start of the twenty-first century.

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[1]National Academy of Sciences, Energy in Transition: 1985-2010 (Washington, D.C.: National Academy of Sciences, 1979), p. 79.

[2]C. Allday, "Nuclear Power, Politics and Public Opinion", Nuclear Energy, April 1979, p. 78.

[3]M. Davis, "Nuclear Power's Vocation in the Energy Strategy of the European Community", Nuclear Energy, February 1979, p. 16.

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At the present, oil is meeting much of the energy demands of the world. However almost every country is feeling some economic strain from the escalating costs of petroleum, and there are increasing possibilities of using the threat of price increases or embargoes as diplomatic bargaining factors. All countries of the world, whether they are producers or exporters, need to cooperate in finding solutions to the problems of energy supply.

While nuclear power cannot alone solve the challenge of increasing energy demand, it is most often listed in conjunction with coal as one of the two major energy suppliers for the next two decades or more. This position was taken by the National Academy of Science's study that began in 1975.[1] In the United Kingdom, the electrical supply industry has carried out several analyses, and there have been speeches by the Chairman of the Electricity Council, the Central Electricity Generating Board, and the Scottish Electricity Board. They all concluded that nuclear power is the best way to meet their growing electrical needs.[2] It appears that two 1,250 Mw nuclear power stations will be needed per year in the late 1980's which will rise to approximately three each year by the late 1990's.

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[1]National Academy of Sciences, Energy in Transition: 1985-2010 (Washington, D.C.: National Academy of Sciences, 1979), pp. 18-19.

[2]Sir John Hill, "Quest for Public Acceptance of Nuclear Power", Nuclear Energy, October 1979, p. 303.

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The European Economic Community, aligned by the Euratom Treaty, forsees an important role for energy from both nuclear and coal in helping to provide economic prosperity for its members (Luxembourg, Denmark, Belgium, Italy, Ireland, France, Germany, U.K., and Netherlands).[1] The Community was sixty percent dependent on imported oil in 1973, but by 1977 was only fifty-one percent dependent. Since directives were approved by their Council of Ministers in 1975 prohibiting the construction of future large oil-fired and gas-fired power plants, it appears that the shift to coal and nuclear is succeeding.

Other studies have emphasized the dual and essential roles of both nuclear and coal power for the near term. Among them are the 1977 study by the Mitre Corporation, _Nuclear Power Issues and Choices_.[2] A second concurring study also funded by the Ford Foundation was done by Resources for the Future and published in 1979 under the title _Energy: The Next Twenty Years_.[3] A "think tank" study by Resources

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[1] M. Davis, "Nuclear Power's Vocation in the Energy Strategy of the European Community", _Nuclear Energy_, February 1979, pp. 15-17.

[2] Mitre Corporation, _Nuclear Power Issues and Choices_ (Cambridge, Mass.: Ballinger Publishing, 1977).

[3] Resources for the Future, _Energy: The Next Twenty Years_ (Cambridge, Mass.: Ballinger Publishing, 1979).

for the Future titled Energy in America's Future: The Choices Before Us came to similar conclusions.[1] Two studies by the U.S. Government Accounting Office forecast shortfalls in electrical energy without the growth of the nuclear power industry, and also support the higher technology breeder reactor.[2]

The shift to nuclear power is making the most notable progress in France. They set a goal of 36,200 Mw of added nuclear capacity to be installed between 1970 and 1985.[3] Earlier delays are being overcome, and twenty-six stations are currently under construction. Between 1980 and 1985, the total amount of electricity from nuclear will be fifty-six percent.[4] The French are simply responding to the high costs of imported oil, and have as a goal a high degree of energy self-sufficiency.

The French are also the leaders in the design and construction of breeder reactors which create plutonium fuel for additional reactors. The reason for building breeders is to become energy independent - even with regard

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[1]Resources for the Future, Energy in America's Future: The Choices Before Us, cited by Nuclear Engineering International, October 1979, p. 10.

[2]Cited in "GAO Supports LMFBR", Nuclear News, July 1979, p. 42.

[3]"Political Will - A Key Factor in Large Nuclear Programme", Nuclear Engineering International, March 1979, p. 47.

[4]Richard Masters, "What Lessons From France?", Nuclear Engineering International, January 1980, p. 15.

to the importation of uranium. If breeder reactors are used, the marginal uranium deposits of France will be practical whereas they would not be if only light water reactors are used. Light water reactors are the most common type used in the United States.

In addition, France is developing its own reprocessing technology to reclaim the fissionable material from the spent fuel rods. This is in contrast to practice in the United States whose policy has been to store the spent fuel while awaiting a decision at some indefinite time regarding their reprocessing or permanent storage as wastes.

A situation that France and other energy-dependent countries are naturally aware of is the relatively inexpensive use of fissionable materials obtained from the breeder as well as reprocessing compared to enriched uranium. No doubt this is the major reason for their emphasis on construction of the fast breeder reactor.

Similar to France's situation is that of Japan, although Japan is even more dependent on imported energy than France. Japan's commitment to nuclear power is ironic in the fact that they are the only country to have experienced the horror of atomic bombing. Yet adequate nuclear capacity is considered to be of vital strategic importance in Japan's economic and political future.[1] Through careful efforts

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[1]Richard Masters, "Towards Greater Independence", Nuclear Engineering International, December 1979, p. 53.

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to maintain public support, Japan's need for adequate nuclear power is presented logically as a key component in a broadly-based and long-term energy and industrial strategy. The efforts are mainly being geared toward reducing their overwhelming dependence on imported oil.

Even by 1990 when the expectation is that nuclear power will be accounting for ten percent of Japan's total energy supply, there is anticipated to still be a sixty percent dependence on imported oil and coal.[1] Also, since Japan has no uranium, and does not wish to substitute dependence on imported uranium for dependence on imported fossil fuels, they are actively pursuing development of the breeder reactor and full capability in the fuel cycle.

Japan regards it as a legitimate right to pursue all aspects of nuclear power technology because of its energy vulnerability implied by heavy importation of fossil fuels. At present the installed capacity of nuclear power stations in Japan is second only to that in the United States.[2]

The Drive for Energy Self-Sufficiency

A desire for energy self-sufficiency seems to be the driving force behind nuclear power. Italy has been referred to as being the most vulnerable industrial

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[1]Ibid. [2]Ibid.

nation to the energy crisis.[1] Romania is planning to achieve energy self-sufficiency by 1990 at which time eighteen percent of the energy would be from nuclear.[2] Approximately thirty percent of Switzerland's electrical power production is from nuclear plants, their only other sources being hydroelectric and imported oil. In a national referendum, a vote of "yes" has allowed nuclear construction to continue with an additional plant planned for 1985 and another by 1990.[3]

Western Europe has decided as a whole that if they are not to be dependent on the Arab countries for oil or be "under Russia's thumb", they must have sufficient energy for meeting all their needs. They are therefore calling for the fullest use of all energy resources available to meet the deficit created by escalating costs of oil, and recognize that this deficit cannot be met without increased reliance on nuclear power.[4]

The Soviet Union is moving ahead rapidly with nuclear power in their own country. Intellectual leaders

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[1]"Italians Discuss Their Energy Future", Nuclear Engineering International, December 1979, p. 3.

[2]"Country Seeks to Regain Energy Self-sufficiency", Nuclear News, September 1979, p. 53.

[3]"Despite Sabotage, Swiss Programme Continues", Nuclear Engineering International, January 1980, p. 9.

[4]Bruce Adkins, "Helping the Politicians", Nuclear Engineering International, January 1980, p. 16.

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writing in Kommunist, which is the Soviet Communist Party's publication for discussion of policy issues, state that "It is impossible to build up the energy base for developed socialism without atomic power".[1] They went on to suggest that large power parks with several reactors at each site might be a more efficient method of building up their nuclear capacity. This idea is not unique to the Soviet Union, having been discussed in most all industrialized countries where the demand for large concentrated electrical generation exists. The Soviet Union is also actively implementing breeder technology.[2]

Eastern European countries have an even firmer commitment to nuclear power than the Western European countries. The leaders of the Eastern European countries plan to have an additional 37,000 Mw of nuclear capacity by 1990. They also will be supplied some electricity from across the borders of Russia.[3]

China too is beginning to aggressively develop its nuclear technology for the purpose of supplying electrical power. In 1979 a group of Chinese nuclear scientists visited the United States for a month-long tour of nuclear

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[1]Cited in "Nuclear News Briefs", Nuclear News, November 1979, p. 28.

[2]Simon Rippon, "International Conference on the Breeder and Europe", Nuclear News, December 1979, p. 63.

[3]"Summit Stresses Nuclear", Nuclear News, August 1979, p. 52.

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facilities, followed by a two-week tour of Canadian plants. A Chinese representative said that the Chinese now regard nuclear energy as an important part of their aggressive program of the "Four Modernizations", which include science and technology, agriculture, education, and military.[1]

At the second International Scientific Forum on an Acceptable World Energy Future held by the University of Miami Center for Theoretical Studies, a consensus emerged that nuclear energy will play a major role in the next century's energy supply system, and the breeder will be an integral part of that system.[2]

In short, nuclear power is a strategic factor being employed around the world to combat the higher costs of fossil fuels, especially petroleum. It is playing an increasing role in the strategies of many countries to enhance their economic stability and national security by decreasing dependence on rapidly escalating costs of energy that come from outside their borders.

One major prerequisite for the growth of the international nuclear industry is capital - and it appears that it will be forthcoming. At the 1979 International Conference on Financing Nuclear Power the view of the bankers present was that "We cannot preserve world stability

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[1]Debby Graves, "Nuclear Contingent Tours U.S. Nuclear Facilities", Nuclear News, May 1979, p. 67.

[2]"Nuclear Seen as Key to World Energy Supply", Nuclear News, January 1979, p. 44.

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without a substantial nuclear power program".[1]

Nuclear Role in Developing Nations

Of particular interest is the part that nuclear power may play in satisfying some of the energy demands of developing as opposed to industrialized nations. An ideal area to investigate this potential is that of Latin America, which is regarded by some as an emerging nuclear market[2] (see table 1). An example of extensive nuclear power growth plans is in the country of Brazil whose increase in electrical demand cannot be taken care of by coal or hydroelectric power. Brazil's situation is not unique, and Latin America appears to offer the greatest external market for all exporters of nuclear reactors and associated services for the next ten years.[3]

There is a psychology behind a developing country's readiness to accept the nuclear option. It is based somewhat on a desire to enter the world of twentieth-century technology with all its perceived advantages that accompany a higher standard of living. It is interesting that most of the

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[1]"Bankers: 'It Has To Be - We'll Find The Financing'", Nuclear News, November 1979, p. 41.

[2]Octave Du Temple and Edward Hennelly, "Latin America: Emerging Nuclear Market", Nuclear News, September 1979, p. 59.

[3]Ibid., p. 64.

TABLE 1

PREDICTED GROWTH IN REACTORS AND POPULATION IN LATIN AMERICA

	Number of Reactors Presently Planned or Announced	Possible Additions (Operating or Under Construction in 2000)	1979 Population (Millions)	Est. 2000 Population (Millions)
Brazil	9	10-30	110	225
Argentina	4*	2-4	25	35
Chile	1	1-2	11	17
Peru	0	1-2	16	35
Columbia	0	1-2	29	48
Venezuela	1	1-3	16	35
Mexico	2	2-10	62	130
Others	0	0-4	71	75
Totals	17	18-57	340	600

*In addition to Atucha-1, already built, and Cordoba, under construction

SOURCE: Octave Du Temple and Edward Hennelly, "Latin America: Emerging Nuclear Market", Nuclear News, September 1979, p. 59.

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opposition to the nuclear option occurs in the most developed nations that have an efficient industrial base and adequate energy supplies.[1] It is a given that vast quantities of energy will be required to bring the developing nations from their low standards of living to even the standards of much of Europe - let alone the United States. Therefore people in the third world countries naturally will not advocate abandonment of nuclear power.

Moreover, they are looking to the industrialized nations to provide them with ways of producing more energy.[2] The recent National Academy of Sciences Study, Energy in Transition: 1985-2010, recognizes that the world market for energy is growing, especially in the developing countries.[3] They feel this growing demand for energy will make them increasingly important in the global energy picture.

In addition, as industrialization progresses, there will be a consequent greater reliance on electric power, of which developing nations now have very little. As they develop, and as personal incomes increase, they will want better housing with more lighting and appliances,

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[1]Sir John Hill, "Quest for Public Acceptance of Nuclear Power", Nuclear Energy, October 1979, p. 302.

[2]C. Allday, "Nuclear Power, Politics and Public Opinion", Nuclear Energy, April 1979, p. 78.

[3]National Academy of Sciences, Energy in Transition: 1985-2010 (Washington, D.C.: National Academy of Sciences, 1979), p. 81.

not to mention air conditioning.[1]

Developing nations currently account for less than ten percent of the current consumption of internationally traded energy.[2] However as mentioned above, their rate of growth in energy consumption is much higher, so that their share may reach as much as twenty percent by the year 2000.[3] This increasing demand will make substitution with nuclear, where possible, even more necessary from an economic and security standpoint.

A large part of the energy needed by developing countries will have to be imported. In addition, heavy investments in electric power will be necessary, even if fuel can be obtained inside the country.[4] The reason is that oil is likely to be preempted by transportation uses, and in most developing countries coal would have to be imported from the United States or Australia.

It is therefore likely that the developing nations will concentrate their investments in nuclear and hydroelectric power, at least until the end of the century.[5] This will

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[1]Ibid.

[2]Mitre Corporation, Nuclear Power Issues and Choices (Cambridge, Mass.: Ballinger Publishing, 1977), p. 67.

[3]Ibid.

[4]National Academy of Sciences, Energy in Transition: 1985-2010 (Washington, D.C.: National Academy of Sciences, 1979), p. 82.

[5]Ibid.

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therefore not only be increasing imports of oil in most cases, but also enriched uranium, unless they develop breeder reactors which is considered too high a technology for developing nations to achieve or maintain. An exception to the use of breeder reactors may be in India which is constructing, with the aid of France, a 15 Mw fast breeder test reactor.[1]

Following is a view of the role that nuclear power may play in developing nations by the National Academy of Sciences:[2]

> As energy growth occurs in developing nations, electricity demand will probably grow more rapidly because electricity prices are less sensitive to fuel costs. If the market is the principal determinant of relative demand, and if there are no non-economic constraints on the rate at which nuclear capacity can be expanded, then two-thirds or more of electricity would probably be supplied by nuclear power, with coal a distant second, consumed mostly in the United States.

For many developing nations it may be a question of either nuclear power growth or retarded economic growth - and the increasing potential for economic growth in developing nations will not be given up easily. Although there are worthy arguments regarding uncoupling the relationship between Gross National Product and the level of energy consumption, there is little debate over energy being

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[1]"India Planning to Build Fast Reactors", Nuclear Engineering International, December 1979, p. 6.

[2]National Academy of Sciences, Energy in Transition: 1985-2010 (Washington, D.C.: National Academy of Sciences, 1979), pp. 76-77.

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an essential ingredient for industrialization to occur in the first place. The already stringent balance of payments problem of many developing nations is only being aggravated by increasing costs of fossil fuels, and the developing countries may be forced to adopt nuclear power at a more rapid rate than is socially and technologically wise.

There are problems associated with installing nuclear power plants in the developing countries that cannot be overlooked. As mentioned earlier, a major factor is the inadequacy of many power grids to handle the enormous amounts of energy that is generated by a modern-size nuclear plant. In the early years of the nuclear power industry, smaller plants were common. However there are significant economies of scale to be realized in building larger plants which are lost in the design of the smaller ones which would be more suited to the needs of most developing countries.

Nuclear power plants represent a very large form of capital investment. Their competitiveness with other forms of electric generation is due to substantially lower fuel costs. Developing countries have more than the normal difficulties in financing and implementing capital intensive projects. If forced to install very capital intensive power plants whose competitiveness depends on the rate of increase in the prices of fossil fuels, the arguments for doing so have less force. However it should be mentioned

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that there are several suppliers who are beginning to tailor their designs to the less intensive power needs of developing nations.

Another problem is that of still being dependent on imported fuel, albeit enriched uranium instead of fossil fuels. The only way around this situation is use of the breeder reactor, which is largely untenable for developing nations.

In addition, nuclear power represents a technology that is very sophisticated for most developing nations. The technology must first of all be imported, and construction supervised by foreign engineers. The developing countries largely lack regulatory bodies adequate to supervise such an industry, and the operators of the plants themselves represent an elite far removed from the average technological skills of their society. This has caused some concern that the nuclear plants might be run in something less than the most efficient and safe manner.

Even if nuclear power were abundant in a developing nation, there might be very limited use of the electrical capacity in the industrial, transportation, and especially agriculture sectors. This largely depends on the industrial, economic, and technological capabilities of the country for utilizing energy in electrical form as opposed to fossil fuel form. The use of large amounts of electrical energy as opposed to other forms may require a substantial peri

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period of technological adaptation that may be impractical even in the long run. It can therefore be said that the extent to which nuclear power is an economic response to high world oil prices will therefore depend on the particular circumstances of the individual developing countries.[1]

There is also an alternative option for alleviating the energy stress produced by rapid economic growth in developing nations. While the likelihood of its being effective are questionable, there is a certain amount of support for it. The option is to keep the cost of petroleum on the world market at a level such that the developing nations will not be pressured into installing nuclear power. This could perhaps be accomplished by intensively developing nuclear power in the industrialized countries of the world that consume approximately ninety percent of the world's fossil fuels.[2] If the industrialized nations continue to consume this percentage of the world's fossil fuels, and the developing nations do not incorporate nuclear power or some other form on a large scale - the developing nations could be precluded from ever attaining the benefits of an industrialized society.

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[1]Mitre Corporation, Nuclear Power Issues and Choices (Cambridge, Mass.: Ballinger Publishing, 1977), p. 16.

[2]Sir John Hill, "Quest for Public Acceptance of Nuclear Power", Nuclear Energy, October 1979, p. 307.

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Opinion

Some developing countries are looking to the industrialized world to take the lead in installing large amounts of nuclear power capacity, thereby leaving the traditional and smaller-scale technologies predominantly for them.[1] This argument is sometimes misunderstood. It is not that the industrialized countries should not make nuclear power plants available around the world, but rather that they can most readily take advantage of nuclear technology in their own countries, thereby leaving more of the depleting oil and coal reserves for the less developed. The entire world is involved in the phenomena of increasing energy costs, and one solution might be for industrialized nations to utilize nuclear power to the greatest practicable extent, while making the same technology available to developing countries as required.[2]

International Views on Cost

In comparison to fossil fuels, electricity from nuclear power plants has in most cases a slight advantage over coal, and is significantly cheaper than electricity from natural gas or petroleum. While most critics will concede that on the surface this conclusion may be valid, they believe the advantage is lost in the form of externalities

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[1]C. Allday, "Nuclear Power, Politics, and Public Opinion", Nuclear Energy, April 1979, p. 78.

[2]Ibid., p. 80.

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or social costs. However the Mitre Corporation study funded by the Ford Foundation, Nuclear Power Issues and Choices, concluded that "nuclear power compares favorably with coal even when the possibility of accidents is included".[1] Their conclusion was not that nuclear power should be developed to the exclusion of coal but rather that both forms of energy were essential. Regarding externalities other than risks of a nuclear mishap, they state:

> We do not believe therefore that consideration of social costs provides a basis for overriding our conclusions, based on economic analysis, of the comparative attractiveness of the two technologies (coal and nuclear) and the desirability of maintaining a mix.2

The study readily admits a degree of uncertainty surrounding nuclear power that makes an absolute cost comparison impossible. However they agree that despite these uncertainties, "our analysis leads us to the conclusion that nuclear power will on the average probably be somewhat less costly than coal-generated power in the United States.[3]

The factors affecting the cost attractiveness of nuclear power in developing nations have already been discussed, and so additional comparisons for nuclear power in the United States and Europe will be examined.

The study Energy in Transition: 1985-2010 by the National Academy of Sciences includes the statement (with

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[1]Mitre Corporation, Nuclear Power Issues and Choices (Cambridge, Mass.: Ballinger Publishing, 1977), p. 18.

[2]Ibid., p. 17. Ibid., pp 7-8.

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a dissenting view) that "In most regions, the average cost of nuclear electricity is less than that of coal-generated electricity, and the difference is likely to continue in the future".[1] The precondition essential for this advantage is listed in a dissenting opinion as a higher utilization factor than might occur due to safety-related nuclear plant shutdowns.[2]

A recent survey of the forty-eight U.S. nuclear utilities resulted in a favorable response toward nuclear power over coal from the forty-three that replied. Their cost comparisons indicated that electricity from nuclear power plants had been more economical than that from coal for the previous three years.[3] The reasons given were that the costs of generating electricity from fossil fuels had increased while the costs of generating electricity from nuclear power plants had remained relatively stable.

The French government's permanent commission on nuclear electricity production has reported that nuclear electricity can be generated for one half the price of oil-generated electricity.[4] Of course the greater

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[1]National Academy of Sciences, Energy in Transition: 1985-2010 (Washington, D.C.: National Academy of Sciences, 1979), p. 19.

[2]Ibid.

[3]"Nuclear Generation Costs Stable in 1978:AIF", Nuclear News, July 1979, p. 33.

[4]"Nuclear Electricity Now Half the Price of Oil", Nuclear News, September 1979, p. 53.

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dependence on imported petroleum relative to the United States is the reason for much of this difference.

At the request of the Swedish Ministry of Industry, a study of the costs of nuclear power in Sweden was conducted. The main purpose was to determine the real costs of electricity produced by nuclear power plants compared to that from other stations. Included in the calculations were considerations of capital investment, direct disposal costs, decommissioning, plus other factors which were not unique to nuclear power. The results of the study show that "In Sweden nuclear power plants produce electricity considerably cheaper than other generating plants, with the exception of some hydroelectric plants".[1]

At a joint meeting of the European Nuclear Conference 79 and the Seventh Congress of the European Atomic Forum, a session was devoted to the economic analysis of nuclear power. While the session did not stimulate any comparison of cost estimates from different countries, special national reports had been prepared for the meeting and most of them showed a "clear-cut advantage for nuclear power over coal and oil".[2]

There are some additional economics in the utilization

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[1] O. Vesterhaugh and B. Blomsnes, "Trends in Nuclear Power in Sweden", Nuclear Engineering International, December 1979, p. 77.

[2] "More Than Just TMI and Schmidt's Speech", Nuclear News, July 1979, p. 65.

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of nuclear power that have to do with fuel transportation and storage. The National Academy of Sciences states that in the international uranium market, "the main reason uranium would normally be preferred by importers is its lower transportation costs".[1] Of course uranium requires special handling compared to oil or coal, and therefore the reduction in costs of shipment are not totally proportional to its lower bulk. They also point out that nuclear fuel supplies have an advantage in that they are more readily stockpiled than coal, thus making nuclear electricity less subject to interruption by strikes, bad weather, and transportation disruptions.[2]

It is reported that in France the storing of three months of oil stocks costs the same as 1½ to 2 years of uranium stockpiling.[3] The European Economic Community also found that it is "far cheaper to stockpile energy in the form of uranium".[4]

The International Market

The international market for nuclear power equipment

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[1]National Academy of Sciences, Energy in Transition: 1985-2010 (Washington, D.C.: National Academy of Sciences, 1979), p. 79.

[2]Ibid., p. 19.

[3]"More Than Just TMI and Schmidt's Speech", Nuclear News, July 1979, p. 65.

[4]"Uranium Cheaper to Store Than Fossil Fuels", Nuclear News, December 1979, p. 46.

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and service is large and growing annually, albeit not without setbacks and problems in almost every country involved. There are approximately five hundred nuclear power plants of 30 Mw and over in the world which are either operating, under construction, or on order.[1] These installations occur in thirty-seven countries. While the United States has the most nuclear power plants in operation and has traditionally been the major exporter of nuclear equipment and services to the world, this leading position in exportation may be changing.

There are several countries that now manufacture and service all segments of the nuclear power industry, most of them having gained their technology from the United States, and their first experience with U.S. manufactured reactors. Westinghouse Nuclear Europe, the largest supplier in the world, with headquarters in London, seems to be shifting from the sale of nuclear plants to the sale of technology. A company spokesman recently said "you can sell plants and make a profit on the sale or you can sell technology and licenses and make money out of that".[2]

This trend toward selling technology may result

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[1]"World List of Nuclear Power Plants", Nuclear News, August 1979, pp. 69-87.

[2]D. E. Richards, "Westinghouse Experience Over the Past 10 Years in Negotiating and Constructing Nuclear Power Plants", Nuclear Energy, December 1979, p. 380.

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in short-term profits for the companies doing the selling, but it has also caused them to lose sales to the competitors they have created, notably France and West Germany - and perhaps in the future, Japan. Also the nuclear steam supply systems can already be manufactured in Spain, Italy, Belgium, Sweden, and Holland, to name a few examples.[1]

The Soviet Union is aggressively exploiting the international nuclear power plant market, as is Canada. At the present time the Soviet Union is concentrating its efforts mostly in Eastern Europe, but this may change as the international market grows.[2] However there is much uncertainty about the rate of growth of the international nuclear power plant market, and the industry is currently bothered with the shortage of new orders.[3]

In conclusion, there is a growing world market for nuclear power plants which is being promoted by the rising costs of petroleum and the desire of countries to achieve a reasonable level of energy self-sufficiency in order to prevent economic or political security from being compromised. The cost attractiveness of nuclear power varies depending on the particular circumstances

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[1]Ibid., p. 371.

[2]"Russians Win Order in Turkey", Nuclear News, July 1979, p. 72.

[3]N. H. Jacobson, "CNA Annual Conference", Nuclear News, August 1979, p. 112.

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of each country but seems to have somewhat equal appeal to both developing and industrialized nations, providing that non-economic factors do not predominate. The generation of electricity from nuclear power appears to be less expensive than that from coal or other fossil fuels. Also the costs of shipment and stockpiling of uranium fuel as opposed to fossil fuels favors the use of nuclear. The scope of the international market for nuclear power plant sales is large and there is considerable competition for it.

This gives rise to the proliferation issue discussed in the next chapter, i.e. should nuclear power reactors and technology be sold and shipped abroad when they could result in proliferation of nuclear weapons via diversion of the nuclear fuel cycle? If nuclear power is an international commodity as has been demonstrated in this chapter, the increased use of it around the world is almost inevitable. The choice of whether or not to export is a major choice facing the American people and the nuclear power industry.

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CHAPTER 2

TO EXPORT OR NOT TO EXPORT: THE PROLIFERATION ISSUE

The Problem

It is generally acknowledged that it is not in the best interests of world peace and stability for more than a minimum number of nations to have nuclear weapons capability. What is not generally acknowledged is that the existence of a civilian nuclear power industry could or might promote a nuclear weapons capability. The recent study by the U.S. Nonproliferation Alternative Systems Assessment Program (NASAP) expressed its central concern that "As nuclear power systems and supporting civilian research and development activities become more widespread or as more advanced systems develop, their abuse, whether overt or covert, may provide a more attractive route to a nuclear weapons capability, whether national or subnational, than other routes."[1]

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[1]U.S., Department of Energy, Assistant Secretary for Nuclear Energy, Nuclear Proliferation and Civilian Nuclear Power, Report of the Nonproliferation Alternative Systems Assessment Program (NASAP), Executive Summary, Draft, December 1979, p. iii. NASAP began in late 1976 and was restructured to respond to President Carter's nuclear power policy statement, which was released in April 1977. The restructured goal of NASAP and the ensuing study has been to provide recommendations for the development and deployment of more proliferation resistant civilian

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There is substantial disagreement between the U.S. government and other governments of the world regarding the magnitude of this risk, and whether it is a risk that can be mitigated via attention focused merely on the proliferation issue. There is also a wide gap between the thinking of the U.S. government and many of the private nuclear industries in this country. In discussing this issue, the position of the U.S. government will be presented and then contrasted with opposing views within and without the U.S. borders.

There seems to be general agreement from all quarters that nuclear weapons proliferation should be avoided. There also seems to be general agreement that all peoples of the world should be allowed the opportunity to benefit from the "nuclear genie" who can, among other things, supply large amounts of electrical energy at competitive prices which might be less volatile than the prices associated with fossil fuels.

The major proliferation debate centers around the contribution that nuclear power programs can make to nuclear weapons programs. This contribution depends on the presence of sensitive materials and facilities

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nuclear power systems and institutions. The draft report, dated December 1979 and released January 17, 1980 consists of nine volumes and an executive summary. It is published as DOE/NE-0001. Copies of the draft documents are available from the Technical Information Center, P.O. Box 62, Oak Ridge, Tennessee 37830 (Attn: NASAP Report).

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used in the processes associated with civilian nuclear electrical power. Sensitive material is weapons-usable material. When separated from other materials, both uranium enriched to high concentrations in the isotopes U-235 (more than about twenty percent) or U-233 (more than about twelve percent) and plutonium are considered to be weapons-usable materials, whether in oxide or metallic form.[1]

Sensitive facilities are those that can produce, or can be easily modified to produce, weapons-usable material. The facilities of greatest concern are those used for enriching or reprocessing reactor fuel. The proliferation risks arise because of the similarities in the materials and facilities used in manufacturing nuclear weapons and generating nuclear electric power. It is a widely held view that the similarities provide significant opportunities for abuse of the nuclear fuel cycle.

The logic behind creating a civilian nuclear power industry in order to acquire nuclear weapons capability is lacking, i.e. it would be the most difficult method. However, some argue that given existing civilian facilities, it would be more economical to divert part of the processes for the manufacture of nuclear weapons than to build separate nuclear weapons facilities from the ground up. In addition, the technical expertise that would be acquired in the

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[1] Ibid., p. 3.

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implementation of a civilian power industry could be useful in the diversion of those facilities and materials to non-peaceful purposes.

The U.S. Government Position

While the United States was the creator of the civilian nuclear power industry and has been responsible for transfer of this technology to much of the free world, it has also set the guidelines for spread of much of nuclear technology. A major development in the implementation of these policies was the Non-Proliferation Treaty which was negotiated and opened for signatures in 1968, and which entered into force in 1970. The Treaty involved the acceptance by non-nuclear-weapons states of international safeguards on all their peaceful nuclear activities, and their agreement not to acquire or manufacture nuclear weapons.[1] The International Atomic Energy Agency (IAEA) was also established early, in 1957, under United Nations auspices to regulate the international transfer of nuclear technology. The most recent U.S. statement of its policies was the Nuclear Non-Proliferation Act of 1978, which codified U.S. terms for nuclear cooperation.

There are two major approaches to the proliferation

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[1]U.S., Department of Energy, Assistant Secretary for Nuclear Energy, Nuclear Proliferation and Civilian Nuclear Power, Report of the Nonproliferation Alternative Systems Assessment Program, Program Summary, Draft, December 1979, p. 8.

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issue. One method focuses on technical measures that can be employed to inhibit diversion of civilian nuclear power to weapons capability. The second method focuses on institutional and policy measures. The technical approach will be discussed first.

In the recent NASAP report, a table of basic technical considerations was compiled against which to evaluate the proliferation potential of any nuclear setting. This information is included in table 5, and is centered around three major groups of assessment factors. These groups are:

> Resources required - the technological base, personnel, and financial resources needed for the specified proliferation activities in light of their inherent difficulty.
>
> Time required - the approximate times needed for the specified proliferation activities, including preparation, removal, and conversion.
>
> Risks of detection - the chances and consequences of detection of the proliferation activities, including preparation, removal, and conversion, and the possible timeliness of detection.(1)

The most important conclusions of the NASAP proliferation resistance assessments are that:

> All fuel cycles entail some proliferation risks; there is no technical fix that will permit operation of a nuclear-power fuel cycle with material that cannot be diverted to use in nuclear weapons or that will

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[1]U.S., Department of Energy, Assistant Secretary for Nuclear Energy, Nuclear Proliferation and Civilian Nuclear Power, Report of the Nonproliferation Alternative Systems Assessment Program, Proliferation Resistance, Draft, December 1979, pp. 1-12, 1-14.

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TABLE 2

CONSIDERATIONS FOR EVALUATING PROLIFERATION POTENTIAL

General Factors (i) The number sites with significant quantities of sensitive nuclear materials (ii) The need for storage and transport of these materials (iii) The quantity of these materials
Form of the Material (iv) The accessibility (radiation level) of these materials (v) The quality (isotopic mixture and chemical form) of the materials (vi) The resources required by different routes to prepare for, remove, and convert these materials to nuclear-weapons purposes (vii) The times required by these activities
Nature of the Facility (viii) The resources and time required by different routes to adapt the facility to nuclear-weapons purposes (ix) The resources and time required for covert replication of fuel-cycle facilities
Degree of Protection (x) The likelihood of detection of abuse (xi) The amenability to institutional arrangements (xii) The amenability of the materials and facilities to safeguarding
Evolution (xiii) The evolution of programs in countries at different stages of deployment.

SOURCE: U.S., Department of Energy, Assistant Secretary for Nuclear Energy, Nuclear Proliferation and Civilian Nuclear Power, Report of the Nonproliferation Alternative Systems assessment Program, Proliferation Resistance, Draft, December 1979, p. 1-13.

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preclude a determined owner-operator from designing a proliferation strategy.

The light water reactor fuel cycle with spent fuel discharged to interim storage, however, does not involve directly weapons-usable material in any part of the fuel cycle and is a more proliferation-resistant nuclear-power fuel cycle than other fuel cycles which involve work with highly-enriched uranium or pure plutonium.

Substantial differences in proliferation resistance also exist between the fuel cycles if they are deployed in non-nuclear weapons states. Some of these differences are technical in nature (e.g., no reprocessing in once-through fuel cycles), and some result from institutional arrangements (e.g., limited deployment of existing international enrichment services).

On the other hand, with the progressive introduction of technical and institutional measures to improve proliferation resistance, these differences may be reduced by the time the fuel cycles eventually come into widespread use. The differences will remain until the necessary improvements have been made, not only in newer facilities, but also in older ones.

The vulnerability to threats by subnational groups varies between fuel cycles; whereas once-through fuel cycles are susceptible to only the most sophisticated threats, closed fuel cycles are vulnerable to a wide range of threats.(1)

It should be explained that "once-through" fuel cycles refer to those involving indefinite storage of spent fuel rods whereas "closed" fuel cycles refer to those whose spent fuel is reprocessed and results in the accumulation of weapons-usable materials.

The second major approach to the proliferation issue is the institutional one. What follows is a discussion of current U.S. policies, assessment approaches, procedures,

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[1]Ibid., pp. 1-15, 1-16.

and major U.S. government observations.

Briefly stated, the reason for the spread of sensitive fuel-cycle activities and facilities is due to international uncertainties about the adequacy and accessibility of uranium supplies (whether warranted or not), and anticipation of growth in demand for nuclear fuel. Some countries are moving toward their own enrichment capabilities and some toward plutonium-based fuel cycles. Some nations are making the same moves to reduce operational, economic, and political dependency on foreign nations for supplies of uranium or enrichment services. In spite of these moves, the International Nuclear Fuel Cycle Evaluation organization estimates that less than five percent of the anticipated world installed nuclear capacity will be provided by fast breeder reactors in the year 2000.[1]

In order to prevent the further spread of sensitive materials and facilities, the U.S. government has reaffirmed its intention to act as a reliable supplier, has re-opened its order books for enrichment services, is expanding its enrichment capacity, and has explored the concept of an international fuel bank as a buffer against temporary bilateral supply problems. The U.S. is also working with other nations toward greater international cooperation

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[1]U.S., Department of Energy, Assistant Secretary for Nuclear Energy, Nuclear Proliferation and Civilian Nuclear Power, Report of the Nonproliferation Alternative Systems Assessment Program, International Perspectives, Draft, December 1979, p. 1-3.

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in spent-fuel storage.[1]

In building its nonproliferation strategy, the U.S. government recognizes that consideration must be given not only to nuclear development and nonproliferation concerns but also to the differing interests of suppliers and consumers, and of nations with nuclear programs in various stages of development. Their strategy does not require the resolution of all the issues at once, and the U.S. feels its strategy should be flexible enough to take into account the legitimate technology development, economic, and program interests of suppliers and users. Also, nuclear power systems, as they evolve, should not significantly enhance the development of a dedicated nuclear-weapons program for any nation.

There are several characteristics of institutional arrangements and possible impacts on proliferation resistance that are considered significant. First of all, the group or nation obtaining nuclear power capacity should incorporate among the partners a genuine aversion to abuse of the facilities or materials handled by them. Secondly, there must be ownership by the proper group such that the cost of any abuse would fall fully on them - thereby acting as a deterrent. Also, proper management and staffing can significantly impact the effectiveness of safeguards. Finally, the quantity and location of sensitive facilities

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[1]Ibid., p. 1-7.

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affect their vulnerability to proliferation threats.

The basic U.S. approach is to reduce proliferation risks by reducing the number or geographic spread of nationally-controlled sensitive facilities. A suggested alternative is the construction of sensitive facilities and handling of sensitive materials by an international organization of some kind. There could also be substantial economies of scale in the construction of a few worldwide facilities rather than many small and scattered ones. On the other hand, these technological economies could be offset by administrative, regulatory, and transportation diseconomies.

Sanctions and the threat of sanctions are viewed by some as an important element of any nonproliferation effort. The threat of terminating a fuel or technology transfer agreement could be a sufficient deterrent to misuse of the nuclear power facilities. This is due to the large monetary investment in such facilities as well as dependence upon their energy. It has also been suggested that further sanctions outside the nuclear arrangements could be employed, e.g. through the United Nations.

The attitude of the U.S. government toward the proliferation challenge is summarized well by the following statement:[1]

> Two tasks confront the U.S. in working to foster a world nuclear-power regime less vulnerable to proliferation. The first task is to limit the damage that may be

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[1]Ibid., p. 1-25.

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> done by the proliferation vulnerabilities in the existing regime. Carrying out this damage-limiting task might entail holding the line against the spread of spent-fuel reprocessing activities. The second task is to begin now to move toward a longer-term policy framework for the future use of nuclear energy, a framework containing fewer proliferation vulnerabilities. Such a framework would serve as a means of incorporating into a safer set of possible outcomes the expanding nuclear activities of many nations that today have programs in various stages of development.

The U.S. government is suggesting an evolutionary approach, which by necessity will be an incremental approach toward increased control and participation in the international nuclear arena.

The U.S. Nuclear Industry Position

The U.S. nuclear industry and the U.S. government disagree substantially over the "means" to achieve the "end". The U.S. nuclear industry also does not want to see nuclear weapons proliferate around the world. However it sees the present policies and actions of the U.S. government as simply crippling their business and limiting their participation in the world nuclear marketplace, while failing to further the goal of nonproliferation.

The U.S. nuclear industry has been the unquestioned leader in supplying nuclear technology to the world. While the early British and French nuclear programs floundered over the utilization of natural uranium reactors designed for weapons production, the United States continued to use reactors based on enriched uranium fuel. By the beginning of the 1970's, the United States had emerged as the

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the dominant actor in the nuclear reactor market with revenues from export sales exceeding the combined revenues of all other exporters.[1]

In 1974 and 1975, while not receiving a single domestic reactor sale, General Electric and Westinghouse acquired twelve new foreign orders. A Westinghouse executive testified that the company receives about twenty-five million annually from licensees, and General Electric reported that roughly forty percent of its nuclear profits come from foreign companies.[2]

However, with the Nuclear Non-Proliferation Act of 1978, significant constraints were placed on the exporting of nuclear materials and facilities. The Act contains more stringent regulations on nuclear exports that those prevailing in other countries or in multilateral agreements. Abraham Katz of the U.S. Department of Commerce feels that "this has placed U.S. producers at a distinct competitive disadvantage in the international nuclear market."[3] An Exxon Company vice-president has corroborated this

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[1]Charles K. Ebinger, International Politics of Nuclear Energy, (Beverly Hills, Calif.: Sage Publications, 1978), p. 24.

[2]"Reactor Exports: New Life for Industry in Third World", People & Energy, January 1979, p. 12.

[3]Abraham Katz, Assistant Secretary for International Economic Policy and Research, U.S. Department of Commerce, speech at Executive Conference on International Nuclear Commerce, New Orleans, Louisiana, 9-11 September 1979, appearing in Executive Conference Digest, (La Grange Park, Ill.: American Nuclear Society, 1980), p. 6.

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observation in his statement that "While U.S. industry can and does compete vigorously on the basis of product quality and selling price, we must squarely confront the injuries to national as well as commercial interests which are inflicted by unrealistic and unproductive export policies and by bureaucratic disabilities."[1]

Gordon C. Horlbert, president of the Westinghouse Power Systems Company has described U.S. nonproliferation policy as a tragic failure to translate legitimate concerns over proliferation into policies that enhance achievement of the goal.[2] Westinghouse has argued for (1) an amendment of the Nuclear Non-Proliferation Act of 1978, (2) improved export licensing performance, (3) support for the IAEA activities including international plutonium storage, and (4) U.S. progress in the development of reprocessing, in view of continued reprocessing activities by other countries.

Concern over export constraints is a very real

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[1]William T. England, Vice President for Corporate Affairs & General Counsel, Exxon Nuclear Company, speech at Executive Conference on International Nuclear Commerce, New Orleans, Louisiana, 9-11 September 1979, appearing in Executive Conference Digest, (La Grange Park, Ill.: American Nuclear Society, 1980), p. 6.

[2]Gordon C. Hurlbert, President, Westinghouse Power Systems Company, speech at Executive Conference on International Nuclear Commerce, New Orleans, Louisiana, 9-11 September 1979, appearing in Executive Conference Digest, (La Grange Park, Ill.: American Nuclear Society, 1980), p. 2.

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issue with the U.S. nuclear industry. When South Africa was looking to purchase two nuclear reactors from an American vendor, the arrangements were disrupted by the State Department who threatened to prevent export licenses from being issued unless certain stipulations were met. The net result was South Africa's prompt approach to a French firm who was happy to fill the profitable orders.

In January of 1978, the President issued an executive order that environmental impact studies would be required on nuclear exports. This restriction could have complicated the export business to an even greater degree if the order were interpreted to include consideration of broad health, safety, and environmental impacts of the reactor in its intended location within the receiving country. Fortunately for the industry, the Nuclear Regulatory Commission decided to consider only impacts on the U.S. or on the global commons in its nuclear export proceedings.[1]

As a result of U.S. government policies with regard to exportation of sensitive facilities and materials, the U.S. nuclear industry is being increasingly looked upon as an unreliable supplier to other countries. Closely coupled with concerns over reliability of supply has been the widespread belief among trading partners that the U.S. is unilaterally altering prior international commitments.[2]

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[1] The Energy Daily, 1 February 1980, p. 1.

[2] England, Executive Conference Digest, p. 6.

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There is considerable feeling that existing U.S. trade agreements have been modified as a direct result of U.S. government nonproliferation efforts, and to the detriment and expense of both vendor and customer. A nuclear company executive has said "If future U.S. undertakings are to be accorded any value in the international community, we are obliged to honor those commitments contained in existing agreements for cooperation and supply agreements.[1]

The United States has especially lost credibility in Latin America with regard to its reputation as a reliable supplier. In fact, U.S. export policies may have helped European firms to gain ground in this market.[2] The development of a Spanish-speaking independent consortium to develop nuclear power is on the horizon. They can use their own uranium resources, Spain and Argentina's technical expertise, with the help of Canadian and European technology.[3]

Because of the decision to not proceed with the Clinch River breeder reactor project, the United States may be falling behind technologically in the development of advanced reactor designs. The reason for not going ahead with the breeder reactor program is simply that the United States, with its abundant fossil fuels and

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[1]Ibid., p. 7.

[2]Octave Du Temple, "Latin America: Emerging Nuclear Market", Nuclear News, September 1979, p. 64.

[3]Ibid.

uranium reserves, can afford to use the "once through" fuel cycle. This "stow away" policy with the spent fuel rods (referred to as "throw away" by opponents) may not be affordable to other countries and certainly does not seem to be acceptable for both economic and energy security reasons. The estimated value of the fissile material remaining in the spent fuel elements of a modern-sized nuclear power plant of 1,000 Mw is about ten million dollars. If this material was reprocessed rather that "stowed away", uranium resources could be extended by perhaps forty percent if simply reused in light water reactors.[1]

It is feasible that the United States may need to import advanced breeder technology, should a decision be made at some later date to rapidly implement it. United States reactor manufacturers such as Westinghouse and General Electric are even now seeking technical information on the French Super Phoenix fast-breeder design, in case it proves commercially competitive.[2]

The position of the U.S. nuclear industry is that if the United States wants to maintain its ability to exercise a leadership position in developing the nonproliferation strategies, it must retain its leadership in

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[1]James J. Duderstadt and Chihiro Kikuchi, Nuclear Power: Technology on Trial (Ann Arbor: University of Michigan Press, 1979), p. 107.

[2]Jonathan Spivak, "France Pursues Drive to Replace Oil Imports With Nuclear Energy", Wall Street Journal, 8 March 1980, p. 1.

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nuclear power. Moreover, actions taken in the name of proliferation which in effect reduce U.S. nuclear power capability and technological leadership, will serve to weaken the future U.S. position in influencing desirable nonproliferation arrangements.[1]

Position of U.S. Allies

The European and Japanese allies, who have far less fossil fuel resources than the United States, believe that U.S. nuclear energy policies are unduly parochial and restrictive.[2] The irony is that the United States is still trying to persuade the rest of the world to adopt them. To paraphrase a statement in the London Times, "The fact of the matter is that the United States is trying to teach by example without having any attentive pupils."[3] Other countries have shown a clear determination to move ahead with their breeder and reprocessing programs regardless of current U.S. nonproliferation policies.

The international proliferation debate has become even more polarized since the 1973-74 Arab Oil Embargo,

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[1]George J. Stathakis, Vice President and General Manager, Nuclear Energy Programs Division, General Electric Company, "The Nuclear Weapons Proliferation Problem: Can We Lead Without Leadership?", address to the Atomic Industrial Forum Conference on International Commerce and Safeguards for Civil Nuclear Power, New York City, 15 March 1977.

[2]Charles K. Ebinger, International Politics of Nuclear Energy, (Beverly Hills, Calif.: Sage Publications, 1978), p. 5.

[3]England, Executive Conference Digest, p. 7.

as nations who possess few fossil fuel resources have moved to develop nuclear power to protect their economies from the vagaries of another major disruption of oil supplies. The United States is matched by few countries in its wealth of energy options.

For those countries that lack the abundant alternatives of the United States, the use of nuclear power is viewed as the only viable short-term solution to reduce their dependency on imported oil. However they are equally determined to not become dependent on the importation of either uranium or enriched uranium for fuel.

Since the United States developed early the best technology for nuclear power plants and fuel, it naturally has had a competitive edge in supplying such technology to the world. The U.S. has even used the European Atomic Energy Community (EURATOM) as a vehicle for ensuring the commercial dominance of American companies in the European nuclear market.[1] In addition, by guaranteeing long-term delivery of enriched uranium supplies, the Europeans were thus discouraged from developing their own enrichment and reprocessing technology.

The result of U.S. efforts to dominate European nuclear commerce has been a great amount of distrust of U.S. motives in promoting a firm international nuclear

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[1]Ebinger, International Politics of Nuclear Energy, p. 15.

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nonproliferation system. From the European perspective, U.S. tenders of technical assistance, assured deliveries of low-cost enriched uranium supplies, and Export-Import Bank financing for U.S. firms selling nuclear reactors abroad appear to be designed to maintain commercial dominance of the European nuclear market rather than to limit the proliferation of European enrichment plants from which bombs can be manufactured.[1]

From the European and Japanese perspectives, the efforts of the U.S. to dominate the enrichment technology in the name of nonproliferation served to maintain a monopoly on the reactor fuel market. This is because the best available nuclear reactor technology for years has relied on enriched uranium.

Sensitive nuclear facilities have been further diffused in Europe because of the European perception that the United States did not have a proper regard for the energy needs of their own countries, as they were dependent on the importation of enriched uranium fuel. This perception grew out of observations that the U.S. government subsidization of uranium enrichment costs has been adjusted without adequate concern for the fuel demands of other countries.

Several other factors have tended to encourage U.S. allies to become independent with regard to the uranium

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[1]Ibid., p. 29.

fuel cycle: (1) the continuing domestic debate on private ownership of enrichment technology, (2) the U.S. curtailment of some future contracts for enriched uranium in June 1974, and (3) the Nuclear Regulatory Commission's decision in March 1975 to halt all exports of nuclear fuel and reactors pending a case by case examination of physical security measures.[1]

Another factor tending toward the spread of sensitive nuclear technologies has to do with the economic strength of major European suppliers of nuclear technology. The industry is very capital intensive and requires a minimum number of orders to turn a profit. Several of the European governments feel they must retain a viable nuclear industry in order to preserve national economic and political stability. If there are not enough orders placed within the European community, it becomes essential that they find foreign markets in order to maintain the commercial viability of their nuclear industries. Some of the eagerness to tap the foreign markets has resulted in controversial sales - for example to Brazil and South Africa by Germany and France, respectively.

However, just when France and Germany were exhibiting greater willingness to follow the U.S. lead, the U.S. government announced to a surprised international nuclear community on October 28, 1976, that it would engage in

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[1]Ibid., p. 42

reprocessing and plutonium recycling in the future only if they were found to be consistent with U.S. international objectives.[1]

This announcement was disturbing to the Europeans and Japan because after the Arab Oil Embargo, millions of dollars had been invested in developing their own complete uranium fuel cycle. It began to appear that the United States was again trying to maintain its monopoly in the enrichment processes by sabotaging the efforts toward self-sufficiency by its allies, under the theme of nonproliferation.

Moreover, considerable investments have been made around the world in breeder reactors utilizing plutonium. If the nonproliferation efforts and policies of the U.S. were too broadly and thoroughly applied, they would tend to slow the development of the breeder technologies to the detriment of the countries developing them.[2]

If the U.S. were so inclined, and were successful internationally in discouraging development of the breeder reactor in favor of light water reactors with a once-through fuel cycle, the possibility of a uranium shortage would no doubt loom as a large possibility in the minds of the

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[1]U.S., Arms Control and Disarmament Agency (1976), cited in Charles K. Ebinger, International Politics of Nuclear Energy (Beverly Hills, Calif.: Sage Publications, 1978), p. 61.

[2]Mason Willrich, "A Workable International Fuel Regime", The Washington Quarterly, spring 1979, p. 20.

U.S. allies. This possible shortage of uranium would tend to encourage development of the breeder rather than discourage it.

It is clear that the paramount interests of the Europeans and Japanese are energy security and political stability. Their extensive research and development expenditures in the breeder technology, as well as investments amounting to hundreds of millions of dollars for enrichment and reprocessing facilities reinforce this observation. The fact is that a country cannot be energy independent, or perhaps under a world crisis situation - even energy secure, if it is dependent on external sources of enriched uranium.

It is noteworthy that no reactor using highly concentrated fissile material as fuel, such as plutonium has yet had any significant commercial use.[1] This fact suggests that energy security considerations may be paramount in the decision to pursue the breeder reactor with its plutonium fuel cycle, and attendant weapons-proliferation potentials.

England regards the technology of the fast breeder reactor as clearly essential, in spite of the proliferation risks associated with the use of plutonium. She regards breeder technology as a means of guaranteeing that growth

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[1] Albert Wohlstetter and others, Swords From Plowshares, (Chicago: University of Chicago Press, 1979), p. 5.

in nuclear power will not be constrained in the long run by uranium supply limitations. It was recently stated that for England, "The (breeder) technology also has some insurance value in that the earlier fast reactors are introduced, the greater the security of fuel supply."[1]

In spite of some public opposition to nuclear power in Germany, their program is continuing - and in the area of sensitive facilities and materials. The former president of West Germany, Herr Walter Scheel has publicly appealed for a greater use of nuclear power "to solve the country's energy problems."[2]

Japan has made a very large commitment to nuclear power and is pursuing the rapid development of its own enrichment and reprocessing facilities. Japan has expressed regret in the apparent loss of support for nuclear power in the United States and has called for renewed U.S. leadership in all aspects of nuclear power and the nuclear fuel cycle.[3] It is clear that the nonproliferation policies of the United States are viewed by some allies as indicative

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[1]"Energy Technologies for the United Kingdom - An Appraisal for RD & D Planning" from Energy Paper No. 39, cited in "Five-Star Rating for Nuclear Technology", Nuclear News, March 1980, p. 62.

[2]"Wind of Change Starts to Blow for Nuclear", Nuclear Engineering International, April 1980, p. 5.

[3]Toshi Ito, Kansai Electric Company, (Osaka, Japan), speech at Executive Conference on International Nuclear Commerce, New Orleans, Louisiana, 9-11 September 1979, appearing in Executive Conference Digest, (La Grange Park, Ill.: American Nuclear Society, 1980), p. 2.

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of a self-seeking nuclear industry, a government lack of sensitivity to the energy needs of others, an effort to retain a dominant position in the sales of reactor fuel, and a naivete about the ability of the U.S. nonproliferation policies to accomplish their goals.

The Third World Position

The attitude of the Third World toward the nonproliferation efforts of the United States is summarized well in the following statement from International Politics of Nuclear Energy:[1]

> Most of the nuclear "have-not" nations reject the notion of superpower strategic nuclear parity as a stabilizing geopolitical force; they reject the argument that horizontal nuclear proliferation is more a threat to world stability than the vertical proliferation of nuclear weapons held by the superpowers; and they assert the right of all sovereign nations to foster their economic independence and strategic security.

Many of the third world countries look upon nuclear power as a means of breaking out of the position of economic dependency that has been their lot since the time of the industrial revolution. Moreover, the implementation of the Non-Proliferation Treaty (NPT) has seemed to them to have as its goal the perpetuation and protection of the interests of those few countries with investments in fuel enrichment and reprocessing. Such an argument is difficult to refute.

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[1]Ebinger, International Politics of Nuclear Energy, p. 12.

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While the United States and other nuclear-weapons states have behaved rather responsibly with regard to the use of nuclear weapons, the Third World regards "vertical" proliferation (increasing strike capability) by the existing weapons states as much of a threat to world peace as the possible "horizontal" proliferation (ownership of nuclear weapons by additional countries) that could result from the spread of sensitive facilities and materials.[1]

For the above reasons, much of the Third World is not supportive of the current U.S. nonproliferation policies with their attendant implications that the major powers of the world will be responsible users of nuclear power, whether for civilian or military purposes, while they would not. A further consideration is fuel supply reliability in the international market. For example, the reasons leading up to Germany's agreement to provide Brazil, a non-NPT signatory, with uranium enrichment and reprocessing technology were (1) the curtailment of enrichment services by the U.S. in 1974, (2) the abrogation of coal export contracts by firms in West Virginia and Virginia, and (3) the Nuclear Regulatory Commission's denial of nuclear fuel to Brazil's Angra I and Angra II nuclear plants after March 1975.[2]

For a country such as South Africa that is developing its own enrichment complex, to cooperate with the IAEA

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[1]Ibid., p. 46. [2]Ibid., p. 54.

and to agree to the terms of the NPT would mean that their enrichment facilities would be open to international inspection and would, in their view, allow the West to acquire valuable commercial information. This same access to U.S. enrichment facilities is denied to South Africa.

The Third World also rejects the argument that the acquisition of enrichment and reprocessing facilities would automatically mean that the nations would build nuclear weapons. They cite the examples of Germany and Japan, among other "near-nuclear" states, who could have built weapons but have chosen not to do so.

The Third World wants to be removed from its Third World status, because whatever way it is viewed, "third world" denotes something less than first class status. The drive for prestige as a nation is important as never before, as suggested in Arms Control and Security: Current Issues:[1]

> In our epoch, the evidence is everywhere of the dominant role of national status-seeking and the drive to 'feel equal'. An entire philosophy of resentful Third World economies bears the telltale name 'dependency theory'. Third World proposals for a 'New Economic and Social Order' reflect a veritable obsession with eradicating the stigmata of inferiority. The walls of every international conference room, from OPEC to the U.N. General Assembly resound with strident demands for equal status.

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[1]Lincoln P. Bloomfield, Arms Control and Security: Current Issues, ed. Wolfram F. Hanrieder (Boulder, Colo.: Westview Press, 1979), p. 295.

At the symbolic level, nuclear power reactors are anything but trivial. Moreover, the Third World perceives a real need for nuclear power if the fossil fuel prices are forced too high by the bidding of richer and more developed nations. The poor countries could have their situation improved by either utilizing nuclear power themselves (complete with their own or shared fuel enrichment and reprocessing facilities) or by the developed nations' extensive implementation of it.

It does appear that the shortage of cheap energy in the world is affecting economic growth almost everywhere. It is also generally the case that the effects of a weak world economy are felt most by the poorer countries. It is a point well taken that as the gap between the rich and the poor countries grows, "circumstances of great social and political uncertainty and unrest (fostered by the economic gap) . . . are likely to exaggerate threats to their security and (cause them to) become involved in military action."[1] The task is to keep the economic gap from broadening as much as possible, by making available the energy required for growth, whether it is fossil or nuclear.

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[1] Frank Barnaby, "Maneuvers in the Indian Ocean", Bulletin of the Atomic Scientists, May 1980, p. 9.

The Net Effect

The solution to the proliferation issue is not simple, and may be unattainable. The current status of U.S. nonproliferation efforts are summarized by the following States General Accounting Office statement:[1]

> U.S. efforts to defer worldwide commercial reprocessing and the premature separation of plutonium are having only limited success. In spite of the administration's policy, many countries are reprocessing or continue plans to develop commercial reprocessing industries. Recognizing these plans and the resulting excess plutonium that may be produced, effective international safeguards and controls over the production, storage and use of separated plutonium are needed. No such systems currently exist.

The statement that "No such systems currently exist" implies that the Non-Proliferation Treaty and the International Atomic Energy Agency are not effective or broad-based enough at present.

Currently, almost all nuclear plant fuel is enriched in the United States, but by 1990, thirty-five to forty percent will be handled elsewhere. In addition, world capacity is expected to triple during the same period.[2] It appears that the spread of sensitive facilities is going to occur regardless of U.S. efforts to prevent it

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[1]U.S., General Accounting Office, Report to the Congress by the Comptroller General of the United States, <u>Nuclear Fuel Reprocessing and the Problems of Safeguarding Against the Spread of Nuclear Weapons</u>, 18 March 1980, p. 52.

[2]Exxon Corporation, Public Affairs Department, <u>World Energy Outlook</u> (New York: Exxon Corporation, 1980), pp. 14-15.

via its nonproliferation policies. This position is supported in a statement made in a reputable study by Resources for the Future, Inc.:[1]

> Moreover, there is the possibility that U.S. policy generally and the passage of the Act (Non-Proliferation Act of 1978) in particular may have effects on nuclear weapons proliferation just the opposite of those intended. The specter of U.S. denial of uranium and enrichment service and of an American veto of reprocessing by third parties may serve as an inducement to the development of indigenous enrichment and reprocessing capabilities and premature interest in breeders.

Similar conclusions were arrived at in a 1977 Mitre Corporation study, Nuclear Power Issues and Choices.[2] The National Research Council's Committee on Nuclear and Alternative Energy Systems (CONAES) came to a like conclusion. Their assessment was that there was no "technical fix" that would avert the nuclear proliferation problem - not even the stopping of the construction of nuclear power plants.[3]

Another study concluded that the trend toward proliferation of sensitive facilities and materials could be turned around but such a reversal was not likely.

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[1]Resources for the Future, Energy: The Next Twenty Years (Cambridge, Mass.: Ballinger Publishing, 1979), p. 446.

[2]Mitre Corporation, Nuclear Power Issues and Choices (Cambridge, Mass.: Ballinger Publishing, 1977), p. 4.

[3]Cited in "Breeders Needed Says CONAES", Nuclear Engineering International, March 1980, p. 8, from National Research Council's Committee on Nuclear and Alternative Energy Systems (CONAES), Energy in Transition 1985-2010 (San Francisco: W. H. Freeman, 1979).

It stated further that if a turn-around were to occur, it would have to be by some form of international agreement.[1]

One needs to focus on the essential cause of the likely failure of the U.S. nonproliferation efforts. The basic reason can be reduced to the fact of the essential discriminatory nature of the present system,[2] i.e. it appears that the nuclear "haves" are trying to prevent peaceful nuclear technology from falling into the hands of the nuclear "have-nots". While the proliferation risks will increase with the spread of sensitive technologies, the risks to world peace may increase at a greater rate if countries are not allowed the benefits of peaceful uses of nuclear power.

One author has advocated an international system for the sharing of nuclear technology with "real" (as opposed to token) participation on the part of those desiring a voice.[3] This system would avoid the current major power domination that currently exists in the IAEA. Among other things, this new international body would supervise and make available (1) the reprocessing of plutonium from reactors, (2) nuclear fuels, notably those based on plutonium and highly enriched uranium, and (3) more distantly, the

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[1]Wohlstetter, Nuclear Policies: Fuel Without the Bomb, p. xiv.

[2]Bloomfield, Arms Control and Security: Current Issues, p. 295.

[3]Ibid., p. 300.

uranium enrichment process.

Finally, it appears that the nonproliferation policies of the U.S. government may have served the interests of the U.S. nuclear industry in the past by protecting their market. No doubt these policies also had a beneficial effect in preventing the spread of nuclear weapons technology. At the present however, the policies are largely ineffective in attaining their goal, may even be counterproductive, and are generally opposed by the U.S. nuclear industry, U.S. allies, and third world countries. The existing policies are operating against the business efforts of the U.S. nuclear industry by restricting their ability to compete in the growing international nuclear market. They are also fostering the growth of competition from former customers.

A related and complicated issue is that of nuclear waste disposal examined in the next chapter. Since most of the concern is over the high-level and long-lived wastes, the study will focus on them. The waste disposal challenge is an integral part of the issues dealt with in the first two chapters in the sense that nuclear power will be stymied in its international growth by failure to provide safe and adequate long-term storage for the nuclear power plant waste by-products. Nuclear weapons proliferation could also be enhanced by failure to securely store spent fuel rods as well as reprocessed materials such as weapons-grade plutonium and concentrated uranium.

CHAPTER 3

THE WASTE DISPOSAL SITUATION

Makeup of Nuclear Waste

The most ubiquitous environmental challenge to the nuclear power industry is the problem of nuclear wastes with their requirements for long-term storage and disposal. Of the more than three hundred radioactive substances created as a result of fission in nuclear power plants, the environmental concern centers around only a handful, known as the "actinides".[1]

As an example of the very slow decay process, plutonium has a half-life of 24,600 years. The waste disposal challenges associated with nuclear power amount to million-year challenges for the actinides and thousand-year challenges for many of the remaining fission by-products, as illustrated in figure 3. These challenges of disposal have been increasingly publicized of late although they have been recognized since the dawn of the nuclear era.

The quantity of radioactive waste to be disposed of is not as great a challenge as the time during which it remains toxic to life. Recently it was pointed out

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[1]Gerald Garvey, Nuclear Power and Social Planning (Lexington, Mass.: D. C. Heath, 1977), pp. 42-43.

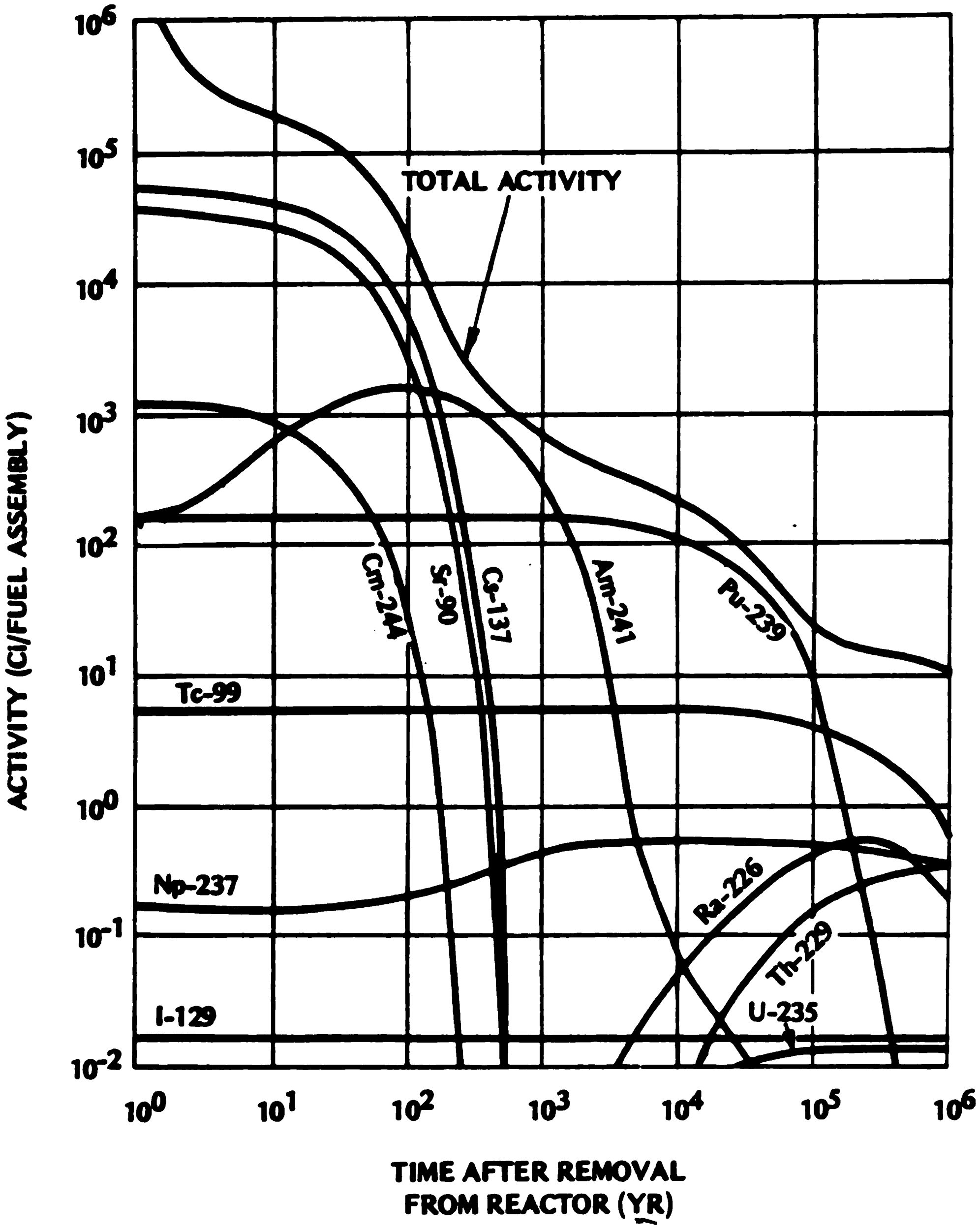

Fig. 3. **RADIOACTIVE DECAY OF PWR SPENT FUEL**

SOURCE: Office of Nuclear Waste Isolation, Battelle Project Management Division, The Disposal of Spent Nuclear Fuel (Springfield, Va.: National Technical Information Service, December 1979), p. 17.

that about five thousand metric tons of radioactive waste has been generated since the beginning of atomic power usage. This quantity was made to appear quite small in comparison to a similar quantity of environmentally persistent chemical wastes that are generated in a single year.[1]

Nuclear wastes may take various physical forms. The current Administration's policy of non-recycling of spent fuel dictates that plans be made for storage of un-reprocessed spent fuel. This form of waste contains large amounts of usable uranium and plutonium. If spent fuel were reprocessed, only the true wastes would need to be disposed of.[2] The location for long-term storage would not likely be different according to the form of the waste, but the encasement and mechanics of storage would.

Regarding the storage of spent fuel, it could be stored in the form of the complete fuel assembly, or it could be stored in the form of (1) full fuel elements, (2) fuel elements with end fittings removed, (3) fuel pins from the bundle intact, but separated, or (4) chopped

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[1]Thomas H. Maugh II, "Toxic Waste Disposal A Growing Problem", Science, 25 May 1979, p. 281.

[2]Atomic Energy of Canada, Public Affairs Dept., Nuclear Fuel Waste (Ottawa, Ontario: Atomic Energy of Canada, 1980).

fuel pins.[1] The various alternatives provide opportunities for reducing the storage package sizes which would tend to have more uniform thermal characteristics.

Although presently not the policy, the high-level radioactive wastes from nuclear power plants could be concentrated and reduced in volume considerably by the reprocessing cycle. By reprocessing, the uranium and plutonium could be extracted for manufacturing more fuel. There is about two hundred times more uranium and plutonium in spent fuel than in the equivalent high-level waste remaining after the reprocessing cycle (approximately 99.5 percent of all uranium and plutonium is removed in reprocessing).[2]

There are storage problems unique to storing both spent fuel and concentrated high-level waste. High-level waste is usually in the form of a borosilicate glass package. This package can contain the same amount of residual waste from approximately four to six packages containing complete fuel rod assemblies.[3] The reliability of glass as a medium for storage has been recently questioned however. Very intensive studies have been conducted that have shown

[1]Office of Nuclear Waste Isolation, Battelle Project Management Division, The Disposal of Spent Nuclear Fuel (Springfield, Va.: National Technical Information Service, December 1979), p. 16.

[2]Ibid., p. 26. [3]Ibid., p. 27.

glass unreliable in some cases.[1] The problem with glass has been breakdown under the particle bombardment from the wastes, and also the accompanying elevated temperatures. Also, as radioactive decay progresses, chemical reactions can occur which change the ability of the glass to contain the high-level wastes. However, while glass has not been seriously discounted, the suggestion has been made that the crystalline structure of ceramics provides a better storage medium, as opposed to non-crystalline glass.[2]

The problems of heating and damaging of the waste containers are generally less with spent fuel because of its lower concentration of the actinides. Although there are economies of size in the concentrated glass or ceramic form of storage, the concentration might have to be reduced to manage the heating effect. In such a case, the size advantage would be negated.

While not an argument for reprocessing as opposed to storage of spent fuel per se, there is a problem of fission product gas that must be dealt with either before or in the spent fuel repository. Processed high-level waste is free of this gas, although it would be possible

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[1]Richard A. Kerr, "Nuclear Waste Disposal: Alternative to Solidification in Glass Proposed", Science, 20 April 1979, pp. 289-91.

[2]Ibid.

to modify the preset form, composition, and geometry of the spent fuel to remove the fission product gas if necessary.[1]

While the United States seems to have adequate uranium resources for the foreseeable future, and as a partial result has chosen to not reprocess its spent fuel, this policy could change. Factors that could bring this about might be (1) increasing extraction and environmental costs in mining with regard to net energy gain,[2] (2) increased environmental constraints, (3) failure to implement the breeder reactor with consequent greater use of light water reactors than anticipated, (4) increased international demand for U.S. uranium fuel exports, and (5) change in U.S. Administration attitudes that might favor reprocessing.

If a decision were made at a future date to retrieve the stored spent fuel for reprocessing, in order to reclaim the uranium and plutonium, special provisions would have to be made in the initial storage process.[3]

There is another reason why retrievability is

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[1]Office of Nuclear Waste Isolation, Battelle Project Management Division, The Disposal of Spent Nuclear Fuel, p. 28.

[2]Resources For the Future, Energy in America's Future: The Choices Before Us (Baltimore: John Hopkins University Press, 1979), p. 355; and U.S., Department of Energy, Preliminary Safety and Environmental Information Document: Fuel Cycle Facilities, January 1980, 7:1-1 to 1-15.

[3]Office of Nuclear Waste Isolation, Battelle Project Management Division, The Disposal of Spent Nuclear Fuel, p. 20.

desirable. It must be kept in mind that serious plans are being made and research conducted for long-term storage of high-level wastes for the first time. Therefore since undoubtedly some mistakes will occur, new technologies developed, and better designs created along with better operational procedures, it would seem desirable to postpone any irreversible methods of storage.[1] If the option of retrievability for a period of years following emplacement is to be maintained, necessary steps would have to be taken in the areas of design of the repository, the waste emplacement, and monitoring systems making possible corrective actions if necessary.

Progression of the Nuclear Waste Issue

During the early years of atomic testing and development, mostly surrounding the Manhattan Project and development of the first atomic bombs, the radioactive wastes were generated almost exclusively as a result of government research. After World War II the Atomic Energy Agency was formed and civilian control began to take upon itself responsibility for greater proportions of the conduct and handling of the fuel cycle. After the completion of the first commercial nuclear power plant in 1957, the amount of nuclear waste slowly began to mount. It became

[1] U.S., Nuclear Regulatory Commission, Secy ED-177 - Advance Notice of Rulemaking on Technical Criteria for Regulating Geologic Disposal of High Level Radioactive Wastes, 10 CFR Part 60, 23 April 1980, p. 19.

increasingly clear that some method would have to be devised for dealing with both long and short-term disposal of radioactive wastes.

Efforts to store high-level radioactive wastes in the past have resulted in occasional breachments of storage vessels, as well as long distance migration of radioactive substances from underground burial sites, finally entering underground water. Seventy-five million gallons of high-level wastes had been stored in special storage tanks throughout the United States by April 1969. During the period of storage, there have been fifteen known leaks from the containers with tens of thousands of gallons leaking into the ground.[1]

The failure of past temporary methods of dealing with high-level waste disposal has precipitated much public concern, contributing to much of the current public opposition to nuclear power. Progression toward the development of effective long-term waste disposal methodologies are necessary however, even if there was not a single additional nuclear power plant constructed. The reason is the large amount of spent fuel elements which are being stored at nuclear reactor sites at the present time. The storage space is limited, and it is approaching the point where the spent fuel must be removed to a permanent disposal

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[1]Garvey, Nuclear Power and Social Planning, p. 43.

location in order for the plants to continue removing spent fuel rods at the time of refueling. This refueling occurs normally around one and a half years after initial loading.

In addition, military and government research is still generating quantities of high-level waste which must be adequately dealt with. However, depending on the growth of the nuclear power industry, the wastes from civilian power plants could assume much larger proportions compared to the military sources of the past.

In spite of the caution regarding projections of future growth in the U.S. nuclear power industry expressed in Energy: The Next Twenty Years, it was conceded that future growth seems likely.[1] An in depth study of all the ramifications of nuclear power by the Mitre Corporation concluded that "nuclear power is one of the options (for supplying electricity) that should be pursued."[2] James J. Duderstadt and Chihiro Kikuchi, engineers at the University of Michigan, in their new book stress that "the real choice is not whether to use nuclear power, but rather the balance between our dependence on nuclear power and coal to meet

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[1]Resources for the Future, Energy: The Next Twenty Years (Cambridge, Mass.: Ballinger Publishing, 1979), p. 423.

[2]Mitre Corporation, Nuclear Power Issues and Choices (Cambridge, Mass.: Ballinger Publishing, 1977), p. 4.

our future demand for electricity."[1] This same recognition that nuclear power will play a significant role in meeting the U.S. energy needs for at least the next twenty to thirty years was put forward very well in an extensive and long-term study by the National Academy of Sciences.[2]

It has been felt for a long time that the solution to long-term storage of radioactive wastes was to place them in underground salt formations. In 1970, the Atomic Energy Commission made a "tentative" selection of a salt formation near Lyons, Kansas for a disposal site.[3] Later it was found that public opposition was greater than anticipated. The implications of the Lyons, Kansas site selection by the Atomic Energy Commission seemed to be to the Lyons citizens that their town was "next to nowhere", and it would not matter if part of their township was made a radioactive "dumping ground." Various reasons were published for rejection of the site, however, the most credible one probably being that the integrity of the underground salt formation had already been breached by various holes drilled during oil exploration and other excavation activities.

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[1]James J. Duderstadt and Chihiro Kikuchi, Nuclear Power: Technology on Trial (Ann Arbor: University of Michigan Press, 1979), pp. 24-25.

[2]National Academy of Sciences, Committee on Nuclear and Alternative Energy Systems (CONAES), Energy in Transition: 1985-2010 (San Francisco: W. H. Freeman, 1979).

[3]U.S., Atomic Energy Commission, Annual Report to Congress of the Atomic Energy Commission for 1970, January 1971, p. 49.

The original tentative decision to store wastes at Lyons was based on a study called Project Salt Vault, carried out by the Oak Ridge National Laboratory from 1965 to 1967. It is now fifteen years since the beginning of that study and no such permanent site for storage has been prepared.

On November 15, 1978 however, Dr. John M. Deutch of the U.S. Department of Energy announced the Department's intention to go ahead with a long-term waste disposal site to be located in a salt bed near Carlsbad, New Mexico.[1] The site would be used for storage of high-level military-generated radioactive wastes, and the application for a storage license was planned to be submitted to the Nuclear Regulatory Commission by 1981. It was hoped that wastes could be first buried by 1985, and if the plan were accepted the costs would be around $400 million for excavation and construction. The costs for such a depository have doubtless increased since that time.

Currently there is a presidential directive to aggressively proceed with long and interim storage of high-level nuclear wastes which was given in the President's Message to Congress on February 12, 1980.[2] In part he said:

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[1]"N. M. A-Waste Burial Planned", <u>Facts on File</u>, 15 December 1978, p. 961.

[2]Presidential Message to the Congress, "Comprehensive Radioactive Waste Management Program", <u>Weekly Compilation of Presidential Documents</u>, 12 February 1980, Vol. 16, No. 7.

. . . for disposal of high-level radioactive waste, I am adopting an interim planning strategy focused on the use of mined geologic repositories capable of accepting both waste from reprocessing and unreprocessed commercial spent fuel. An interim strategy is needed since final decisions on many steps which need to be taken should be preceded by a full environmental review under the National Environmental Policy Act. In its search for suitable sites for high-level waste repositories, the Department of Energy has mounted an expanded and diversified program of geologic investigations that recognizes the importance of the interaction among geologic setting, repository host rock, waste form, and other engineered barriers on a site-specific basis. Immediate attention will focus on research and development and on locating and characterizing a number of potential repository sites in a variety of different geologic environments with diverse rock types. When four to five sites have been evaluated and found potentially suitable, one or more will be selected for development as a licensed, full-scale repository.

It is important to stress the following two points: First, because the suitability of a geologic disposal site can be verified only through detailed and time-consuming site-specific evaluations, actual sites and their geologic environments must be carefully examined. Second, the development of a repository will proceed in a careful, step-by-step manner. Experience and information gained in each phase will be reviewed and evaluated to determine if there is enough knowledge to proceed with the next stage of development. We should be ready to select the site for the first, full-scale repository by about 1985 and have it operational by the mid 1990's . . .

It does appear that definite steps are finally going to be taken to implement high-level waste storage. However, there are several methods of disposal possible.

The Most Promising Method of Disposal

The current trend is toward the use of mined geologic repositories.[1] There is an obvious need to store wastes in locations where any geologic changes take place over a very long period of time. The reason for this is that many of the fission products of nuclear reactors require at least a thousand years of storage for radioactive decay to render them harmless, while some of the actinides may require up to a million years for them to lose their ability to inflict radiation damage upon humans.

There are various locations that appear to have the geologic stability essential for such long-term storage. The geologic formations should be relatively isolated from circulating ground water; they should be able to contain the waste without losing their properties upon which the decision to store was based; they must be capable of being thoroughly technically analyzed; and it must be economically and technically feasible to construct a long-term waste disposal facility within it.[2]

Various mining techniques already available could generally be used in constructing a repository. However,

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[1]U.S., Department of Energy, Proposed Rulemaking on the Storage and Disposal of Nuclear Waste, 15 April 1980, p. II-28.

[2]Ibid.

there are some ways in which a repository differs from an ordinary mine:[1]

- -The objective is to bury material rather than to remove ore.
- -The radioactive wastes add thermal energy to the geologic formation.
- -The mine extraction ratios are much lower.

Figure 4 illustrates a model of a radioactive waste repository in a salt mine. Burying in salt is attractive for several reasons. One of the major concerns of waste disposal is having it inadvertently escape into ground water. The very existense of water-soluble salt beds testifies to the absence of circulating ground water. In addition, depending on whether spent fuel rods or concentrated glass or ceramic-enclosed high-level waste is deposited, if the heat generated was sufficient, the salt would slowly melt over the containers further isolating them from the environment. Of course this would complicate any efforts toward retrievability. That is a reason why this melting phenomenon would be most appropriate to solidified and concentrated high-level waste with the uranium and plutonium reprocessed.

Overall guidelines for disposing of the high-level wastes in a repository will now be discussed. First of all, the containment and isolation of the wastes will

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[1] Office of Nuclear Waste Isolation, Battelle Project Management Division, The Disposal of Spent Nuclear Fuel, p. 22.

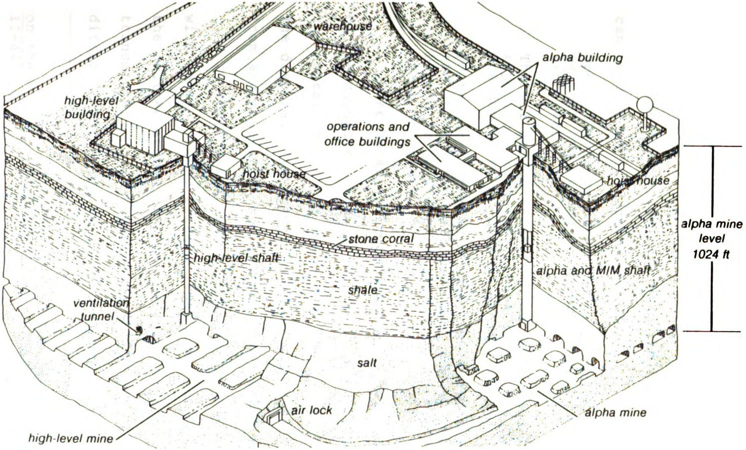

Fig. 4 Model of a national radioactive waste repository in a salt mine

SOURCE: U.S., Atomic Energy Commission, Radioactive Wastes, by Charles H. Fox, (Oak Ridge, Tenn.: USAEC Division of Technical Information Extension, 1969).

be achieved by placing the packaged waste hundreds of meters below the ground surface. After placement, the chances of their re-entering the biosphere are very low, the only possibility receiving much consideration being via ground water.

The time of dealing with the high-level wastes can be divided into three periods:[1]

> Operational period -- the time when the repository is open and during which waste can be emplaced or retrieved.
>
> Thermal period -- the period after closure of the repository when radioactive levels and heat production are dominated by fission product decay.
>
> Post-thermal period -- the time following decay of the short-lived radionuclides, during which the radiological hazard is dominated by the decay of actinides and their daughters.

The mined geologic disposal system is composed of the subsystems made up of the natural site itself, the container for the waste, and the constructed repository. The disposal site itself would be sufficiently removed from any population centers to insure added protection.

The natural system includes natural barriers that will serve to keep radionuclides from reaching man for the desired amount of time, keep the waste in place, limit transmigration via underground water, and prevent or make difficult intrusion by human trespass. There are several

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[1]U.S., Department of Energy, Proposed Rulemaking on the Storage and Disposal of Nuclear Waste, pp. II-43 and II-44.

factors which could affect the natural system, and fall under the broad categories of geologic, tectonic, hydrologic, and resource factors.

Under the category of geologic factors one must consider (among others) the structure and thermal properties of the system. The rock types currently being considered by the U.S. Department of Energy for storage of high-level wastes are salt, granite, shale, tuff, and basalt.[1] There are several locations where deposits of these rock types appear suitable for a repository.

Regarding tectonic factors, of greatest consequence might be faulting, seismic activity, uplift, or natural stress states. The possible repository sites are being investigated with a view toward ensuring low hazards associated with these tectonic factors. These factors, while seeming insignificant in the short term, must be carefully considered when planning a repository that must retain its integrity of purpose for tens to hundreds of thousands of years. In terms of the longest time that might be needed to store high-level wastes, it does appear that any discussion of long-term storage must be viewed in a very real sense as "interim" storage.

Although the necessity of keeping high-level wastes isolated from ground water has already been mentioned,

[1]Ibid., p. II-72.

it should be stressed that "knowledge of ground water hydrology is perhaps the most important requirement for understanding the long-term behavior of a mined geologic repository."[1] Therefore, on the basis of all known acceptable hydrologic criteria, numerous sites in the United States have been evaluated and found satisfactory for waste repositories.

Regarding resource factors, a major consideration is the possibility that mineral or energy resources in the proximity of the repository might become economically extractable in future years. While the repository would initially be located where such a possibility would be minimal, it is difficult to determine what effects future technologies and demand might have on the economies of extraction. Again, the repository site must be selected to minimize these possibilities.

Alternative Disposal Methods

Various research groups throughout the United States have conducted studies on several locations for permanent storage of high-level radioactive wastes. Their efforts received a boost from the conclusion of President Carter's interagency task force, i.e. that salt beds may not be the best location for storage. One interesting suggestion for long-term storage is to use various locations

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[1]Ibid., p. II-76.

off the coast where a particularly suitable red clay is found on the ocean floor. This clay has certain chemical and physical properties that would prevent radioactive wastes from entering the ocean waters when the wastes are buried only slightly beneath the surface of the ocean floor. The mechanics of the process would be to store wastes in bullet-shaped canisters that would be dropped from the water's surface through a chute of some kind with the canisters hitting the clay hard enough to bury themselves perhaps thirty meters under the ocean floor. The clay would flow in behind the canister, sealing it from exposure to the ocean water.[1]

The foregoing suggestion for subseabed disposal was predicated upon high-level wastes being concentrated after being reprocessed. Much of the mechanics of the process would doubtless not be suitable for disposing of entire fuel rod assemblies. The U.S. Department of Energy is currently more interested in deep sea burial in remote regions of the ocean. At the most desirable regions, a thick deposit of sediment has formed over very long periods of time. It appears that the sediments are the result of the collection of wind-blown fine dusts from the continents and other sources that have filtered down to the ocean floor over time. The sediments range

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[1]Richard A. Kerr, "Geologic Disposal of Nuclear Wastes: Salt's Lead is Challenged", Science, 11 May 1979, pp. 603-606.

from tens of meters up to a kilometer in depth and the sedimentation process is still continuing. It would be feasible for the waste containers to be slowly covered by the sedimentation and protected from the water environment and the very minimal aquatic life in those regions.

Another method of possible disposal is called the "very deep hole" disposal concept. In this method, a hole would be drilled between ten thousand and fifty thousand feet. The packaged spent fuel would be placed deep within the earth. After drilling the holes and the wastes put in place, the hole would be sealed and monitored as in the mined geologic disposal method.

There are some concerns with this method however. It is very difficult to determine geologic effects at such great depths. Neither remote sensing or manned examination is possible. Retrievability would be impossible with such a method and the tolerances required in drilling the hole required for such storage may be technologically impossible at present. The placing of the waste containers would be difficult because of inadequate cable technology, and general alignment would also pose problems.

The rock melting concept as a means for disposing of wastes has its problems also. The basic idea is to place the waste deep underground in such a concentrated fashion that the radioactive heat of decay would melt the rock surrounding it. Over a period of time the rock would cool and solidify, thus trapping the radioactive material in a relatively insoluble mass, deep underground. The problems center around the inadequacy of testing and observing the geologic strata at the proposed depth of ten thousand feet or so, both before and after storage. Of course retrieval would be impossible and only very concentrated high-level wastes would be suitable for such a disposal method.

Disposal of high-level wastes by mined geologic disposal on an island has been given some consideration because of the added remoteness it would afford from socio-economic activity. Many small islands have no mineral or agricultural value, being created by volcanic activity thousands of years earlier. Many islands, because of their location would be free from the possibility of advancing ice caps or severe climactic changes. Nonetheless there is some question about the interaction between the water environment of the island and the ocean body surrounding it. Such a selection could have international repercussions.

Disposal in the ice sheets of the polar regions has been proposed. The process would involve drilling relatively shallow holes into the ice near the center of the polar caps. The waste containers would be deposited and covered with water and allowed to freeze over. The heat from the waste containers would melt the ice around them and they would slowly descend to the bed rock under the ice sheet. While it is known that the center of the ice sheets slowly migrate outward and are eventually broken off as icebergs, the length of time for this transmigration should be sufficient to allow the wastes to decay to a harmless level.

Deep well injection disposal would utilize technology that is well developed and already being used for low-level radioactive liquids in the Soviet Union. The spent fuel would be mechanically or chemically processed to produce a liquid or cement slurry. This slurry would be injected under tremendous pressure into a porous layer such as sandstone that lies between an upper and lower layer of shale. Between the shale layers the waste would be effectively isolated in perpetuity.

Transmutation, while not a disposal method, should be mentioned because it could reduce what perhaps might be a million-year disposal problem to a thousand-year one.[1] It has been suggested that this could be done by reentering the actinides into the fuel cycle by putting them back into the cladding of fuel elements. In the reactor, the actinides would be transmuted by neutron bombardment into shorter lived by-products that would require storage for less than one thousand years.

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[1]Garvey, Nuclear Power and Social Planning, p. 44.

Environmental Considerations

The U.S. Department of Energy published a five volume study in May 1980, regarding the effect upon the environment of the current U.S. spent fuel policy.[1] This study deals with the environmental impacts from radioactive wastes in the following circumstances: (1) nuclear power facilities, (2) independent spent fuel storage facilities, (3) during transportation of spent fuel, (4) geologic repository (assumed to be in a salt formation), (5) during fuel reprocessing (if resumed) and fabrication, and (6) at facility decommissioning.

The study states that each phase of encounter with high-level wastes (as well as low-level) will result in some small amounts of radioactivity being released to the environment. Also it was pointed out that the work force would be exposed to limited amounts of radiation and would experience occupational accidents comparable to the rate of those involved in similar type work.

The effects of radiation doses on populations was looked at in terms of the population living within fifty miles of the above facilities and activities. The effects were also examined on the United States population and the world population. The study is based on an assumption

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[1]U.S., Department of Energy, Final Environmental Impact Statement: U.S. Spent Fuel Policy, 5 Vols., May 1980.

of 1985 start-up of storage facilities and also examined the effects of delaying start-up until the year 2010. The doses of radiation from the above facilities and activities range from about 1,000 man-rem to the world population if disposition begins in 1985 as opposed to 85,000 man-rem if fuel disposition is delayed until the year 2010.[1] About half of the dosage is received by people living within fifty miles of the facility. For the sake of perspective, natural radiation doses in the same period to the world population is calculated to be about 200 X 10^9 man-rem.

For the alternatives which assume disposal or storage facility startup by 1985, the total health effects measured in malignancies and genetic effects in the world population range from two to thirty-two. For contrast, the worldwide natural radiation dose during this same period would result in 120 million health effects. If the disposal facility start-up is delayed until the year 2010, the total health effects in the world population range from thirty-four to one hundred and thirteen. Worldwide natural radiation induced health effects during the same period will be about 200 million.[2] It is important to note that while the total numbers are small, it does appear that there are some marginal reasons for early implementation

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[1]Ibid., Vol. 1, Executive Summary, p. 16.

[2]Ibid., p. 20.

of long-term waste disposal facilities.

The environmental risks from major abnormal events and accidents such as tornadoes or criticality were determined to be less than one rem per man. Also transportation and storage risks were evaluated and included sabotage scenarios. It should be kept in mind that the clandestine diversion of high-level radioactive wastes would not be attractive to most people because of the inherent risk that could result from improper handling, and the knowledge necessary for diverting it to any directed purpose.

There are additional environmental factors to be evaluated in the mined geologic disposal of high-level radioactive wastes. Some of them will be discussed.

The land used at the waste disposal facility could be degraded to a degree by the activities of transportation and excavation during the disposal process. However, after decommissioning the site, the land could be returned to its original or an improved condition.

During construction and operation of the facility, a certain amount of water would be required for operations, and therefore sites would be selected where the impact on the local water supply would be acceptable. The nickel and chromium used in the making of stainless steel which is used in the construction of the waste storage containers are mostly imported. This is a constraint that is not expected to be significant. The energy required for construction and operation fall within the range of any large industrial activity, and pose no problem. The environmental impacts of noise, non-radioactive pollutant discharges into the air and water during construction and operation, waste rock storage and disposal, and aesthetics are all environmental factors which must be taken into consideration and mitigated wherever possible.

It has been determined that operational phase radiation doses to the population would amount to 0.1 percent of the dose that the same population would receive from naturally occurring sources. The long-term impacts of a mined geologic repository focus mostly on the effects of possible release of radionuclides into the biosphere. The facility will be designed to minimize any such release, and the effects, should any such release occur, would be difficult to measure because of their small magnitude.

There could be a minimal change in the surface temperature of the ground (less than one degree Fahrenheit) from the heat generated by the decaying buried isotopes. It is not felt this would adversely affect the plant or animal biota. Should any uplift of the ground occur, it would be minimal and have little environmental impact. The transportation impacts would center around the established rail and highway systems. Some additional land would be needed for transportation routes to the site but should be no greater than that of any comparable industrial project.

Since there is some public concern over the transportation of high-level wastes to central disposal facilities, it should be stressed that spent fuel shipping containers are carefully designed to ensure a substantial margin of safety. The Atomic Energy Commission was developing containers able to withstand derailings at normal speeds, and canisters that could absorb the impact of being dropped from considerable heights onto solid concrete without rupture.

There is great public debate over the shipment of radioactive materials, and very occasionally a mishap involving some low-level radiation materials occurs. Unfortunately the distinction is not often made between the million or so shipments of low-level radioactive materials which occur on a routine basis each year, and the much more seldom shipments of high-level radioactive materials.[1]

The amount of land dedicated to the construction of long-term waste disposal facilities should be brought into perspective. However the following analysis, while useful, applies only to the waste left to be stored after reprocessing, which is currently not being done. A typical power plant produces approximately the equivalent of ten canisters of high level waste each year. If these canisters were stored in rows, ten meters apart, about ten square miles would be needed to accommodate all of the radioactive

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[1]Duderstadt and Kikuchi, Nuclear Power: Technology on Trial, p. 107.

wastes produced over the next thousand years, at the current rate of production.[1] In addition, the cost of waste disposal and plant decommissioning together amounts to only about 0.7 mills per kilowatt-hour generated over the life of a nuclear plant, a nominal expense considering the revenue generated by the plant over the useful operating time of some thirty to forty years.[2]

Institutional Considerations

Governor Edmund Brown of California once made as astute observation when he said that nuclear power was "fundamentally a political issue." The social and political aspects of dealing with long-term waste disposal must be managed in a variety of institutional settings. There has been much study on the proper Nuclear Regulatory Commission regulations and guidelines for such an activity. Several voluminous environmental impact studies have been undertaken and completed that go into great detail in assessing the effects of long-term waste management by various means.

The licensing of water basin storage for spent fuel, both at nuclear power plants and reprocessing plants, has been going on for nearly twenty years. The safety parameters for such storage could be extended to mined geologic disposal sites with less stringent guidelines

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[1]Ibid., p. 113. [2]Ibid.

appropriate to the reduced risk. The reduced risk is of course due to the lack of proximity to an operating reactor or a reprocessing facility. The knowledge already exists for meeting the safety parameters prescribed for on-site storage of spent fuel presently in effect.

Because of the Atomic Energy Commission's unfavorable experience with the citizens of Lyons, Kansas in their first attempt at establishing a mined geologic disposal facility, and undoubtedly tensions in other states where tentative sites were being investigated, the Department of Energy plans to follow a program of close cooperation with states that have likely sites for mined geologic disposal facilities. Meetings with representatives of the governors' offices will be held, and technical as well as non-technical discussions carried on. While nothing is said about any state's right to reject a proposed location of a mined geologic disposal facility, The President said in his statement on February 12, 1980 that " Our relationship with the states will be based on the principle of consultation and concurrence . . . ."[1]

Both Congress and the Administration have supported legislation that lays the groundwork for the establishment of mined geologic disposal facilities. The Department

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[1]Presidential Message to the Congress, "Comprehensive Radioactive Waste Management Program", Weekly Compilation of Presidential Documents, 12 February 1980, Vol. 16, No. 7.

of Energy has also made extensive environmental studies and gathered data in order to comply with the National Environmental Policy Act of 1969. The Department of Energy approach to satisfying environmental procedures in a rapid manner will be to "eliminate repetitive discussion."

In order to insure state and federal cooperation, President Carter established a "State Planning Council". The Council is composed of fifteen governors or other elected officials, and four from the Executive departments and agencies. In addition to the frequent consultation with the states, there will be opportunity for the public to review the proceedings.

Specific supporting statements for mined geologic disposal have come from both the Nuclear Regulatory Commission and the Environmental Protection Agency. The NRC stated[1]:

> We agree that a repository should be developed and tested as soon as possible.

Similarly, EPA stated[2]:

> We agree with the Department that the option selected for implementation appears to be the best of those

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[1]J.B. Martin, letter dated October 25, 1979 to C. Heath (DOE), "Comments on draft EIS (DOE/EIS-0046-D) by the NRC staff" as cited in U.S., Department of Energy, Proposed Rulemaking on the Storage and Disposal of Nuclear Waste, 15 April 1980, p. III-33.

[2]W. N. Hedeman, Jr., letter dated September 27, 1979, to D. Heath (DOE), "Comments on draft EIS (DOE/EIS-0046-D) by EPA" as cited in Department of Energy, Proposed Rulemaking on the Storage and Disposal of Nuclear Waste, p. III-33.

> considered . . . . It is also unlikely that there would be any viable alternative available in the near future. For this reason we believe DOE's program should be vigorously pursued.

In summary, the actinides, because of their very long half-lives and extreme toxicity, must be isolated virtually permanently from the environment. The current professional leaning toward mined geologic disposal over other alternatives comes at the culmination of about thirty years of research on this matter. The environmental considerations seem to have been thoroughly investigated, and the environmental impact of not proceeding with mined geologic disposal facilities may outweigh the impact from proceeding, i.e. in terms of radiation effects upon the population.

It seems that particularly burdensome and lengthy proceedings have accompanied the nuclear power industry growth and associated activities in years past. Perhaps because of past experience there seems to be emerging evidence of a well organized program and commitment to dealing with the high-level waste disposal challenge in a more expeditious manner than heretofore.

One of the most fascinating psychological phenomena of this age is how the public perceives and reacts to the presence of nuclear power technology. The fact that the international market for nuclear power plants is growing, supports the observation that a society makes tradeoffs when deciding to accept or reject a technology and its associated externalities, e.g. the French and Japanese acceptance in return for increased national security and energy independence.

It is also apparent that France is less concerned with proliferation than the United States - as it exports nuclear power plants and technology in order to keep its own reactor manufacturing industry healthy. The same willingness to live in less than a risk-free world is demonstrated by the forthright manner in which France and other European countries are dealing with nuclear wastes. These sociotechnical aspects of nuclear power are examined in the next chapter.

CHAPTER 4

NUCLEAR POWER: A SOCIOTECHNICAL EVALUATION

History of Public Attitude

The public attitude toward nuclear power prior to 1955 was generally favorable. The public concern that did exist about nuclear power was generally born out of knowledge of the devastating effects of the two atomic bombs used on Japan near the end of World War II. Following the war, the dominant concern was with the effects of atomic bomb and weapons development.

During the period between 1955 and 1961 however, there was increasing journalistic interest in the dangers of nuclear power. Various minor accidents had occurred in test reactors in the United States and abroad. The U.S. Atomic Energy Commission (AEC) issued the first major safety report called WASH-740[1] citing the possible catastrophic consequences of a major reactor accident.

During this period however, the nuclear industry was gearing up for rapid growth. While there was only one plant in operation prior to 1961, there were fourteen in operation with another thirty-nine under construction

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[1] U.S., Atomic Energy Commission, Theoretical Possibilities and Consequences of Major Accidents in Large Nuclear Power Plants, 1957.

by 1968. Moreover, the size of the newer reactor was ten-fold that of the early ones.

The first public concerns focused on the thermal impacts of the cooling waters from the plants being released into streams. In 1970, the Calvert Cliffs decision[1] forced the AEC to include environmental impacts in its licensing decisions. This institutionalization of environmental protection stimulated a shift in public focus from the environment to the safety issues during the 1970's.

The question of risk has been an issue from the very beginning for the nuclear power industry. It was even felt that the risk was either so high or so uncertain that the nuclear power industry might not develop because of the cost of adequate insurance coverage. In view of this problem, Congress passed the Price-Anderson Act of 1957 setting the limits of liability in an accident to $560 million.

In an effort to determine what the actual risks were for nuclear power, the AEC contracted in mid-1972 for a multi-million dollar study which was carried out by Norman Rasmussen, Professor of Nuclear Engineering at the Massachusetts Institute of Technology, and was coded WASH-1400, or more informally, the "Rasmussen Report".[2]

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[1]Calvert Cliffs Coordinating Committee v. U.S. Atomic Energy Commission, 449 F. 2d 1109 (D.C. Cir. 1971).

[2]U.S., Atomic Energy Commission, Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants, August 1974.

Professor Rasmussen allayed the fears of the public somewhat by comparing the chances of death caused by a nuclear accident to those of being killed, for example, in an auto wreck, an airplane crash, by drowning, or in a fire. He concluded that the chances of a thousand people being killed by a nuclear accident were considerably less than the chances of the same number being killed by a meteor crash.[1] The concern for safety resumed later however, in spite of various reassurances by the AEC. In 1978, the NRC published the conclusions of its Risk Assessment Review Group, which was appointed in 1977 to evaluate the Rasmussen Report. The group was to: (1) determine the value of WASH-1400, (2) evaluate the views of Rasmussen's peers in the industry, (3) study the methodology used by Rasmussen, and (4) recommend whether or not the report should be used as a basis for decisions in the reactor licensing process.[2] To make a long story short, they found some fault with the report, basically in the fact that the methods to evaluate risk were not as reliable as they were given credit for.

The findings of the NRC review group must have aggravated the uneasiness that many electric utility companies already felt with regard to the growing uncertainties

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[1]Gerald Garvey, Nuclear Power and Social Planning, (Lexington, Mass.: D. C. Heath, 1977), p. 41.

[2]U.S., Nuclear Regulatory Commission, Annual Report 1978, 14 February 1979, p. 213.

of nuclear power, especially the uncertainty about what the future commitment of the Federal government might be. In a report on the review group's findings in an early 1979 issue of Public Utilities Fortnightly, [1] the nuclear power industry seemed to be very sensitive to the "winds of change".

No doubt they were glad to find out a month later that in a total of 119 NRC decisions based to some degree on the Rasmussen Report, only one required reviewing under the new guidelines established. The reason given for this was that the Rasmussen Report was not a major basis for the decisions made by the regulatory body to issue construction permits and operating licenses.[2]

Perhaps more important than the actual risks of nuclear power is the way risks are perceived by the public. It is a psychological fact that people tend to fear that which they do not understand. The AEC and the utility industry, being aware of this psychological principle, have exerted great effort toward making the public more informed regarding the operation of nuclear power plants. In 1969, the AEC concluded that "more effort must be devoted to communications between the nuclear proponent

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[1] "Nuclear Agency Becomes Critical of Rasmussen Report", Public Utilities Fortnightly, 15 February 1979, pp. 31-32.

[2] "NRC Review Affirms Licensed Nuclear Facilities' Safety", Public Utilities Fortnightly, 15 March 1979, p. 30.

and the man-on-the-street with answers stated in simple everyday language".[1]

This approach to public skepticism was correct according to a 1976 Gallup Poll which determined that of the persons interviewed, forty-five percent would object to a nuclear plant being built near their home, and forty-two would not object. Yet of those persons surveyed who had not followed the ongoing discussions in the media regarding nuclear safety, seventy-one percent opposed the building of a plant near their home.[2]

The conclusions that can be derived from the Gallup Polls regarding how to best assuage public opposition to nuclear power are ambiguous however. The nuclear power industry and the AEC for years have attempted to assure the public of a very low risk factor with nuclear power, and attempted to allay their fears by various public relations efforts. Yet the psychological principle seems to have failed them because a Gallup Poll in 1956 indicated only twenty percent of the people surveyed were afraid to have

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[1]U.S., Atomic Energy Commission, Annual Report of the Atomic Energy Commission for 1969, January 1970, p. 2.

[2]George H. Gallup, The Gallup Poll: Public Opinion 1972-1977, 2 vols. (Wilmington, Del.: Scholarly Resources, 1978), 2:798.

a nuclear power plant in their community.[1] while in 1976, after twenty years of public relations efforts, the percentage had more than doubled to forty-five percent.[2]

In 1979, the industry is still trying to "educate" the public however, and the public is still resisting atomic power. At the Edison Centennial Symposium in San Francisco in April 1979, some of the speakers seem to have descried anew a need for public education with regard to the science of nuclear power, and deplored what was referred to as "scientific illiteracy".[3]

The perspectives with which one can view nuclear risk are numerous. In 1969, the AEC proudly announced that for the third consecutive year, refunds had been given to various holders of nuclear liability commercial insurance policies because of the high safety record achieved.[4] In 1973, the AEC again proudly announced that in the sixteen years of the nuclear power industry, with 180 power-reactor years of operating experience, there was not a single public radiation induced injury. They went on to repeat

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[1]George H. Gallup, The Gallup Poll: Public Opinion 1935-1971, 3 vols. (New York: Random House, 1972), 2:1400-1401.

[2]Gallup, The Gallup Poll: Public Opinion 1972-1977, 2:798.

[3]Richard L. Meehan, "Nuclear Safety: Is Scientific Literacy the Answer?", Science, 11 May 1979, p. 571.

[4]Atomic Energy Commission, Annual Report to Congress of the Atomic Energy Commission for 1969, pp. 14-15.

the comment of the National Safety Council calling the record "nothing short of extraordinary".[1]

By 1978 however, the tenor of the Annual Report had changed. The emphasis in 1978 was on the improvement of reactor safety, in accordance with an amendment to the Energy Reorganization Act of 1974 which directed the NRC to "develop a long-term plan for projects for the development of new or improved safety systems for nuclear power plants".[2]

New appreciation for public safety is indicated by the fact that the designer of five east-coast nuclear power plants brought to the attention of the NRC a computer program error that made their derivations regarding safety against earthquakes invalid.[3] This did not mean that the plants were unsafe but rather meant that they did not know what the built-in safety factor was. Since it was an unknown factor that could affect public safety, the NRC ordered the plants shut down while the safety factor was re-calculated.

In addition, following the Three Mile Island event involving a Babcock-and-Wilcox-built reactor and primary

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[1]U.S., Atomic Energy Commission, 1973 Annual Report to Congress, 2 vols., 31 January 1974, 1:37.

[2]U.S., Nuclear Regulatory Commission, Annual Report 1978, 14 February 1979, p. 215.

[3]"Life: An Atom-Powered Shutdown", Time, 26 March 1979, p. 55.

cooling system, all of the remaining Babcock and Wilcox installations throughout the country were shut down (or encouraged to remain shut down if they were currently being re-fueled) until a thorough safety study could be conducted on each one of them. The total generating capacity of these two shut-down groups was 12,256 Mw, or twenty-three percent of all installed nuclear capacity.

However, the public attitude toward the NRC and the nuclear power industry is something less than appreciative. Even though there has never been a single life lost from a major nuclear accident, after the Three Mile Island event the public seemed to earnestly look for opportunities to vehemently criticize both the industry personnel and the technology.

During a "CBS Reports" special program following the Three Mile Island event, it was brought out that 2,835 incidents had occurred in 1978 that were considered violations of NRC rules.[1] Of course almost none of these offenses could be considered threats to public health or safety, but that fact seemed to be irrelevant to the television correspondent.

The reliability of mechanical and electrical devices was also a focal point in an article appearing in Science magazine. Four mechanical failures were listed: (1) spare

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[1]CBS, "CBS Reports", 1 May 1979.

auxiliary feedwater pump, (2) relief valve in the primary coolant loop, (3) water level indicator, and (4) an automatic system designed to contain radioactive leaks.[1]

It appeared that nuclear power had come full circle. A form of power that was to be very competitive with other energy forms had become so unpredictable in terms of capital, time, and trouble that many utilities were developing serious reservations about it.[2]

However it is surprising how resilient public attitude has been toward acceptance of nuclear power following Three Mile Island. In March of 1975 a Harris Poll[3] showed supporters of nuclear power outnumbering those who opposed it by three to one. Between April 1979 and January 1980, more than forty publicly available polls were conducted by leading pollsters, asking wide ranges of people, both state and national, their opinions about the accident and about nuclear power in general. Taken together, a reasonably clear picture emerges of the public's reaction to the accident.

The public generally regarded the accident as

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[1]Eliot Marshall, "A Preliminary Report of Three Mile Island, Science, 20 April 1979, pp. 280-81.

[2]Morris K. Udall, "Nuclear Power: On the Razor's Edge", Public Utilities Fortnightly, 24 May 1979, pp. 13-15.

[3]Cited in "Public Opinion and Nuclear Power Before and After Three Mile Island", Resources for the Future, Resources (Washington, D.C.: Resources for the Future, January-April issue), p. 5.

something that could have been avoided if better operational precautions had been taken.[1] However, one out of four felt that the danger of the accident had been greatly exaggerated by the press.

A most interesting fact arising from analyzing all the polls is that only moderate increases in opposition to nuclear power came about as a result of Three Mile Island.[2] Shortly after the accident, a previous twenty-six percent gap between those who favored and those who opposed building more nuclear power plants narrowed to a one percent difference. However, by August of 1979 the gap had again widened to nineteen percent more in favor than opposing. This trend has been erratic however, and as of January 1980, the gap in favor of nuclear power was twelve percent.

Surprising to many in the anti-nuclear movement, there was only a slight increase in sympathy with them. What appears to have occurred (and still seems to be the case) was an increased polarization of views. There are a few more hard-core proponents for nuclear power than there are those favoring complete shutdown. The simple matter is that despite Three Mile Island, many people believe nuclear power is needed and still believe that nuclear power is not unsafe or can be made safe. In a Rocky Mountain regional poll, seventy percent of the

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[1] Ibid., p. 6. [2] Ibid.

respondents said that they thought "the safety systems for nuclear power plants can be perfected enough to prevent accidents such as the one that occurred in Pennsylvania from happening again".[1]

The net result of Three Mile Island and subsequent controversy seems to have missed much of the potential benefit, i.e. there is no doubt that public awareness of the fact that there was a nuclear power debate was enhanced, but there is little or no indication that the understanding of the nuclear power process of generating electricity was changed in the least.

The Total Social Cost of Nuclear Power

One of the most recent and comprehensive studies completed on the social costs of coal and nuclear power was done at the University of Chicago where work was initiated under a grant from the National Science Foundation. Their methodology is set forth is their summary section:[2]

> A method is given - and applied - to determine the optimum mix of fossil-fueled and nuclear-fueled electric power generating plants, for the United States, for the next thirty years. The criterion of judgement is the total social cost, including both the apparent or 'internalized' costs and the hidden or 'externalized' costs. The method involves making estimates of as many of the factors as possible that contribute to the costs, finding the total cost implied by these

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[1]Ibid., p. 7.

[2]Linda Gaines and others, TOSCA: The Total Social Cost of Coal and Nuclear Power (Cambridge: Ballinger Publishing, 1979), p. 1.

estimates, and then varying the estimates widely to determine how sensitive the choice of mix is to the estimates.

The factors that were considered and varied in the study were as follows:[1]

- Demand, as a function of time
- Initial capital costs, including carrying charges
- Operating and maintenance costs, apart from fuels
- Fuel costs
- Research and development including advanced system costs
- Property damage from pollution
- Heat dissipation
- Health effects of pollution
- Safety of normal operations
- Spent fuel storage
- Large accidents
- Terrorism, sabotage, and diversion
- Discount rate of all factors except human life
- Discount rate of human life

The costs were all computed for scenarios that are all coal, seventy-five percent coal, an equal mixture of coal and nuclear, seventy-five percent nuclear, and all nuclear. The approach had its roots in the approach of Pigou, who built a theory of public expenditure on the idea that "public" choices - choices made by governments - should provide maximum social benefits for a given total social cost.[2]

The analysis deals only with conventional light water reactors, of the boiling-water or pressurized-water

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[1] Ibid., pp. 2-3.

[2] A. C. Pigou, A Study in Public Finance, 3rd ed. (London: MacMillan & Co., 1947), Part I, Chap. V, as cited in Gaines, TOSCA: The Total Social Cost of Coal and Nuclear Power, p. 6.

types. The analysis seemed to be unbiased and rather comprehensive. For example, it is often mentioned that a major cost factor not taken into consideration by nuclear utilities is the research and development monies expended by the taxpayer through the Federal government. This was factored in.

Human health and safety costs were calculated based upon the criteria of willingness-to-pay (e.g. for insurance), discounted future earnings, and payments for risk either taken or avoided. In the calculations, $1 million was used as the value of any single life.[1]

Regarding the costs of accidents, it first was necessary to determine the probability of an accident. Since the decision of the Nuclear Regulatory Commission to decline using the risk estimates of WASH-1400, and in view of the fact that no subsequent substantial risk assessment has been made, the group had to improvise. They decided to assume that the risk assessment in WASH-1400 was greatly in error - too low by a factor of one thousand.[2] Taking this much higher risk factor, they completed the cost calculations.

Based on the most adverse assumption concerning nuclear power, i.e. that no new technology would be

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[1]Gaines, TOSCA: The Total Social Cost of Coal and Nuclear Power, p. 21.

[2]Ibid., p. 102.

introduced during the study period, the cost of coal and nuclear-generated electricity over the next thirty years was as follows:[1]

- All coal	$657 billion
- 1/4 nuclear	$645 billion
- 1/2 nuclear	$635 billion
- 3/4 nuclear	$624 billion
- All nuclear	$613 billion

These calculations were also based on an assumption of no increase in fuel costs for either coal or uranium. However, undoubtedly both will increase, and the increase will affect the coal generation of power to a much greater extent because of its larger percentage of total cost relative to capital investment. If both coal and uranium costs increased at equal rates, there would be a savings of $135 billion by going all nuclear over the next thirty years,[2] as opposed to the $34 billion shown above with stable costs for both types of fuel.

Many other analyses have been conducted to determine the total social costs of nuclear and coal power. While no dollar value was affixed to the projections, the National Academy of Sciences reported that the estimated annual fatalities from the operation of a standard 1,000 Mw power plant could range up to 120 for a coal plant and

[1]Ibid., p. 85.

[2]Ibid.

and only 0.9 for a nuclear plant.[1]

Another more comprehensive study was put forth by Dr. Herbert Inhaber of the Atomic Energy Control Board of Canada.[2] What he attempted to show was that all forms of power generation, even the most seemingly benign, (e.g. solar, windmills, etc.) do involve transportation, manufacturing, assembling and maintenance risks that must be considered. While some of his conclusions have been subsequently criticized and then addressed again by Inhaber, it is worthwhile that such comparisons be generated.

It is also a regrettable failure on the part of the U.S. government that there is apparently no federal agency charged with preparing and publicizing hazard comparisons for different energy forms, on a continuing basis. Without such data, the public falls prey to the only basis of decision making (for example in the nuclear power issue), namely, sensationalized news media and perhaps emotional reaction to it.

Numerous persons have been killed in gas fires

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[1]National Academy of Sciences, Risks Associated With Nuclear Power: A Critical Review of the Literature, 1979, Summary and Synthesis chaps., as cited in David Bodansky, "Alternative Choices for Future Sources of Electricity Generation", address prepared for the Governing Board Seminar, American Public Power Association 1979 National Conference, Seattle, 15 June 1979.

[2]Herbert Inhaber, "Risk With Energy from Conventional and Non-conventional Sources", Science, 23 February 1979.

and explosions, and there have been many deaths and injuries in the mining and shipping of coal. Yet no one has asked for a moratorium on the use of natural gas or coal.

In spite of the fear of radiation-induced health effects both during and after Three Mile Island, a preliminary assessment of the radiation effects on the approximately two million people residing within fifty miles of the Three Mile Island nuclear station resulting from the accident of March 28, 1979 is as follows:[1]

> The projected number of excess fatal cancers due to the accident that could occur over the remaining lifetime of the population within fifty miles is approximately one. Had the accident not occurred, the number of fatal cancers that would be normally expected in a population of this size over its remaining lifetime is estimated to be 325,000. The projected total number of excess health effects, including all cases of cancer (fatal and non-fatal) and genetic ill health to all future generations, is approximately two.

Since the "CONAES Report"[2] and the Resources for the Future study, Energy: The Next Twenty Years[3] stress predominant dependence on coal and nuclear power for electricity generation for the next twenty to thirty years, it would seem appropriate to examine in more detail the

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[1]Bureau of Radiological Health, "Summary and Discussion of Findings from: Population Dose and Health Impact of the Accident at the Three Mile Island Nuclear Station" (preliminary assessment), (Rockville, Md.: Bureau of Radiological Health, 10 May 1979).

[2]National Academy of Sciences, Energy in Transition: 1985-2010 (San Francisco: W. H. Freeman, 1979).

[3]Resources for the Future, Energy: The Next Twenty Years (Cambridge: Ballinger Publishing, 1979).

scope and nature of the wastes deriving from each. While the costs in human sickness and death from many of the by-products of coal-burning power plants have not been determined, it is known that their effects are deleterious to health. On the other hand, the effects of radiation from nuclear power plants have been much more thoroughly scrutinized.

The major waste product from the burning of coal is carbon dioxide, produced from a normal-sized plant at the rate of about five hundred pounds per second. Other than possible climatic changes which are not fully understood, carbon dioxide is not a problem. As for the really dangerous gases that are emitted when coal is burned, the most important are compounds of sulfur. The annual effect from a typical plant is twenty-five fatalities, 60,000 cases of respiratory disease, and $25 million in property damage.[1] A single coal-burning power plant emits as much nitrogen oxide as 200,000 automobiles, and scrubbers or precipitators do not currently reduce this.

In addition, another class of pollutant released in the burning of coal is hundreds of different organic compounds, at least forty of which are known to cause

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[1]Bernard L. Cohen, "A Tale of Two Wastes", professor of physics and of chemical and petroleum engineering at University of Pittsburg and Director of Scaife Nuclear Laboratories.

cancer, the best known being benzpyrene which is the principal cancer-causing agent in cigarette smoking.[1]

Based on the best available or near-future technology, perhaps ninety percent of the sulfur emissions could be eliminated, but even at this level there would still be five fatalities per year, or five thousand times the number of deaths due to a nuclear power plant, according to this study.[2]

If the dangers to life and health are greater from the burning of coal than from the splitting of atoms in a nuclear power plant reactor, why is there so much of the public, the press, and the political forces favoring coal over nuclear? A possible explanation is that wastes from burning coal do their damage through chemical reactions, whereas nuclear wastes do theirs through the radiation they emit. Even though they are very harmful, chemical poisons are at least familiar, whereas radiation is viewed by the public as something foreign and mysterious, and therefore more to be feared.

Yet radiation is not new or mysterious. All surface life has always been bombarded by radiation in the form of cosmic rays, from natural radioactivity in rocks and soil, from natural potassium and carbon in our bodies, and from natural radon gas in the air we breathe. In short, social welfare is not being optimized by choosing to burn

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[1]Ibid. [2]Ibid.

coal rather than to split atoms to generate heat for electricity in most cases.

The Problem of Perception: a Case Study

In order to demonstrate the problem which the public seems to have in accepting the nuclear option, an examination will be made of a recent decision made as a result of a public opinion poll that was conducted in the Lansing and surrounding area. Those persons questioned receive their electricity from the Lansing Board of Water and Light. Each customer received a note in late 1979 letting him know of the Board's need to add additional generating capacity in order to meet the growing demands for electricity in its service area. Four choices were offered, and will be discussed separately.

The first choice was to add no additional power supply at the time and rely solely on energy conservation to reduce electricity demands to provide necessary capacity to serve growth. The advantage would be no large capital investment or debt. The disadvantage would be possible forced conservation procedures if voluntary conservation was not successful and growth in consumption continued.

The second option was installation by the mid-1980's of a 160 Mw coal-fired steam turbine generating unit at the Erickson Station located in Delta township. This would provide adequate capacity to serve customers' electrical needs into the early 1990's. Financing the cost of this option requires borrowing $194 million which would be paid solely from electric revenues. The advantages are that the generating unit would be under exclusive Board control, and the local economy would benefit from increased Board employment and from approximately $17 million of wages paid workers during the plant's construction. The disadvantages are an increased debt on the Board's operation by approximately $194 million, the adverse impact on air quality in the metropolitan area, and the cost of electricity will be more expensive than the following options, three or four.

The third option involves ownership participation in nuclear generating plants now under construction by Consumers Power (Midland plant) and Detroit Edison (Fermi Unit No. 2) and scheduled for operation in about 1984. Financing the cost of this option would require borrowing $122 million. The advantages are diversity in power supply locations, a reduction of dependence on coal for producing electricity, no adverse impact on air quality in the metropolitan area, less indebtedness than under the second option, and the power delivered to Lansing would be lower in cost than the second option (power cost savings over a thirty year period would be about twenty-seven percent, or in money terms, about $250 million). The average residential customer's share of the projected power cost savings would average $7.50 per month or $90 per year. The disadvantages are the business risk associated with nuclear power, which are greater than with conventional coal-fired generating plants due to regulatory uncertainty regarding plant-safety and waste-disposal requirements, some loss of control in partial ownership since plants would not be operated by the Board, and the loss of benefit to the Lansing economy with the loss of on-site construction wages and increased Board employment.

The fourth option would require the Board to join the non-profit Michigan Public Power Agency. In addition, other cost-saving purchases can be pursued through this agency. Presently eighteen municipal electric utilities in Michigan are members of the Agency. The Board, by joining this agency, could become a member of the projects involving Agency ownership in Consumers Power Company and in Detroit Edison nuclear plants. The total amount of nuclear capacity owned by the Agency in these two plants would include 100 Mw for the Board's use. The cost of power delivered by the Agency to the Board would be about the same as the cost under the third option. The advantages and disadvantages of the third option are applicable to this option also. An additional advantage is that the debt incurred to finance ownership would be against the Agency and not a direct debt to the City of Lansing.

The members of the Lansing Board of Water and Light are appointed by the Mayor with City Council concurrence, and are responsible under the Lansing City Charter for making the decision. Acting under the pressure of special interest groups and results from a public opinion poll, the Board reluctantly chose the more expensive number two option, coal.

The Board was originally planning to purchase into the two nuclear plants. It was the least expensive option for both the Board and the Board's customers. It also would result in no local health risk or environmental degradation, and provided maximum business flexibility by membership in the Michigan Public Power Agency.

As the Board deliberations over whether to go coal or nuclear progressed, there was a coalition of opposition forming. The major forces were the environmental interest group, Pirgim, which is essentially opposed to nuclear power and has a "no-growth" economic philosophy; a local newspaper figure; and a local political party committee, among others. The coalition formed under the name of Rate-Payers United. Their efforts in the media, City Council, and Board of Water and Light meetings resulted in considerable opposition to the purchase of nuclear capacity, such that the Board commissioned Market Opinion Research of Detroit to conduct a poll of a representative number of Board customers to obtain their views on the various options.[1]

The poll was conducted in mid-November of 1979, and the results were published in December. Eight hundred customers were polled regarding the four options - 500 in Lansing, 200 in East Lansing, and 100 in outlying areas. As a result of the conclusions drawn from the poll and the opposition previously mentioned, the Board of Water and Light made the decision to build the coal plant addition rather than purchase nuclear capacity.

There is an attitude of distrust and skepticism toward big business and big energy companies in particular today. There is a prevailing attitude that these large enterprises thrive at the expense of the small entrepreneur. There is particularly a distrust of the nuclear power industry which is quite large and very capital intensive.

There is a widely held hope and even belief that the energy situation is a temporary phenomenon that has been brought about by inadequate attention to research and development efforts in alternative technologies, and also by a "conspiracy" of large energy conglomerates to control the price of energy. There is also a feeling that the large government bureaucracy has partly caused the energy situation, and with proper management, the

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[1]Market Opinion Research, "Analysis of Lansing Board of Water and Light Residential Customer Reactions to Various Options for Additional Electric Generating Capacity and Electricity Conservation" (Detroit: Market Opinion Research, December 1979), Job no. 9367.

"crisis" will be alleviated. In addition, some people blame the environmentalists for their efforts in the legislative area that have resulted in restrictive and repressive measures upon free enterprise. There is a fond hope that there will be a rapid technological solution to rising energy costs, i.e. a new technology such as nuclear fusion which is wrongly purported to be nuclear-waste free.

The concerns of the public center around fear of a nuclear major event (i.e. meltdown and steam explosion resulting in breachment of the reinforced concrete containment building) that could result in the deaths of hundreds or even thousands of people in the immediate area surrounding the plant. There is fear of the long-term effects of low-level radiation that is improperly assumed to derive from normal nuclear operation. It is feared that a nuclear mishap would produce birth defects, cancer and severe degradation of the environment. It is also feared that nuclear wastes can not be handled and disposed of safely.

In the case of nuclear power, the public should be aware of <u>all</u> the facts. One of the main causes of the problems facing the nuclear industry today is that it was "over-sold", i.e. it was promoted in its infancy to be very, very cheap, perfectly harmless to the environment, risk-free - in short, an energy panacea. People were not that naive in 1957 when the first power plant was completed, and they are less so now.

The opposition to nuclear power often focuses on a few factual statements from very credible sources that show that nuclear power can be dangerous if improperly safeguarded. They seem to be constantly searching for and capitalizing on statements by nuclear engineers, former employees of the Nuclear Regulatory Commission, high-level scientific figures, etc. It is true that in looking hard enough, a high credibility source can always be found that will support almost any position, no matter how radically out of tune it might be with the consensus of peers. The focus of the Board of Water and Light's efforts should have been on the position of the "consensus of energy peers", which unanimously favor nuclear over coal in many situations where cost, health, and environmental considerations indicate nuclear as a better choice.

The best method for attaining the desire of the Board of Water and light to purchase nuclear-generated electricity for the Lansing residents would have been a strategy to reeducate the public. This methodology would have been helpful because the public not only does not have the correct facts upon which to base its opinions regarding coal and nuclear (which will be clearly demonstrated in an analysis of the results of the public opinion poll), but they also have a fear of nuclear power based on their erroneous knowledge. The erroneous knowledge and consequent fear have been fostered by an improper and imbalanced presentation of facts, opinions, and possibilities in the past. It is also going on now, and it can best be countered by an approach based on an attempt to reeducate.

The relative advantages of the nuclear power option were mentioned earlier. Briefly they are lower cost to the consumer and to the Board of Water and Light, greater energy diversity, no local environmental degradation, and no pollution to cause adverse local health effects.

The nuclear-power option is compatible with the existing organizational and technical structure, i.e. the power would be sent over existing Consumers Power transmission lines and distributed over the local Board of Water and Light power grid. It is actually more compatible than the coal-power option because of the lack of need for a new generating station. The technical complexity of nuclear power is higher than that of coal-power, and regulatory complexity is greater. The complexity to the consumer however, would be the same, i.e. either way, he only has to flip on a light switch.

There are some <u>cultural</u>, <u>social</u>, <u>organizational</u>, and <u>psychological</u> <u>barriers</u> to the nuclear power option. The <u>cultural barrier</u> centers around the growing value system based on the idea that smallness is better, or bigness is bad; that a decentralized approach is the best approach; that the concept of "appropriate technology" is incompatible with massive power plants supplying only one form of energy, i.e. electrical; and that the individual is being "swallowed up" in an increasingly complex and overpowering system of forces. These cultural values all serve to inhibit the choice for nuclear power.

The major social barrier to the nuclear option is probably "conflict", i.e. when conflict and factionalism exist within any society, any change that one faction in the conflict adopts or espouses may automatically be rejected by other groups. The change or innovation suffers "guilt by association". It does seem that because of the value system mentioned above, which is essentially anti-bigness, any idea or option proposed by a large business entity will be opposed simply because of the existing conflict in values between the large corporations and the small individual consumer. The Board of Water and Light is not that large, but when it advocates a nuclear option, the Board is immediately associated in the minds of the average consumer with the large nuclear power industry with its billions of dollars in investments.

The organizational barrier to change is basically the threat to the power and influence of the Lansing area citizens over the source of their electrical power, i.e. if their electrical power supplier joins the Michigan Public Power Agency and buys electricity from Detroit Edison and Consumers Power, the local autonomy and the political control over the supplier will be diminished, albeit it is hardly a constructive form of influence at present - in fact it has been used in the recent case under discussion to opt for a less desirable (based on the facts and stated criteria of the local consumers) source of electrical energy (the local coal-plant expansion).

The psychological barrier to change is probably the most significant. The customers have an incorrect perception of nuclear power, and have fears that are not based on the facts. They also feel comfortable with the fact that coal power has been used to supply their electricity in the past which they have been satisfied with, and they wish to continue to obtain their electricity from coal-fired plants . . . even if it costs more ($7.50 per month more per average customer) to do so.

In answer to the poll question: "In your opinion, what are the most important factors the Board of Water and Light should take into account in making a decision on various power generation options for the mid 1980's?", the following leading responses were obtained from the eight hundred persons polled:[1]

- Cost (in some form)	41%
- Safety	15%
- Maintain independence	9%
- Environmental effects	7%

In examining the results of the poll in greater detail, it is found that what the people say is most

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[1]Ibid., p. 5.

important to them is really not what is most important, that they are basing many of their opinions on erroneous or lacking information, and that there is a degree of irrationality present that can be explained only in terms of fear of nuclear power.

For example, one of the top reasons given by customers for choosing coal over nuclear was that it was "cheaper".[1] This is clearly incorrect since the customers were told that electricity from a nuclear plant would cost the average customer $7.50 less per month over a thirty-year period than electricity from a coal-fired plant.[2] They favored coal over nuclear even though the safety they were concerned about (next highest criteria listed) would not be adversely affected at all by the two nuclear plants not located in the area, which were being built regardless of the Board of Water and Light's decision, but on the contrary would be affected through the introduction of carcinogens in the particulates and sulfur dioxides from the local coal plant.

"Maintaining independence" was a high-priority item but favors nuclear over coal to the extent of $250 million, or twenty-seven percent savings over a thirty-year period which would be realized in reduced debt to the city - and debt tends to restrict independence by

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[1]Ibid., p. 9. [2]Ibid., p. 15.

making one dependent on the financial institutions lending the money; also the reliability of the power would be greater coming from the Consumers Power and Detroit Edison grids rather than only one local source because of their greater number of plants and less probability of a power shortage or brown-out; also independence would be enhanced by the fact that the city would not be totally dependent on coal whose prices and delivery could be unpredictable.

"Environmental effects" were also mentioned as highly relevant by the eight hundred polled, and forty-one percent agreed that a major disadvantage of a coal-fired generator would be the negative impact on the air quality of Lansing.[1]

It is clear that the choice of those polled of coal over nuclear contradicts the very top four criteria that the same people listed as major factors in selecting a source of electrical generation. More important, they contradicted themselves in the same poll and should have been aware of their own contradictions.

It appears that psychological aversion to nuclear power is the real cause of opposition. In a 1980 published interview by the Media Institute of Washington, D.C., Dr. Robert L. Dupont, a recognized psychiatrist and expert in the study and analysis of "phobias" gives some of his opinions regarding the public apprehensions toward nuclear

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[1] Ibid., p. 10.

power. He made the following statement after viewing thirteen hours of videotapes of nuclear-energy news coverage on television:[1]

> A phobia is a malignant disease of 'what ifs'. The phobic thinking process is a spiraling chain reaction, to use an atomic-energy analogy, of 'what ifs', and each what if leads to another. 'What if this happens, and then what if that happens, and then what if the other thing happens?' Phobic thinking always travels down the worst possible branchings of each of the 'what ifs' until the person is absolutely overwhelmed with the potentials for disaster . . . Most of the 'nuclear disasters' I saw described on the television tapes were 'what ifs'.

Nuclear Power and the Future

In the future, increased attention to the comparative analysis of risks of other fuel cycles appears favorable to nuclear energy.[1] The necessity of increasing knowledge about the hazards of coal-burning is critical, if enlightened choices are to be made in future energy policy.

Because of the current attention being given to nuclear power and its liabilities, Consumers Power Company of Jackson, Michigan has had to alter some of its previous policies regarding announcements of power-plant shutdowns.[2] In the past, a written announcement was given as a courtesy

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[1]Roger E. Kasperson and others, "Public Opposition to Nuclear Energy: Retrospect and Prospect", Science Technology and Human Values (Cambridge: MIT Press, Spring 1980), p. 21.

[2]R. J. Fitzpatrick and H. E. Spieler, Public Affairs Planning and Research, Consumers Power Company, conversation at offices in Jackson, Michigan, July 1980.

to local news media informing them of any shutdowns of any of their nuclear power plants. The reasons for the shutdowns were largely for routine maintenance, inspections, safety retrofits, or refueling. However, the notices frequently made front-page headlines as if something catastrophic had happened. The problem was solved by including in the announcements all of the power plant shutdowns, whether nuclear or coal. As a result, it was no longer newsworthy.

There is an additional factor, however, that tends to complicate a comparison between nuclear power and coal. This is the matter of disproportionate risk. The risk of living near a nuclear power plant can be compared in one sense to the risk of living below a large hydroelectric dam. If the dam were to break, the damage would be concentrated on the residents in the immediate downstream area. In the same way, the risk of injury in the event of a "worst possible" nuclear mishap is greatest to those in close proximity to the plant.

With regard to coal burning, the risk of illness or death due to inhalation of the emissions, though again greater near the plant, is diffused over hundreds and even thousands of square miles daily. This extent in turn depends on the height of the stacks and the wind movement. The risk of using coal for electrical power is also displaced to the coal-mining regions in the form of "Black Lung" and mining accidents, to the railroad personnel that transport the coal, and to automobile-train collisions.

Even though based on history - the risks of illness or death of living near a nuclear power plant are almost infinitely less than those of living near a coal-burning plant, the risks are not nil. Since they are not nil but are not measureable because of the absence of any public deaths due to radiation from a nuclear power plant, the public opposition could perhaps be allayed by allowing nearby residents to benefit from their proximity.

This could be done by utilizing a cogeneration process whereby the efficiency of the nuclear plant (or coal also) could be at least doubled. This is accomplished by diverting steam from the turbines and piping it to surrounding areas to supply energy at a much cheaper cost. This concept of compensating local residents for assumed risks, whether real or imagined, is not new. President Giscard of France has already announced plans to apply this same principle by reducing electricity rates for residents living near nuclear power plants.[1]

Finally, energy policy contains within it very large social and political considerations. These considerations are not nearly as well understood as the technical factors. Though much social benefit could be derived from

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[1]Jonathan Spivak, "France Pursues Drive to Replace Oil Imports With Nuclear Energy", Wall Street Journal, 8 March 1980, p. 1.

a program to increase public awareness of the total costs of nuclear power versus coal and other forms of energy, this approach by itself would probably be inadequate. The social and institutional characteristics of energy systems which greatly affect public perceptions of them deserve much more attention. Nuclear power, once a technical issue, has become a political issue. As such, it must be addressed as any other political issue by those who have an interest in wise use of energy resources for the future.

The next chapter helps to illustrate the choices and the future of the nuclear power industry. The State of Michigan already has a greater percentage of its electricity supplied from nuclear power than the nation as a whole. It was also involved in the early development of nuclear breeder technology, as well as an early experimental commercial reactor.

While the people of Michigan are concerned with the international choices and future of the nuclear power industry only to the extent of the cumulative interest of individual citizens, they have a more than proportionate interest in the choices surrounding waste disposal and the sociotechnical impact upon Michigan society. The reason for this interest is first of all the availability of numerous technologically feasible sites for long-term waste disposal, as well as the demand for such sites created by the spent fuel from Michigan's nuclear power plants. Secondly, Michigan's heavy dependence on energy from outside her borders is an inducement to find the most economical and reliable sources of energy internally.

In addition, Michigan is in the process of completing the installation of three new reactors at two sites that will add substantially to already existing capacity. Finally, Michigan's soft, yet energy-intensive and industrially-based economy cannot withstand the increasing costs of fossil fuels as well as those states with less vulnerable energy-economies.

CHAPTER 5

NUCLEAR POWER IN MICHIGAN

Michigan Nuclear History and Development

Overview of Fermi 1: Experiences of Atomic Power Development Associates and Power Reactor Development Company

Some of the earliest development and operational experience with the fast breeder reactor occurred in the State of Michigan. It came about as the result of some pioneering interest which was stimulated by a few individuals at the Detroit Edison Company and at the Dow Chemical Company.

On January 10, 1955, the U.S. Atomic Energy Commission (AEC) announced its Power Reactor Demonstration Program inviting private enterprise to present plans for building nuclear power reactors in cooperation with the AEC. Then on March 30, 1955, the Detroit Edison Company, on behalf of itself and the Central Hudson Gas and Electric Corporation, the Cincinnati Gas and Electric Company, Consumers Power Company, Delaware Power and Light Company, Long Island Lighting Company, Philadelphia Electric Company, Rochester Gas and Electric Corporation, and the Toledo Edison Company, offered to participate in the Power Demonstration Program by designing, constructing and operating an experimental fast-neutron breeder reactor electric power plant. On August 8, 1955 the AEC accepted the proposal as a basis for negotiation. This, together with studies jointly initiated by Detroit Edison and Dow Chemical, was the beginning of Fermi 1.[1] (Please refer to figures 5 and 6 for locations of this and other plants discussed in this section, as well as franchise areas.)

There were two basic groups that were responsible for making Fermi 1 a reality, both of which had membership from the aforementioned group of companies. The first group was called Atomic Power Development Associates (APDA). This group had the responsibility for providing much of the supporting engineering, research, and development work. The second group was called the Power Reactor Development Company (PRDC). This group had the responsibility of building, owning and operating the reactor. Ultimately they were dissolved within a few months of each other.

Five years and three months after the first equipment was ordered, a milestone was achieved when the entire primary system of the Fermi Plant, then the world's largest liquid-metal-cooled reactor system, was filled to operating level with 345,000 pounds of sodium. The fill

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[1]Eldon L. Alexanderson, "Power Reactor Development Company," Fermi 1: New Age for Nuclear Power, ed. E. Pauline Alexanderson (LaGrange Park, Ill): American Nuclear Society, 1979), p. 39.

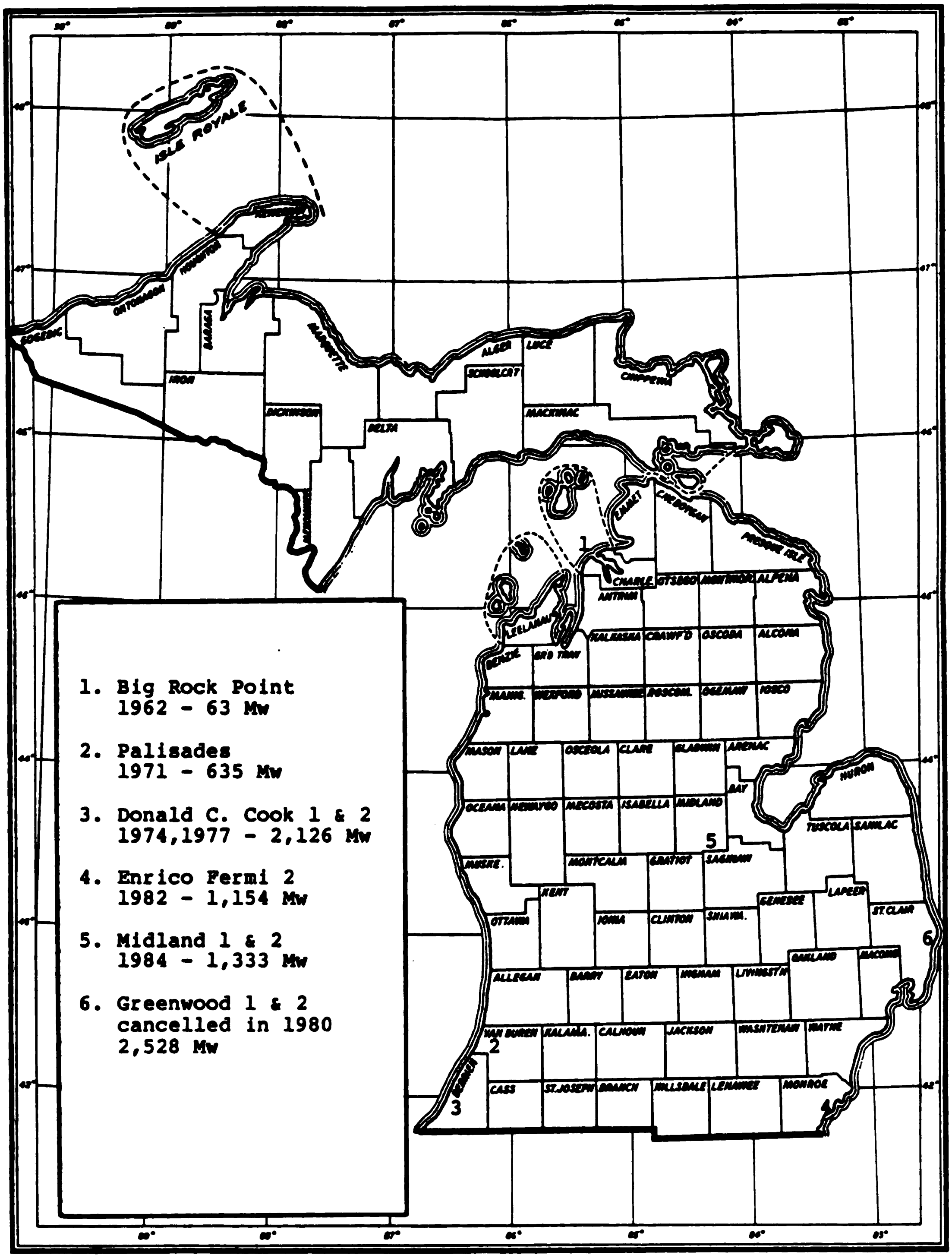
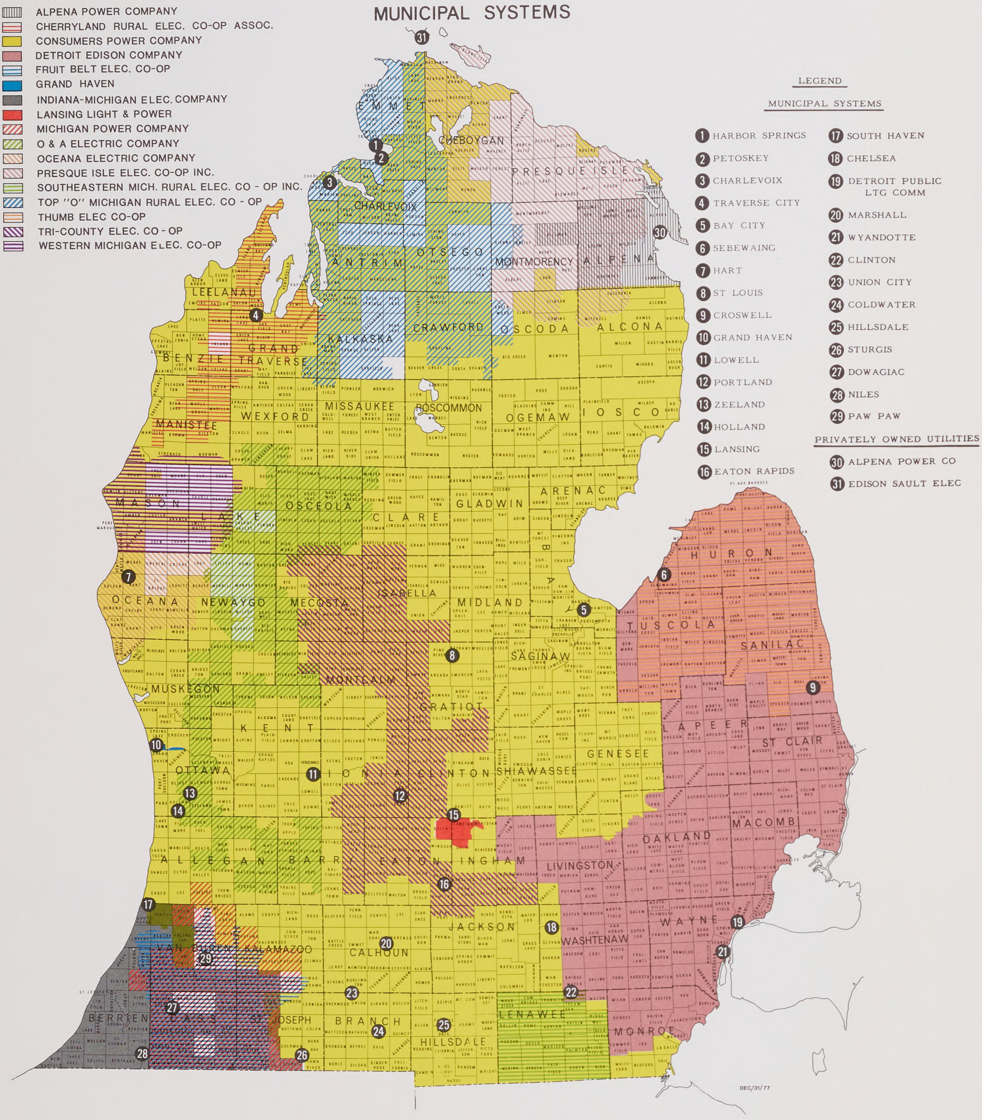


Fig. 5. Location of nuclear power plants in Michigan

Fig. 6 FRANCHISE SERVICE AREA OF PRIVATELY OWNED UTILITIES GENERAL SERVICE AREA OF RURAL ELECTRIC COOPERATIVES AND MUNICIPAL SYSTEMS



was completed without incident during a 9-hour period starting the night of November 30 and ending at 7:00 a.m. on December 1, 1960.[1]

Over the following months, various high temperature problems were encountered as a result of the liquid sodium method of cooling. However, these challenges were met one by one, and on May 10, 1963 the Power Reactor Development Company received a provisional operating license for maximum power of one megawatt. Culmination of the long APDA-PRDC effort occurred when the Fermi reactor became critical at 12:23 p.m. on August 23, 1963.[2]

Low-power nuclear tests were begun immediately. Since the program progressed smoothly and on schedule, PRDC filed an application for a license for high-power operations with the AEC on March 12, 1964. A milestone in the history of the Fermi Plant was reached on July 8, 1966 when the power was increased to 100 megawatts. This was not only the culmination of years of engineering effort on the Fermi reactor, but it was the highest power reached by any fast reactor. By the end of that month, the reactor had been started about 390 times.[3]

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[1]Alton P. Donnell, "Atomic Power Development Associates-From Inception to Dissolution," Fermi 1: New Age for Nuclear Power, p. 62.

[2]Ibid, p. 67.

[3]Ibid, p. 68.

On October 5, 1966 when the reactor was operating at 34 megawatts, during a power ascension the radioactivity level in the inert gas blanketing the primary sodium system rose substantially, indicating the presence of gaseous fission products. A small amount of this radioactivity leaked into the building. The automatic protective equipment performed properly, sealing the building from the atmosphere and preventing any further escape of radioactivity. Following the incident, investigation revealed that fuel melting had occurred in at least two of the subassemblies, and that the molten fuel had penetrated the steel walls of the two subassemblies so that they were physically bonded. The reason for the fuel melting was obstruction of coolant flow through three or four subassemblies, caused by one of six zirconium plates that had become detached inside the reactor. It was later decided to detach and remove the remaining ones since they were not required for safe operation.

After much research, development, and learning from the incident, the reactor was again started up on July 18, 1970. However, much public and unfavorable awareness of the incident was promoted by the book, We Almost Lost Detroit, by John Fuller. In response to Fuller's book, Earl M. Page, a reactor physicist employed by APDA and associated with the Fermi 1 project since 1960 published a counter-statement.[1] Page attacked systematically the three major themes or impressions conveyed throughout the book. The impressions were stated as follows:[2]

1. We almost lost Detroit as a result of the Fermi 1 fuel melting incident of October 5, 1966.

2. Any mistake in nuclear power-plant design, construction, or operation will most likely lead to disaster.

3. The government performed a reactor-safety study hoping to show that the risk to the public is low, but when the risk turned out to be high, they suppressed the study.

Earl Page successfully invalidated each of John Fuller's major arguments. "Losing Detroit" is impossible even in the worst possible nuclear power-plant disaster - because of the lack of a critical mass. However, fantasy is often more saleable than fact. Although the rebuttal by Page seems to have been thorough, it was probably less widely read than Fuller's book.

The Fermi 1 project continued through 1971 and into 1972 on funds pledged by member companies of the Edison Electric Institute and funds committed by the Detroit Edison Company. During this period, all components and systems operated without significant incident,

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[1]Earl M. Page, "We Did Not Almost Lose Detroit, A Critique of the John Fuller Book: 'We Almost Lost Detroit'" (Detroit: Detroit Edison).

[2]Ibid., p. 3.

demonstrating the operating capability of large flowing sodium systems. The experience, with minor difficulties, made a substantial contribution to liquid-metal-cooled fast reactor technology. From those favorable experiences, it was concluded that continued operation of the plant would contribute significantly to fast-reactor development.

With continued operation in mind, PRDC and APDA outlined a six-year program for optimum plant use. This would cost $50 million. The program included operating the reactor to the extent of the life of the existing fuel, followed by operation with a uranium oxide fuel at a power level of about 400 megawatts. The program was never realized because a lack of adequate financial support forced the plant to be decommissioned.

The efforts on the part of Detroit Edison Chairman, Walker Cissler, and the Edison Electric Institute to raise the $50 million were laudable. Unfortunately their efforts were stymied by a seeming loss of commitment on the part of the AEC to the project as expressed by its unwillingness to contribute a remaining needed amount of $6 million -- a relatively small amount compared to the over $2.0 billion for the proposed Clinch River Breeder Reactor Demonstration Plant. The reluctance of the utility industry to contribute to Fermi was understandable. Contributions by the utility industry to the AEC's proposed demonstration breeder reactor were to be $250 million. The money market was tight, and capital for needed expansion of conventional generating facilities was difficult to raise. It would not be prudent for the utility industry to finance a project that in the opinion of the AEC was not making a significant contribution to the national Liquid Metal Fast Breeder Reactor program.[1]

Background on D.C. Cook 1 & 2, Big Rock Point, and Palisades

Donald C. Cook 1 and 2 nuclear plants are located in Bridgman, Michigan. The operating licenses were issued on October 24, 1974 and December 23, 1977, respectively. They are both pressurized water reactors manufactured by Westinghouse, with a combined capacity of 2,126 megawatts. These two plants are owned by the Indiana and Michigan Electric Company of Fort Wayne, Indiana. It is noteworthy that these two units account for seventy-five percent of the current operating capacity in Michigan, but only ten percent of the output is distributed in Michigan.[2] It is possible that a larger percentage of the output could be channeled to Michigan, but this would involve reselling the power to one of the two existing major utilities (Consumers Power or Detroit

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[1] James E. Meyers, "The Decommissioning of Fermi," Fermi 1: New Age for Nuclear Power, p. 272.

[2] Michigan Energy and Resource Research Association (MERRA), Toward a Unified Michigan Energy Policy ("White Papers" series) (Detroit: MERRA, 1980), p. 148.

Edison), or adjusting the franchise service areas - which is not likely (see figure 2).

The Big Rock Point nuclear plant was Consumers Power Company's first nuclear project and the fifth commercial nuclear power plant in the nation. It is of 63 megawatts capacity and was issued an operating license on August 30, 1962. The reactor is of the boiling-water type, manufactured by General Electric Company. This is a very small reactor compared with the current normal size of 1,000 megawatts or more.

Nuclear-development programs sponsored by the Atomic Energy Commission, electric utilities, and suppliers have been carried on at Big Rock Point since the start of its operation. The Big Rock Point plant also served as a training facility for preparing company personnel for operation of the Palisades plant. In addition, it provided training for personnel from other utilities in the U.S. and abroad: from Niagara Mohawk Power Corporation, Boston Edison Company, and from Canada, Sweden, and India.[1]

The cost of Big Rock Point is striking in its comparison with the construction costs of current plants - notwithstanding the much smaller size. For example, the

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[1]Information from internal Consumers Power Company information data sheets (Jackson, Michigan: Consumers Power, 15 September 1979), p. 3.

cost of Big Rock Point was $25.8 million for 63 megawatts capacity, or $410 per kilowatt capacity; the cost of Palisades was $186 million for 635 megawatts or $293 per kilowatt; and the cost of Midland 1 and 2 combined (projected) is $3.1 billion[1] for 1,333 megawatts or $2,326 per kilowatt capacity. However, this cost will be considerably reduced (or the profitability of the plant increased) by the fact that large amounts of steam will be sold to the Dow Chemical Company in Midland.

The current problem facing Big Rock Point has to do with spent-fuel-rod storage.[2] In June 1979, Consumers Power Company requested approval from the Nuclear Regulatory Commission for increasing the storage capacity of the spent-fuel storage pool at Big Rock Point by installing closer storage racks. This modification would make possible fuel storage through approximately 1990. The current spent fuel storage capability will be exhausted in 1981. The storage of spent fuel is necessary because national policy currently does not permit reprocessing of spent reactor fuel, and no permanent disposal facility has been constructed.

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[1]Frank J. Kelley, Attorney General, statement before the Special Joint Committee on Nuclear Energy (Lansing: Michigan Legislature, 3 March 1980).

[2]Interview with Judd L. Bacon, Managing Attorney, Consumers Power Company, Jackson, Michigan, 20 November 1980.

Several intervenors have challenged the installation of new storage racks, and public hearings will be held during the early part of 1981. Since the next refueling is scheduled for Fall of 1981, at which time the extra storage capacity will be needed, it is essential to the full operation of Big Rock Point that they are successful in their application.

The Palisades Nuclear Power plant was issued an operating license on March 24, 1971. It is interesting that the license issued was a provisional one, subject to review after the first eighteen-month trial period. When application was made to change the provisional operating license to a forty-year operating license, no action was taken by the licensing board for one reason after another. The result is that Palisades has been on a day-to-day operating basis since 1973 while the application is still pending.[1]

As the Palisades plant was nearing completion, several environmental groups intervened, opposing the granting of a license on the grounds that cooling towers and additional radioactive-waste equipment were needed.[2] In order to resolve the objections and obtain an operating

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[1]Ibid.

[2]"Palisades Plant Settlement Agreement between Consumers Power Company and Michigan Steelhead and Salmon Fisherman's Assn., et al." (Jackson, Michigan: Consumers Power, 12 March 1971).

license, Consumers Power consented to install cooling towers and additional radioactive-waste equipment for an approximate cost of $30 million. Licensing delays caused additional expenses of $28 million, and inflation added another $34 million. These required modifications increased the final construction cost to $186 million, as opposed to the originally planned $93 million.

In August 1973, operation was stopped because of a steam-generator-tube leak. Upon investigation, it was determined that some engineering design deficiencies and improper water chemistry were causing steam-tube corrosion. It took almost thirteen months to correct the situation and resume operation.[1]

As a result of its losses, Consumers Power Company filed suit in Federal District Court in Grand Rapids against five firms which supplied components and design work for the Palisades plant. Settlements were obtained both in and out of court during 1976-77 for between $68 million and $88 million, depending on the future value of certain uranium-fuel assemblies.[2]

Consumers Power then filed for approval to replace the steam generators, but the application had not been

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[1]Information from internal Consumers Power Company information data sheets (Jackson, Michigan: Consumer's Power, 15 September 1979).

[2]Interview with Judd L. Bacon, Managing Attorney, Consumers Power Company, Jackson, Michigan, 20 November 1980.

approved as of Fall 1980. However, Consumers Power is not anxious about this delay, since during a 1978 refueling outage, inspections of the steam generators revealed that no significant corrosion had taken place during the past operating cycle. The need to replace the steam generator is also not as urgent as earlier due to the declining rate of growth in power demand in the state.[1] A current suit between Consumers Power Company and the NRC has to do with a $450,000 fine imposed for the alleged leaving open of "containment-isolation valves". The fine was three times the fine assessed against the operators of the Three Mile Island Nuclear Plant, and the largest fine in nuclear regulation history - for safety violations determined by the NRC.[2] It is noteworthy that the fine was a cumulative total of daily fines, that the burden of proof is on the NRC to establish that the valves were open the entire period, and that the opened valves in themselves would not have produced the series of events leading up to the mishap at Three Mile Island.

Two other plants (Quanicassee 1 and 2) of 1,100 megawatts each were scheduled to be completed in the early 1980's. These plants were to be located just east of Bay City,

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[1]Ibid.

[2]Frank J. Kelly, Attorney General, Statement before the Special Joint Committee on Nuclear Energy, 3 March 1980.

Michigan. However, they were both cancelled in 1974 after Consumers Power had expended $13 million.[1]

Midland 1 and 2: Progress and Problems

On December 14, 1967 Consumers Power announced its intention to construct its largest nuclear plant on a 1,000 acre site in Midland, Michigan. The plant will be the world's first industrial, cogeneration nuclear energy center. It will be capable of generating 1,333 megawatts of electricity for Michigan and at the same time delivering large amounts of steam for industrial use at Dow Chemical.

During 1968, contracts were awarded for construction of various components of the nuclear plant. The Midland units were scheduled for commercial operation in 1974 and 1975.[2] On January 13, 1964, the company's application for a construction permit was filed with the Atomic Energy Commission. For the next four years the AEC conducted licensing hearings. In addition, there were repeated legal appeals from organizations and individuals opposed to construction of the Midland plant. Finally the AEC issued construction permits for the Midland units on December 15, 1972. However, the repeated delays made it necessary for the commercial-operation dates to be extended to 1979 and 1980.

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[1]Ibid.

[2]Information from internal Consumers Power Company information data sheets (Jackson, Michigan: Consumers Power, 15 September 1979).

A sample of the context of interventions that occur against nuclear power plants can be found in the official AEC proceedings leading up to the granting of construction permits for the Midland plant. The following excerpt from AEC proceedings regarding the environmental impact of the Midland nuclear plant is insightful:[1]

> Intervenors on the other hand challenge the (Consumers Power Environmental impact) survey as completely inadequate and assign a 'conservative' value of $36,000,000 to the flora and fauna to be disturbed by construction. Approximately $30,000,000 of this amount is for the losses of bird and animal life alone. The method used to arrive at these evaluations was to estimate populations of species which could be expected to be found in the area on the basis of existing studies. Intervenors then estimated the number of each species expected to be found and assigned an arbitrary value to each bird and animal, for example, $10.00 per sparrow and $10.00 per mouse. Intervenors' witness, Dr. Stuart Holcomb, made no allowance for the effect of predation, although he conceded that predation would take a considerable toll . . . nor did he make any allowance for the fact that many of the birds to be found are generally considered pests (indeed there are bounties in the State of Michigan on some of them). He then multiplied his final figure by 30, representing the expected life of the plant of 30 years. The Board finds this method of evaluation and calculation wholly unsupportable. We note without further comment, for example, that the figures shown include $151,000 per year as the value of mice to be lost and $190,000 per year for varieties of sparrows - a total of some $10,000,000 over the life of the plant for mice and sparrows alone.

In 1973 and 1974, aspects of construction work at the plants were interrupted because of the actions by

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[1]U.S., Atomic Energy Commission, Before the Atomic Safety and Licensing Board, in the matter of Consumers Power Company (Midland Plant, Units 1 and 2), Initial Decision, 14 December 1972.

intervenors and the AEC. The intervenors continued to seek revocation of the construction permits. In addition, the adverse economic climate being experienced by the electric utility industry, and especially by Consumers Power, caused additional delays. Consumers Power Company's financial situation had been weakened by the previous extended outage of the Palisades plant, and the accompanying loss of revenue. For these reasons the commercial-operation dates for Midland Units 1 and 2 were extended to 1981 and 1982.

During 1975, the Atomic Safety and Licensing Board, the Michigan Court of Appeals, and the Michigan Supreme Court gave favorable judgments to Consumers Power regarding various intervenor actions. However, in 1976 the U.S. Court of Appeals for the District of Columbia Circuit remanded to the Nuclear Regulatory Commission for re-review several of the issues involved in the original granting of construction permits, including re-evaluation of Dow Chemical Company's need for process steam from the nuclear plant. In addition, there were issues of antitrust that had to be settled.

Finally, in a unanimous decision of the U.S. Supreme Court issued on April 3, 1978, the validity of the original 1972 construction permits was upheld. This action overturned the decision of the U.S. Court of Appeals for the District of Columbia Circuit. In its opinion, the U.S. Supreme Court stated that "Administrative proceedings should not be a game or a forum to engage in unjustified obstructionism".[1] In addition, the intervenors were assessed $20,000 by the Supreme Court to be paid to Consumers Power Company for court costs.[2]

In the meantime, the agreements for the purchase of large quantities of process steam by Dow Chemical from the Midland Plant had become obsolete due to the delays in construction. As a result new agreements were signed, based on Consumer Power's ability to place the Midland Plant in commercial operation for process steam service to Dow Chemical on or before December 31, 1984. Should the construction deadline not be met, Dow Chemical would have the option of buying out of the contract for approximately $300 million.[3] Because of the construction delays observed in the past, there has been concern expressed by the Dow Chemical Company about whether it should continue to plan on the process steam's being available on time.[4] Currently the process steam is being supplied by Dow

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[1]Ibid.

[2]Constance Ewing Cook, Nuclear Power and Legal Advocacy (Lexington, Mass.: D.C. Heath, 1980), pp. 99-100.

[3]Interview with Robert Fitzpatrick, Vice President for Public Relations, Consumers Power Company, Jackson, Michigan, 1 July 1980.

[4]Frank J. Kelly, Attorney General, statement before the Special Joint Committee on Nuclear Energy, 3 March 1980.

Chemical's own power plants which are becoming obsolete, experiencing intermittent violations of EPA pollution regulations, and generally preventing the company from expanding its operations as it would prefer.[1] There have been public and private statements by management of Dow Chemical in Midland to the effect that it should seriously consider building new and additional process steam generating capacity, and forget about being involved in the Midland Plant.[2]

During construction, settling of a generator building became an issue, and while the issue has not been resolved, the physical-settling problem has been remedied by loading the building with sand to expedite the settling process. Construction on the remainder of the plant is proceeding on schedule, and as of early September 1979, the Midland project was approximately sixty-three percent complete.[3] Consumers Power Company remains confident that a nuclear plant at the Midland site will have the least impact on the environment compared to any alternative, and that it can

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[1]Interview with Judd L. Bacon, Managing Attorney, Consumers Power Company, Jackson, Michigan, 10 November 1980.

[2]Informal conversation with Dow employee on 12 July 1980 in Flint, Michigan at U.S. Senator Carl Levin's Gasohol/Alcohol Conference.

[3]Information from internal Consumers Power Company information data sheets (Jackson, Michigan: Consumer Power, 15 September 1979).

provide steam and electrical power at a rate that will keep the region competitive with other parts of the country.

Nonetheless, because of the current economic and regulatory uncertainties with regard to nuclear power, Consumers Power Company has no plans to construct another nuclear plant after Midland is completed - for the foreseeable future.[1]

Fermi 2: Progress and Problems

The construction permit for Fermi 2 was issued on September 26, 1972. It is a boiling-water-reactor type with a capacity of 1,100 megawatts. Although plans for the project were announced in 1968 and the initial completion target date of 1976 set, financial conditions at Detroit Edison caused work on the plant to be halted in 1974.[2] Work resumed in 1977 when the company's financial condition improved. Another contributing factor was the sale of twenty percent of the plant to two rural electric cooperatives, Northern Michigan Electric Cooperative, Inc., and Wolverine Electric Cooperative, Inc.[3]

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[1]Gordon L. Heins, Vice President, Systems Operators, Consumers Power Company, Jackson, Michigan, address at an "Energy Forum" on the Michigan State University Campus, East Lansing, Michigan, 9 October 1980.

[2]"Fermi 2 Nuclear Power Plant", Newsletter (Detroit: Detroit Edison, Summer 1978).

[3]Ibid.

Fermi 2 shares the site with the old Fermi 1 plant which now operates as a standby oil-fired generating station. The site is located thirty miles southwest of Detroit. The new target date for completion in 1980 was set back to early 1982 in order to "allow the company to evaluate the reports of President Carter's Special Commission, the Nuclear Regulatory Commission, and other agencies investigating the recent Three Mile Island incident".[1]

Fermi 2 was reported to be eighty-two percent complete as of early 1980.[2] However, the costs for construction have been escalating. The original cost for completion in 1976 was $229 million, followed by $988 million for completion in 1980, and now perhaps $1.7 billion for completion in 1982 or 1983.[3] The delays imposed by intervenors and regulatory revisions and additions seem to be the major reasons for the escalating costs. Most of the delays are beyond the control of the power companies.

Fermi 3 was an additional nuclear power plant planned by Detroit Edison for completion in the late 1970's. However, it was canceled in 1975 after only preliminary studies were made and after only $6 million had been expended.

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[1]"Fermi 2 Nuclear Power Plant", Newsletter (Detroit: Detroit Edison, Summer 1979).

[2]Frank J. Kelly, Attorney General, statement before the Special Joint Committee on Nuclear Energy, 3 March 1980.

[3]Ibid.

Greenwood 2 and 3: The Decision to Cancel

In May of 1971, the Board of Directors of Detroit Edison approved a generation-expansion plan that included Greenwood Units 2 and 3. The decision to build these plants was made based on the success of nuclear power that was being demonstrated in that time period.[1] This success was demonstrated by the completion of nine nuclear units in the U.S. between 1968 and 1971. The average project duration was less than five years, and resulted in electrical capacity costs that compared favorably with those of coal-fired power plants. In addition, other power plants were proceeding on schedule - including Fermi 2.

The construction of Greenwood 2 and 3 nuclear plants was favored over coal in the early 1970's also because of the passage of the National Environmental Protection Act of 1979 and the Clean Air Act Amendments of 1970 which established stringent particulate and sulfur-dioxide emission parameters.[2] It was very clear that although a high percentage of the emission from a coal-fired plant could be eliminated by existing technologies, the removal of the emissions

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[1]Wayne H. Jens, Vice President, Nuclear Operations, Detroit Edison Company, "Testimony, State of Michigan Before the Michigan Public Services Commission, In the Matter of the Application of the Detroit Edison Company for Accounting and Ratemaking Authority Relating to Its Greenwood Nuclear Units 2 and 3 Projects" (Case No. U-6474), Spring 1980, p. 2.

[2]Ibid., p. 3.

became increasingly expensive as attempts were made to clean out the last few percentage points. Any legislation changing the level of allowable emissions at the higher levels could be disastrous to cost projections for a coal plant due to the economic sensitivity at these levels.

Greenwood 2 and 3 construction was also encouraged by the uncertain technology for removing coal sulfur emissions and the difficulty of siting a new coal-fired generator plant in the Detroit Edison service area. Siting problems were due to the need to improve ambient air quality in almost all industrialized areas. In addition, the Federal Government was supportive in its fuel-enrichment services, and it appeared that it would assume responsibility for disposing of the nuclear wastes. Nuclear power was also not a political issue in 1971. However, construction was never begun on Greenwood 2 and 3. The reason was that it was unnecessary in order to proceed with initial preparation. A considerable amount of engineering and environmental studies are required in order to even prepare an application for a construction permit. Initial application was filed in 1973 for a construction permit, but work was suspended on the project in 1974. It was decided on February 26, 1979 to resubmit an updated application for a construction permit. However, the accident at Three Mile Island began on March 28, 1979. Soon after the accident it became clear that the Nuclear Regulatory Commission would be using all its resources to investigate the incident. Detroit Edison was advised by the NRC that no work would be done on the licensing of the Greenwood Units 2 and 3 for "some time".[1] The situation was probably made to look more dismal because of the fact that Greenwood 2 and 3 were to use Babcock-and-Wilcox-type reactors, like those at Three Mile Island. It was then decided to stop work on the Greenwood Nuclear Project pending the results of the NRC investigations. A recommendation to terminate the Greenwood Nuclear Project was made soon after, and was approved by the Detroit Edison Board of Directors on March, 24, 1980.[2]

The decision not to construct the Greenwood units was based primarily on the following:[3]

1. Licensing uncertainty.
2. Financial risk of starting construction of a large nuclear unit.
3. Lack of a national and public commitment to nuclear power.
4. Uncertain viability of reactor design (Babcock and Wilcox).
5. Difficulty in obtaining adequate human resources for the project.
6. Unresolved siting questions concerning Greenwood.
7. Unresolved issues with respect to high and low level waste disposal and reprocessing.

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[1]Ibid., p. 27. [2]Ibid., p. 28.

[3]Ibid., pp. 28-29.

8. Projected inability to schedule the Greenwood Nuclear Project to meet the forecast need, and

9. The need for increased amounts of nuclear accident insurance for property damage and replacement energy costs during an outage.

The Greenwood Nuclear Project was canceled after an expenditure by Detroit Edison of $73 million.[1] This was the most economical course of action in view of the foregoing criteria. It is doubtful if anyone will buy a nuclear power plant for about five years,[2] but Detroit Edison has publicly stated that it would consider another generation project in the future.[3]

Implications of the Three Mile Island Accident for Nuclear Power Plants in Michigan

Certainly the impact of Three Mile Island has been unfavorable to the entire nuclear industry. Even though the NRC's order to shut down all Babcock and Wilcox reactors following Three Mile Island did not affect the plants operating in Michigan, several other actions did impact,

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[1]Interview with Wayne H. Jens, Vice President, Nuclear Operations, Detroit Edison Company, Detroit, Michigan, 12 November 1980.

[2]Ibid.

[3]Wayne H. Jens, Vice President, Nuclear Operations, Detroit Edison Company, "Testimony, State of Michigan Before the Michigan Public Services Commission, In the Matter of the Application of the Detroit Edison Company for Accounting and Ratemaking Authority Relating to Its Greenwood Nuclear Units 2 and 3 Projects" (Case No. U-6474), Spring 1980, p. 43.

or will impact, Michigan's Nuclear Power Program. They are as follows:[1]

1. A series of bulletins was issued to all operating nuclear power stations, informing them of the details and circumstances of the accident and directing certain measures to be taken to deal with possible similar conditions. Licensees were required to review and modify their operating procedure for operator and safety-system responses to various accident conditions. Safety circuits were modified at the D.C. Cook plant. NRC inspection personnel were dispatched to the various plants to insure that the prescribed steps had been followed.

2. Following Three Mile Island, the NRC temporarily halted testing of personnel applications for operator licenses pending the adding of special training to deal with events similar to that at Three Mile Island.

3. A number of measures were required of all plants in Michigan to improve their safety margins as a result of the findings of the Three Mile Island accident, e.g. increased testing of key high pressure safety and relief valves, assuring that all gaseous-and liquid-flow paths from the reactor containment would be closed in event of a TMI-type accident, and verifying the adequacy of power supplies and backup power sources for safety components. It was conceded that the Fermi 2 and Midland project-completion dates could be adversely impacted by the NRC longer-term requirements.

4. The requirement of "Licensee Event Reports" and a new NRC office to systematically assess the significance of the various operating incidents and malfunctions which are required to be reported to the NRC.

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[1]James G. Keppler, Director, Nuclear Regulatory Commission Region III, before the Special Joint Committee on Nuclear Energy (Lansing: Michigan Legislature, 15 October 1979), 2:13, pp. 3-11.

5. Utilities were asked to meet the criteria of a Nuclear Regulatory Commission guide for emergency planning for nuclear accidents along with city, county, and state governments.

6. The Nuclear Regulatory Commission installed direct phone lines from each operating reactor control room to the NRC headquarters and regional offices - with a view toward establishing better communication systems.

7. A Nuclear Regulatory Commission resident-inspector program was expanded, to include resident inspectors at all operating reactor sites - backed up by inspectors operating out of the Nuclear Regulatory Commission regional office. Resident inspections were projected to be assigned to the Big Rock Point and Fermi plants in early to mid 1980. This will complete resident inspection assignments in the State of Michigan.

Certainly there exists a potential for cost increases for nuclear power as a result of safety modification requirements following Three Mile Island. However, it must be kept in mind that while the electricity costs from nuclear power plants are going up due to improved safety modifications and backfitting, the cost is also increasing for electricity from coal-fired power plants due to increased pressure to control emissions. In spite of the fact that nuclear power-plant costs have increased at the rate of about $140 per kilowatt capacity over the five-year period prior to 1978,[1] the costs still compare favorably with coal.

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[1]William E. Mooz, Cost Analysis of Light Water Reactor Power Plants, Rank Report R-2304-DOE, June, 1978, p. 31 as cited in the testimony of Gregory C. Minor before the Special Joint Committee on Nuclear Energy (Lansing: Michigan Legislature, 15 October 1979), 2:14.

Performance of Michigan Nuclear Power Plants Compared With That of Other Nuclear Power Plants in the United States

There are several methods for comparing the performance of nuclear power plants. It is important to compare them on the basis of size, as well as when they went into operation, i.e. age of plant. The first comparison will be made on the basis of average capacity factor.[1]

Big Rock Point's performance was compared with that of other small demonstration plants of similar age that were still licensed to operate as of June 30, 1979.[2] Many of the smaller plants like Big Rock Point had been removed from operation. In comparing Big Rock Point with four other similar plants, it showed a capacity factor since its initial operation through June of 1979 of 52.2 percent. This compared favorably with the average of the five plants of 53.3 percent.

The Palisades plant does not compare as favorably with other similar plants. However, this is not due to

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[1]Capacity factor, relative to design capacity, is the percentage actually produced of the electrical energy that could have been produced if the unit had operated at its design capacity for all of the time during a period. Capacity factors of less than 100 percent result from operating units at less than their design powers, when the units are not shut down, and from outages, scheduled and forced.

[2]Bill Scanlon, memorandum to Special Joint Committee on Nuclear Energy (Lansing: Michigan Legislature, 1 November 1979) 1:22, data taken from Operating Units Status Report: Data as of 6-30-79, NUREG-0020, Vol. 3, No. 7, U.S. Nuclear Regulatory Commission, July 1979.

lack of operational expertise at Consumers Power, but rather to design errors resulting in erosion of the tubing of the steam generator. As was mentioned earlier, Consumers Power filed suit against five of the companies involved in the manufacturing/construction of the plant and won the case. As a result of the design problems, however, the plant was off-line from August 1973 until early 1975. The capacity factor of the Palisades plant, since initial operation, is therefore 37.0 percent as opposed to an average of 58.1 percent for the six plants of its type combined.

The performance of D.C. Cook 1 was compared with that of units with capacities greater than 1,000 megawatts which came on line before January 1, 1977. It compares favorably with a capacity factor of 60.5 percent as opposed to 54.2 percent average for eight plants combined. D.C. Cook 2 also compared favorably with a capacity factor of 66.8 percent against an average of 50.9 percent for the total of three plants in its category. The performance of D.C. Cook 2 was compared with that of units with capacities greater than 1,000 megawatts which came on line after January 1, 1977.

A second basis for comparing the performance of nuclear power plants is "forced-outage rates".[1] The four operating nuclear power plants have an average cumulative

[1]An "outage rate" is the percentage of time that a unit is out of service, i.e., not producing electricity. There are two types of outage: scheduled (e.g., for re-fueling or planned maintenance) and forced (e.g., when a problem arises requiring a shutdown of the reactor).

forced outage rate from the date of first commercial operation to June 30, 1979 of 20.4 percent.[1] At first glance, this figure would seem to indicate a high outage rate when compared with the average for all U.S. plants of 13.6 percent in the first six months of 1979, 9.5 percent for 1978, and 7.6 percent for 1977. However, only four operating plants make up the average for Michigan, and one of the four is only 63 megawatts (Big Rock Point). This plant is much smaller than the U.S. average, and its outage rate would tend to unfairly skew the Michigan average. In addition, the Palisades plant has had problems with the steam generator as mentioned before, which were unique - as indicated by the successful law suits by Consumers Power against the manufacturers and installers. The remaining D.C. Cook 1 and 2 with a cumulative forced-outage rate of 11.7 percent compares favorably with that of all U.S. nuclear plants combined of 13.6 percent in the first six months of 1979, 9.5 percent for 1978, and 7.6 percent for 1977. In addition, the outage rates and capacity factors tend to vary over a wide range from plant to plant, and the small number of plants in Michigan does not provide a

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[1] U.S., Department of Energy and Nuclear Regulatory Commission, Operating Units Status Report, Licensed Operating Reactors ("Grey Book"), Vol. 1, No. 9 (Sept. 1977) through Vol. 3, No. 7 (July 1979), as cited by Bill Scanlon, Committee Staff Director, in the "Staff Report on Incidents at Michigan's Operating Nuclear Power Plants", Special Joint Committee on Nuclear Energy (Lansing: Michigan Legislature, 15 October 1979), 1:4, p. 19.

statistically significant base for comparison to the national average. The wide range in operation experienced is indicated by comparing D.C. Cook 1 and 2, both of the same design and capacity, which have experienced a cumulative forced-outage rate of 6.0 percent and 17.4 percent respectively from the date of first commercial operation through June 30, 1979.

A third basis for comparison of Michigan's nuclear power plants to other nuclear plants is according to its compliance with U.S. Nuclear Regulatory Commission safety regulations. A system was designed by James Keppler, Director of Nuclear Regulatory Commission's Region III, to evaluate the regulatory performance of the nuclear power plants in his region (which includes Michigan). Director Keppler states:[1]

> I wish to make it clear that these numbers are useful for indicating trends from year to year but should not be used on an absolute basis to compare different plants. The reason for the latter is that different nuclear power plants have differing regulatory and reporting requirements which they must meet. This is due to the differences in plant design and the time frames in which the licenses were issued.

Director Keppler devised a weighting system for different incidences of noncompliance with Nuclear Regulatory Commission regulations. The heavier weights were assigned to those incidences which were considered to

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[1]James G. Keppler, Director, U.S. Nuclear Regulation Commission, Region III, letter to the Special Joint Committee on Nuclear Energy (Lansing: Michigan Legislature 23 October 1979), 1:5, pp. 1-6.

contribute more to the possibility of a dangerous situation developing. He also had records kept of the number of times a situation of noncompliance occurred. These separate incidences were multipled by the weights designated for their category, and added to achieve a total for each separate nuclear power plant in the region. In 1978, D.C. Cook 1 and 2 had a total of thirty-three incidences of non-compliance compared to a regional average of nineteen (six two-unit plants in Region III were taken as a basis for comparison). The weighted value of the noncompliance incidents was 290 for D.C. Cook 1 and 2 compared to 134 for the comparable plants in the region.

The Palisades plant experienced thirty-four incidences of noncompliance compared with an average of twenty-three in its category in Region III during 1978. The weighted value of the noncompliance incidents was 268 for the Palisades plant compared with 214 for the average of all five comparable plants in Region III.

Big Rock Point was not included in the rating system because the system was not applied to plants that are relatively old, or have peculiarities and problems that make meaningful comparisons with newer plants difficult.

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[1]James G. Keppler, Director U.S. Nuclear Regulation Commission, Region III, letter to the Special Joint Committee on Nuclear Energy (Lansing: Michigan Legislature, 30 June 1980), 1:6, p. 1.

It appears that on the basis of the three methods for comparing Michigan nuclear power plants with other nuclear power plants in the United States, i.e., average capacity factor, forced-outage rate, and incidences of regulatory noncompliance - that there could be some improvement. However, the improvement would not need to be of a large magnitude in order to attain the Region III and national averages for comparable plants. Also the unusual conditions regarding the operation of Big Rock Point and Palisades seem to account for much of the variation from the average.

Contribution of Nuclear Generated Electricity to Total Electricity in Michigan

A Look at Historic Contribution

Before looking at the role that nuclear power performs in providing electricity for Michigan, it would be helpful to compare Michigan's total capacity and consumption trends to that of the nation as a whole. The increase in total generating capacity (all types) in the State of Michigan since 1972 has been 63.9 percent compared with 51.1 percent for the United States.[1] However, the change in electrical consumption since 1972 in Michigan has been only 12.6 percent compared with 26.8 percent for the nation as a whole.

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[1]"Consumption of Electricity in the United States and Michigan", Staff Report, Special Joint Committee on Nuclear Energy (Lansing: Michigan Legislature, 23 June 1980) 1:23, pp. 3-4

It is clear that the slowing economic growth being experienced in the United States has had a disproportionate impact on the State of Michigan. As of December 31, 1979, the total installed electric-generating capacity in Michigan was 22,800 megawatts, or 3.7 percent of the U.S. total capacity of 615,686 megawatts at that time.[1] Michigan citizens consumed 77.1 billion kilowatt-hours of electrical energy in 1979.[2]

There are other Michigan trends that are noteworthy. The end uses of electricity in the residential, commercial, and industrial sectors differ markedly from those in the country as a whole. Approximately 3.5 percent less electricity is used in the residential, 4.5 percent less in the commercial, and 8.0 percent more in the industrial sector than in the United States as a whole.[3] These differences are due to the heavy concentration of industry in the state, and a lower percentage use in residential units of electric heat and hot-water systems.[4]

Regarding the percentage of electrical energy produced from nuclear fission in Michigan compared with the

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[1]Ibid. [2]Ibid.

[3]"Uses of Electricity Consumed in the United States and Michigan", Staff Report, Special Joint Committee on Nuclear Energy (Lansing: Michigan Legislature, 26 June 1980) 1:24, p. 1.

[4]Ibid.

nation as a whole, Michigan is certainly a leader. With the exception of the year 1974 when the Palisades plant was shut down, Michigan has consistently produced, since 1972, a greater percentage of electricity within its borders from nuclear fission than the United States as a whole. In 1972, Michigan produced 3.2 percent of its electricity from nuclear fission compared with 2.9 percent for the United States.[1] In 1979, 18.6 percent of the electrical energy produced in Michigan was from nuclear fission compared with 11.0 percent for the United States.[2] Approximately 12 percent of Michigan's total electricity is exported to other states, (mostly from D.C. Cook 1 and 2), and approximately 18 percent is imported.[3] Nuclear energy accounts for 5 percent of the total energy input to the Michigan economy.[4]

Looking at an Old Michigan Forecast

In 1962, a study leading to a long-term forecast for energy and the Michigan economy was proposed by Mr. Walker Cissler of Detroit Edison. The proposal was made at

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[1]"Sources of Electrical Energy Produced and Consumed in the United States and Michigan", Staff Report, Special Joint Committee on Nuclear Energy (Lansing: Michigan Legislature, 30 June 1980), 1:25, p. 3.

[2]Ibid. [3]Ibid.

[4]U.S., Department of Energy, Energy Information Administration, "State Energy Data Report", April 1980.

a meeting of the Michigan Economic Development Commission of the Michigan Department of Commerce. The proposal was carried out, and resulted in a book published in 1967.[1]

The published study was to make projections and forecasts up to and including the year 1980 for the different forms of primary energy - coal, natural gas, petroleum, hydroelectricity, and nuclear. It also placed the forecasts in perspective by outlining the prospects in key Michigan industries and the possibilities of financing economic expansion.

It is almost uncanny that a forecast was made for 18.7 percent of the electricity in 1980 to be produced by nuclear means.[2] This is almost identical to the 18.6 percent actually experienced in 1979.[3] Since little change in total Michigan installed capacity has occurred in 1980, the forecast was about as close as possible. It is true that in the same forecast a projected consumption of 95.3 billion kilowatt-hours in Michigan was made for 1980 (compared to 77.1 billion actually experienced in

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[1]Michigan Energy Survey Committee, Energy and The Michigan Economy: A Forecast (Ann Arbor: The University of Michigan, 1967).

[2]Ibid., p. 194; this forecast was made by James H. Climer, then Market Research Supervisor for Consumers Power Company.

[3]Sources of Electrical Energy Produced and Consumed in the United States and Michigan", Staff Report, Special Joint Committee on Nuclear Energy, 1:25, p. 3.

1979[1]). However the nuclear forecast retains a large amount of its validity because it did not suffer disproportionately as the growth in total electrical demand declined with a declining Michigan and national economic-growth rate.

The 1967 study was certainly cognizant of Michigan's dependence on the automobile industry and the disproportionate impact of national economic swings.[2]

> Modern transportation and communication techniques mean that any region is highly responsive to changes in the national economy. It cannot be emphasized too often that this is particularly true for a region such as Michigan whose economic fortunes are so closely tied to a single industry with nationwide markets.

Nuclear Power's Future Contribution

The future contribution of nuclear power to the total electrical supply in Michigan is very difficult to anticipate at this time. It is known that the average lead time for bringing on line a nuclear power plant is ten to fourteen years - and even longer in some cases. However, the lead time is determined more by the regulatory process (which seems to be very dependent on the political climate) than by any other single factor. Evidence of this is found in the completion of some early U.S. nuclear power

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[1]"Consumption of Electricity in the United States and Michigan", Staff Report, Special Joint Committee on Nuclear Energy, 1:23, p. 4.

[2]Michigan Energy Survey Committee, Energy and The Michigan Economy: A Forecast, p. 47.

plants in approximately three years, and the current completion times being experienced in some other western nations of well under ten years. It can be projected with some certainty what the nuclear capacity will be in Michigan in 1990, i.e, simply the present installed capacity plus the Midland and Fermi 2 units which are well on their way to completion. It is unlikely that any regulatory reforms or change in public attitude would allow any additional nuclear capacity to be on line by 1990. Beyond 1990 there will probably be more nuclear power.

The current attitude of the major utilities in the state is pessimistic for the short term. Consumers Power remains, in theory, committed to nuclear power. However, while John Selby, President of Consumers Power, has made it clear that he remains determined to complete the Midland plant, he said on at least one occasion that he regretted that it had ever been started.[1] Gordon L. Heins, Vice President of Systems Operations at Consumers Power, also made a recent statement that the company had no present plans for future nuclear power plants.[2]

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[1]John R. Emschwiller, "Nuclear Nemesis: Using the Law's Delay, Myron Cherry Attacks Atomic Power Projects", The Wall Street Journal, 10 March 1978, p. 1; as cited in Constance Ewing Cook, Nuclear Power and Legal Advocacy (Lexington, Mass.: D.C. Heath, 1980), p. 105.

[2]Gordon L. Heins, Vice President, System Operations, Consumers Power Company, at "Energy Forum" on the Michigan State University Campus, 9 October 1980.

What is really being said is that there will be no more nuclear plants built in the present regulatory climate.

Although Wayne Jens, Vice President of Nuclear Operations at Detroit Edison, was pessimistic regarding the near-term purchase of any nuclear power plants,[1] he affirmed that Detroit Edison will definitely consider future nuclear generation projects.[2] Walter J. McCarthy, Jr., President and Chief Operating Officer of Detroit Edison, also stated the Company's position in an address prepared for "Energy Event '80" in Troy, Michigan:[3]

> All of the technical, strategic, and managerial reasons still exist today for the development of new nuclear power plants. What does not exist is a clear government policy that is fairly sure to persist for a long enough period of time that utility managements can be sure of completing the plant, of being able to predict its costs, and be able to operate it upon completion. Nuclear power - can America really do without it? I don't think we can do without it.

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[1]Interview with Wayne H. Jens, Vice President, Nuclear Operations, Detroit Edison Company, Detroit, Michigan, 12 November 1980.

[2]Wayne H. Jens, Vice President, Nuclear Operations, Detroit Edison Company, "Testimony, State of Michigan Before the Michigan Public Services Commission, In the Matter of the Application of the Detroit Edison Company for Accounting and Ratemaking Authority Relating to Its Greenwood Nuclear Units 2 and 3 Projects" (Case No. U-6474), Spring 1980, p. 43.

[3]Walter J. McCarthy, Jr., President and Chief Operating Officer, Detroit Edison Company; address delivered at "Energy Event '80" in Troy, Michigan, 5 May 1980, pp. 16-17.

A recent study of the Energy Administration of the Michigan Department of Commerce has projected the Michigan nuclear capacity in the year 2000 to be 10,320 megawatts.[1] This would be 5,009 megawatts more capacity than that presently operating and under construction. This forecast, if met, would require the construction of roughly five more modern-sized nuclear power plants in Michigan by the year 2000.

The Michigan Energy and Resource Research Association (MERRA), in its 1980 "White Papers" report,[2] made a projection of nuclear capacity in the year 2000 for Michigan by extrapolating in a different manner from the data utilized in the aforementioned Michigan Department of Commerce report. MERRA used U.S. Department of Energy historical data to determine that a single 1,000-megawatt nuclear plant produces approximately 0.06 quad of energy per year. Based on the "most probable" estimate of about one-half quad of nuclear energy by the year 2000, MERRA estimated that five new 1,000-megawatt nuclear generating plants would be required by the year 2000. These five plants

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[1]Michigan, Department of Commerce, Energy Administration and the Michigan Energy and Resource Research Association (MERRA), Michigan Energy Prospects to the Year 2000 (Lansing: Michigan Department of Commerce, November 1979), p. 19.

[2]Michigan Energy and Resource Research Association (MERRA), Toward a Unified Michigan Energy Policy ("White Papers" series) (Detroit: MERRA, 1980), p. 148.

do not include the Midland and Fermi 2 plants now under construction. It is interesting that the Michigan Department of Commerce and MERRA made the same projections for additional capacity for the year 2000 by two different methodologies.

Impact of Electric Automobiles on Demand for Electrical Power in Michigan

There is much discussion about the rate at which electric automobiles will be introduced into the market. There is also a large question as to the impact it will have upon the need for additional electrical-generating capacity. Martin W. Gilmore of the Governor's Energy Awareness Advisory Committee made a recent statement that from 25,000 to 40,000 electric vehicles could be on Michigan highways by the end of 1983.[1] Electric automobiles are not new, but they are receiving a lot more attention of late - especially at the "Michigan Energy Expo '80", in the Fall of 1980. The major automobile manufacturers have prototypes that operate from lead-acid batteries. The Bradley Company, which manufactures various automobile accessory kits, is presently marketing an electric automobile for $14,400. Half of its weight is made up of 1,600 pounds of lead-acid storage batteries that must be periodically recharged.

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[1]Interview with Martin W. Gilmore, Program Director, Michigan Governor's Energy Awareness Advisory Committee, Lansing, Michigan, 8 August 1980.

If electric cars were recharged during the night at off-peak periods, there could be an increased use of now under-utilized existing capacity. This would be a welcome increase in business for the utilities if such a pattern of recharging were to evolve.

In its _1979-1980 Long-Term Electric Forecast Summary_,[1] Consumers Power Company projected an average annual increase in electrical demand due to electric vehicles from 1979-1994 of 0.2 percent. The forecast assumes that the marginal penetration of new passenger electric vehicles will reach about 12 percent by 1989 and about 14 percent by 1994. This would imply that up to 10 percent of total passenger cars by 1994 would be electric.[2] The projection made by Consumers Power of 1,390 million kilowatt-hours for electric vehicles in 1994,[3] was based on interviews with automobile-industry personnel, among other sources.[4]

The Detroit Edison Company was not as optimistic in its long-term forecast for electricity to be supplied for electric vehicles, i.e., 208.8 million kilowatt-hours

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[1]Consumers Power Company, _1979-1980 Update: Long-Term Electric Forecast Summary_ (Jackson, Michigan: Consumers Power, 1979), p. 1:7.

[2]Ibid., p. 1:22. [3]Ibid.

[4]Interview with Philip L. Bickel, Director of Corporate Planning, Consumers Power Company, Jackson, Michigan, 21 October 1980.

by the year 1994.[1] However, the principal engineer for load forecasting suggested that the projection would perhaps be revised upward in the future.[2]

An interesting twist that would increase greatly the demand for electric automobiles, and in turn the demand for cheap and abundant electricity, could be in the making at Lawrence Livermore National Laboratory in California. At the present time, an "aluminum-air fuel" electric cell is being developed with ten to fifteen times the power output per pound of the lead-acid cell.[3] Such cells would not be recharged but rather would have their aluminum plates replaced every 1,000 to 3,000 miles. At the time of replacement, a reaction product would be removed for recycling. A prototype aluminum-air-powered vehicle could be on the road by 1986 with an accelerated program - according to John F. Cooper, a research chemist who helped develop the cell.[4] If such cells are feasible, a viable method of

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[1]Detroit Edison Company, Load Forecast: Electric Energy Use and Demand 1981-1995 (Detroit: Detroit Edison, 2 October 1980), Table A-14B.

[2]Interview with George L. Ball, Principal Engineer-Load Forecasting, Detroit Edison Company, Detroit, Michigan, 12 November 1980.

[3]"Aluminum and Water-Fueled Cell Looks Good in Tests for Electrics", Energy Insider, Vol. 3, No. 22 (Washington, D.C.: U.S. Department of Energy, 27 October 1980), p. 8.

[4]Ibid.

decreasing reliance on oil imports would have been found - and for a sector of the economy (i.e., transportation) that has not been amenable to such shifts to alternative energy sources in the past. Since large amounts of electrical energy are required to make aluminum, (and no doubt to recycle the "reaction product") there could be an unforeseen demand for large nuclear plants, justified to a great extent on the basis of national security. The Pacific Northwest, where a large amount of aluminum manufacturing is centered, has already begun to turn to nuclear power - as the potential for cheap hydroelectric power has been practically exhausted.

Overall Projected Electricity Demand for Michigan

In spite of the economic recession currently impacting the electricity demand in the State of Michigan, both Consumers Power and Detroit Edison are projecting growth in electricity demand to continue in the years ahead, although at a much slower rate than the traditional annual seven percent experienced in the early 70's. Consumers Power Company is projecting an average annual growth rate in demand of 2.75 percent between the years 1979 to 1994.[1] The Detroit Edison Company is projecting an average annual

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[1]Consumers Power Company, 1979-1980 Update: Long-Term Electric Forecast Summary (Jackson, Michigan: Consumers Power, 1979), p. 1:2.

growth rate in demand of 2.72 percent during the same period using 1979 as the base.[1]

Impact on Michigan of Nuclear Shutdowns or Delays

The impact of a nuclear moratorium either in Michigan or nationally would have large impacts on (1) oil burned for generating electricity, (2) electrcity costs to consumers, and (3) electrical-system reliability. For example, with regard to the Midland nuclear plant now under construction, each year of delay in completing the plant results in an additional burning of 1.5 million barrels of oil.[2] This amounts to slightly over four percent of the 34,667,312 barrels of oil produced in Michigan in 1978.[3] A similar increase in oil use might be expected if Fermi 2 were shut down after it began operation,[4] or a total of near nine

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[1]Detroit Edison Company, Load Forecast: Electric Energy Use and Demand 1981-1995 (Detroit: Detroit Edison, 2 October 1980), p. I-1.

[2]David A. Lapinski, Senior Staff Engineer, Power Resources and System Planning, Consumers Power Company, letter to Tommy J. McPeak (Jackson, Michigan: Consumers Power Company, 6 November 1980).

[3]Michigan, Department of Commerce, Energy Administration and the Michigan Energy and Resource Research Association (MERRA), Michigan Energy Prospects to the Year 2000 (Lansing: Michigan Department of Commerce, November 1979), p. 25.

[4]David A. Lapinski, Senior Staff Engineer, Power Resources and System Planning, Consumers Power Company, letter to Tommy J. McPeak (Jackson, Michigan: Consumers Power Company, 6 November 1980).

percent of the oil produced in Michigan in 1978 from the inoperation of just these two plants.

If a nuclear moratorium were imposed in the State of Michigan, the net replacement-power cost in 1981 for Consumers Power alone would be $240 million, increasing to $625 million by 1985.[1] If there were a national moratorium on nuclear power plants, the net replacement power cost in 1981 for Consumers Power would be $311 million, increasing to $703 million by 1985.[2] Without the Palisades, Big Rock, and Midland nuclear power plants, the electrical load will exceed installed capacity by 1987, and rotating blackouts might be needed to keep load in step with capacity.[3]

Review of Some Conclusions of the Michigan Energy Resource Research Association (MERRA)

The Michigan Energy and Resource Research Association's "White Papers" recognizes the cutback in plans for U.S. nuclear plants in the past few years.[4] However, it regards this reduction to be primarily the result of adverse economic conditions and reduced forecasts for electricity

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[1]D.M. Zwitter and M.J. Hipple, Consumers Power Company, internal correspondence to Gordon L. Heins (Jackson, Michigan: Detroit Edison, 14 June 1979). p. 1.

[2]Ibid. [3]Ibid.,attached memorandum, p. 2.

[4]Michigan Energy and Resource Research Association (MERRA), <u>Toward a Unified Michigan Energy Policy</u>, p. 143.

demand rather than a rejection of nuclear power.

MERRA also argues for a balanced approach to the energy situation, in which nuclear power will play an integral part:[1]

> While other energy forms (other than nuclear) may be used to generate electricity, certain economic and legislative constraints on oil and gas; production, transportation, and environmental constraints on coal; and a number of practical scientific and engineering constraints on alternative energy forms require that we utilize all power and cost-effective technologies available, resulting in a generation mix, rather than relying totally on any one source of primary energy.

The point is well taken that if there were a reversal in the current economic trends, especially in the industrial community, the impact on future generation supply to meet demand could be dramatic. The difficulty in forecasting demand over the ten-to-fourteen-years lead time for construction of a large coal or nuclear power plant is very problematical. The lead times for large power plants are considerably longer than the lead times for making industrial-plant additions - in the event of an economic upturn. The need to maintain adequate reserve margins is also emphasized in order to meet unexpected load demands. These unexpected load demands could be due to unusually severe weather conditions in the immediate service area or in surrounding areas that might thereby be unable to assist the stricken area in Michigan. It would not be wise to be

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[1] Ibid.

totally dependent on oil because of the heavy importation content (approximately fifty percent). Nor would it be well to depend exclusively on coal - because coal-generated electric capacities can be threatened or cut back by wet, frozen, or strike-depleted coal supplies.[1]

MERRA projects a gradually decreasing growth rate in electricity demand, compared with historical averages, in the coming years. There is also a shift expected in the utility industry's mix in generating capacity. The trends indicate an increase in coal utilization, and a decrease in oil and natural-gas burning through 1990. The slack left by restriction in oil and natural-gas burning will be made up for with increased nuclear power generation, whose contribution will accelerate near and after 1990.[2] The shifts that are projected, according to MERRA, do take into account the "economic and political factors confronting the electric utility industry",[3] i.e., <u>in spite of</u> the political factors affecting nuclear power. The current significant legislative pressure to reduce or eliminate oil and natural gas as long-term fuel for new generating

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[1]<u>Nucleonics Week</u>, Vol. 19, No. 10, 9 March 1978, p. 1, as cited in Michigan Energy and Resource Research Association, <u>Toward a Unified Michigan Energy Policy</u>, p. 144.

[2]Michigan Energy and Resource Research Association, <u>Toward a Unified Michigan Energy</u>, p. 145.

[3]Ibid.

stations is expected to continue for the foreseeable future. This will undoubtedly make nuclear power more attractive in the future, being the only viable alternative for generating large amounts of electricity, other than coal.

Michigan is almost entirely contained within the power-grid system called the East Central Area Reliability Coordination Agreement (ECAR) extending to the west border of Indiana, to the south border of Kentucky, and to the east border of West Virginia. The projected reserve margin in Michigan is about 1.4 percent less than the projected ECAR average, but the estimates for growth in net energy demand and peak hourly demand are also 1.0 percent less.[1] However, should the planned electrical-plant additions be delayed, MERRA feels that difficulties in meeting demand will occur. It also suggests the possibility that they may be more serious than in ECAR as a whole because of the smaller projected Michigan reserve margin.[2]

MERRA is optimistic for the future of nuclear power in the U.S., and also in Michigan. As was mentioned earlier, it is in agreement with a projection of five new 1,000-megawatt nuclear plants on line by the year 2000. It also speaks optimistically of the breeder reactor, suggesting that any problems of implementation will not require major new technical discoveries:[3]

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[1]Ibid., p. 147. [2]Ibid., p. 148. [3]Ibid., p. 156.

Although a major engineering effort is necessary to demonstrate and deploy any energy concept, no technological breakthroughs are required for the LMFBR (Liquid Metal Fast Breeder Reactor).

MERRA has several conclusions that are noteworthy:[1]

1. Nuclear power is technologically capable of assuming a greater role in the energy picture of the state, if social and political forces are tempered with the resource realities of the future.

2. With the use of nuclear cogeneration for process heat and other projected applications, significant portions of our total energy production may also be nuclear generated in the future.

3. Increased electrification of the economy will be necessary to support greater industrialization, newer technologies, and pollution-preventing and resource-conserving devices such as electric cars. Nuclear energy will be required to supply an increasing portion of this need.

MERRA feels the State of Michigan should undertake a study to determine how it can best be assured of future sites for construction of energy-generation projects - nuclear included. Any steps taken should consider all resource limitations, environmental restrictions, political opposition, with due regard for public health and safety.

Regarding policy recommendations, MERRA rejects the idea of a nuclear power moratorium, whether a state-imposed ban or from the federal level in the form of moratoria on licensing, construction, or operation of proposed, under construction, or operating nuclear power plants in the State of Michigan. The constitutionality

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[1] Ibid.

of such a move is questioned, in addition to whether a strong and growing Michigan economy could be maintained without existing and planned nuclear power plants. Cooperation with federal authorities is argued for, in order to find ways to site, license, and construct plants within a short time period - largely by means of regulatory reform. The same cooperation is encouraged in the search for satisfactory locations for nuclear-waste repositories.

Finally, MERRA concludes that Michigan should become an "Agreement State" under the provisions of Section 274b of the Atomic Energy Act. Michigan was authorized to do this under Public Act 54 of 1965, but has not yet done so.[1] The purpose of assuming this status is so that Michigan can share certain of the federal regulatory functions now reserved for the Nuclear Regulatory Commission without such an agreement. The net result of such participation would be an increase in the expertise and capabilities in the area of nuclear energy and radiological health.

Review of Michigan Society of Professional Engineers' Policy Statement[2]

This policy statement, arrived at "after debate and due consideration", is addressed to the State of Michigan.

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[1] Ibid.

[2] Michigan Society of Professional Engineers, "Nuclear Power Policy", statement; (Lansing, Michigan: Michigan Society of Professional Engineers, 7 April 1979).

It encourages development of all U.S. energy options in view of the heavy dependence on imported oil and the growing instability of many oil-producing regions of the world. It agrees with the National Academy of Sciences[1] and Ford Foundation[2] studies that coal and uranium will be primary fuels for electric power production for the next twenty years.

The Michigan Society of Professional Engineers concede that the uses of neither coal or nuclear power are without risks - yet the risks are "acceptable". Compared with coal for electrical generation, "nuclear energy, at its present advanced state of development and deployment, is felt to be the cleanest, safest, and least expensive option". Several components to an overall nuclear program are recommended:[3]

1. Presidential support for an accelerated light-water-reactor construction program.

2. Accelerated project for disposal of military nuclear wastes as a demonstration effort for high-level wastes from commercial power plants.

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[1]National Academy of Sciences, Committee on Nuclear and Alternative Energy Systems (CONAES) Energy In Transition: 1985-2010 (San Francisco: W.H. Freeman, 1979).

[2]Resources for the future - administered and sponsored by the Ford Foundation, Energy: The Next Twenty Years (Cambridge, Mass.: Ballinger Publishing, 1979).

[3]Michigan Society of Professional Engineers, "Nuclear Power Policy", statement; (Lansing, Michigan: Michigan Society of Professional Engineers, 7 April 1979).

3. Greater certainty in the Nuclear Regulatory Commission licensing process with a view toward ultimately cutting the review period by one-half.

4. A national educational program on nuclear power.

5. Continued nonproliferation efforts.

6. Resumption of spent-fuel reprocessing, breeder-reactor development, and expeditious construction of off-site spent-fuel storage faciltes.

The Policymaking Process and Michigan's Electrical Energy Future

Supported by a National Science Foundation grant, some professors at the University of Michigan have developed a system called "Valve-Oriented Social Decision Analysis" (VOSDA).[1] In a letter to the Special Joint Committee on Nuclear Energy of the Michigan State Legislature,[2] they discuss alternatives in the energy policy-making process with regard to electrical utilities. They believe that the most effective actions which could be taken by the Michigan Legislature to deal with the energy issues would be in the choice of an appropriate policy-making process rather than attempting to choose between various alternative energy options, e.g. nuclear, coal, conservation, solar, etc.

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[1]Kan Chen, J.C. Mathes, Keman Jarboe, and Sydney Solberg, Value-Oriented Social-Decision Analysis (VOSDA), funded by NSF Grant OSS77-16294, 1 January 1978 to 31 December 1980, (Ann Arbor: The University of Michigan).

[2]Kan Chen and others, "The Policymaking Process and Michigan's Electrical Energy Future", letter to Special Joint Committee on Nuclear Energy (Lansing: Michigan Legislature, 9 June 1980), 1:28.

Three theoretical levels of energy-policy decisions are presented.

The first level has to do with regulatory policy-making which has been traditionally carried on by the Michigan Public Services Commission in cooperation with the legislative process. These policies have to do with granting of franchises to utilities and setting allowable rates of return on investment.

Strategic planning is the second level of energy-policy decision-making. This planning has traditionally been done by the utilities themselves. This is one of the most sophisticated types of planning that a utility does. It requires an understanding of the demands and trends in demand of various segments of the electrical marketplace. To give an idea of the complexity of this process, an overview will be presented of the "potential independent variables" that Consumers Power Company took into consideration in preparing its 1979-80 electric forecast update.[1] For the residential sector, eighteen potential independent variables were "attempted";[2] for the commercial sector, there were thirteen variables;[3] for the industrial sector, there were fourteen variables.[4]

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[1]Consumers Power Company, 1979-1980 Update: Long-Term Electric Forecast Summary, (Jackson, Michigan: Consumers Power, 1979).

[2]Ibid., p. 12. [3]Ibid., p. 16. [4]Ibid., p. 18.

Working with this total of forty-five independent variables requires large amounts of historical data, future projections from diverse sources, and a tremendous degree of expertise to arrive at required annual projections of demand and supply extending fifteen years into the future.

The third level of energy-policy decision-making is the operational planning level. This sphere of planning focuses on specific choices such as power-plant size, location, timing, type, and connection with the existing power grid. This level has also traditionally been handled by the power companies, but has been increasingly influenced by political and social factors.

The University of Michigan study group identified to the Special Joint Committee on Nuclear Energy four basic models for the energy-policymaking process:[1]

1. Private utilities continue to do both strategic and operational planning; the State is limited to its traditional role of monitoring and approving these plans.

2. The State does both strategic and operational planning; private utilities merely implement these plans.

3. The State contributes to and cooperates in strategic planning by the private utilities as well as approves the strategic plans after they are produced, leaving operational planning to the utilities.

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[1]Kan Chen and others, "The Policymaking Process and Michigan's Electrical Energy Future", letter to Special Joint Committee on Nuclear Energy (Lansing: Michigan Legislature, 9 June 1980), 1:28, pp. 2-3.

4. The State produces strategic plans upon which private utilities are directed to develop a set of consistent operational plans, which will be examined and approved by the State.

There is general agreement between the utilities that there must be a degree of cooperation in the policy-making process. However, there is sharp disagreement as to what level the cooperation should take place on. The study group lists the pros and cons of each of the four alternatives above. One of the strongest pros for the choice of option one (status-quo) is that "it has worked in the past".[1] One of the strongest cons of option four is that "the State does not now, and will not likely in the future, have a viable process and the technical knowledge to do strategic planning".[2]

It is doubtful that there will be any dramatic changes in the policymaking process which would include quantum increases in State participation. However, the threat of such participation, growing out of social and political issues surrounding the nuclear-power option, has unquestionably affected the strategic and operational planning by the utilities.

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[1]Ibid., p. 4

[2]Ibid., p. 6.

Discussion of Michigan Legislature Special Joint Committee on Nuclear Energy: May 1979 to September 1980

The Special Joint Committee on Nuclear Energy was created by the Michigan Legislature in May of 1979 by House Concurrent Resolution 160 to study a range of issues related to nuclear energy in Michigan. In addition, it investigated various possible alternatives for meeting the future electrical-energy needs in the State. Seventeen meetings were held: one for organizing, two for establishing formal findings and recommendations, and the remaining fourteen for having expert testimonies from various government officials and informed citizens. Among other questions, the Committee discussed the possibility and impact of nuclear accidents, Michigan's preparedness for an emergency, the economics of nuclear energy, radioactive wastes, alternative energy sources and their economic feasibility, and Michigan's energy-policymaking processes.

In the draft final report of the Committee,[1] it is clear that there has been a degree of energy wisdom imparted to its members. Throughout the proceedings, extending over approximately fifteen months, there were testimonies favoring nuclear power, and those opposing it. There were very few "neutral" testimonies, the neutrality

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[1]Special Joint Committee on Nuclear Energy, <u>Final Report: 2nd Committee Draft</u> (Lansing, Michigan: Michigan Legislature, 8 September 1980).

being assessed by the observed biases apparent in the testimonies. The content of the testimonies and the degree to which one-sided data were employed to substantiate claims, testify to the very emotional and political nature of the nuclear-power issues.

Three basic questions were addressed by the Committee:[1]

1. What are the feasible alternatives to the use of nuclear energy?

2. How are public-policy decisions being made on nuclear energy and other methods, and how might these decision-making processes be improved?

3. What are issues of particular significance related to nuclear power itself which should be of concern to State government in Michigan?

The first question presupposes that there are feasible alternatives to the use of nuclear energy. The fact of its being asked presupposes that alternatives should be sought. The conclusions of the Committee correctly do not focus on alternatives in the sense of "replacements" for nuclear energy, but rather upon a conservation-renewable resource path. Of course the successful implementation of such a path is out of the sphere of interest of the nuclear-power industry, and probably out of the sphere of control of any governing body - local, state, or national. However, it is not out of the control of the free-market mechanism which still largely allocates supply and demand

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Ibid., p. 3.

for electricity. Regarding the two alternatives of coal and nuclear for generating electricity, the Committee did conclude that:[1]

> Quantitatively, the health risks associated with power from coal-fired plants are probably higher than those associated with power from nuclear plants . . .

Regarding the second question, it was concluded that the utilities largely made the policy decisions on electrical-energy production in Michigan. It also concluded that there is currently no capability in Michigan State government for independently evaluating the electrical energy needs of the future, in the State. It also concluded that it does not presently possess the capability for deciding between the best alternatives or for particpation in the decision-making for energy policy.[2]

The Committee's third question, relating to nuclear power issues of "particular significance", focused on several widely debated issues. The issue of waste disposal was properly characterized as involving more than just technical questions, which the Committee observed were largely answered - in the view of "many experts".[3] Other issues considered were the possibility of nuclear accidents and the steps necessary to protect the surrounding population.

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[1]Ibid., p. 11. [2]Ibid., p. 15. [3]Ibid., p. 17.

In concluding a discussion on the present and projected roles of nuclear power in Michigan, it can be said with some certainty that there will be more of it, if those currently having control over the implementation process retain their control. There is currently no expertise to replace that amassed by the utilities over years of experience in supplying cheap and abundant energy in the most useful form of electricity. It is doubtful if an alternative source of such expertise could be assembled without dramatically increasing the costs of electrical energy.

The Special Joint Committee on Nuclear Energy of the Michigan Legislature made a statement early in its findings which summarizes well the overall nuclear-power and energy situation:[1]

> Nuclear power is a complex technology for producing electrical energy with steam-driven generators of enormous generating capacity. Because use of nuclear-power technology has serious economic, social and environmental consequences and because uses of other available technologies for meeting electrical energy needs have such consequences also, public-policy decisions relating to nuclear power are among the most difficult and challenging. Such policy decisions cannot be made by considering nuclear power alone. Every method for meeting electrical-energy needs, by reducing the need for electrical energy or by building electrical-generating capacity, has advantages and disadvantages . . . benefits and costs.

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[1] Ibid., p. 3.

The next two chapters explore the current impact of past and present U.S. choices with regard to the role that nuclear power plays in meeting energy demand. The degree of this impact is measured in terms of imported oil that is required to replace the energy that could have been supplied by the nuclear power plant capacity shortfall for the year 1980. This imported-oil-equivalent is then quantified both in terms of percentage of total oil imports as well as the amount of imported oil that can potentially be replaced by every installed megawatt of nuclear power.

CHAPTER 6

THE NUCLEAR POWER SHORTFALL

Background for Determining the Shortfall

There were a total of seventy-one operational nuclear power plants in the United States at the start of 1980.[1] These plants represented a "nameplate rating" capacity of 54,594 Mw.[2] Capacity expressed as "nameplate rating" refers to the actual rated output of the electrical generators of a power plant. There is about a five percent difference in nameplate rating capacity and net capacity,[3] which is nameplate rating capacity less the needs of the power plant. Another kind of capacity is "maximum dependable capacity" which represents the dependable main-unit net capacity, and varies throughout the year because the unit efficiency of each generator varies with seasonal cooling water temperature variations which can be significant.

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[1] U.S., Department of Energy, Energy Information Administration, Annual Report to Congress 1979, 3 vols., n.d., 2:153.

[2] Melvin E. Johnson, telephone interview, U.S. Department of Energy, Energy Information Administration, Coal and Electric Power Statistical Division, Office of Data and Interpretation (Washington, D.C.), 17 December, 1980.

[3] U.S., Department of Energy, Energy Information Administration, Monthly Energy Review, September 1980, p. 102.

Usually maximum dependable capacity is the highest net dependable output of the turbine generator during the most restrictive seasonal conditions (usually summer).[1] For the purposes of this discussion, nameplate rating capacity will be used. This method of expressing capacity was selected because it can be applied to both nuclear and non-nuclear power plants, and it does not vary due to changes in efficiency of operation throughout the year. Where forecasts are analyzed that were expressed in something other than nameplate rating capacity, the forecasts were modified to express nameplate rating capacity.

The nuclear capacity forecasts which will be evaluated here were made between 1964 and 1975. The first two forecasts to be examined were obtained directly from very intensive government studies and the remainder were obtained from The Energy Index, which is a lengthy volume published annually by the Environment Information Center in New York.[2] The Energy Index contains various data and forecasts concerning the entire energy field. For the purposes of this investigation, all forecasts pertaining to nuclear power for the year 1980, that appeared in The Energy Index through 1975, were included. This is not

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[1]Ibid., p. 98.

[2]Environment Information Center, Energy Reference Department, The Energy Index, vol. 1 covering the period 1970-73, and one vol. per year thereafter, New York: Environment Information Center.

to suggest that all reputable forecasts were included by the publisher, but the forecasts should be representative in that they were at least a broad sampling. Also, since all of the nuclear forecasts published by The Energy Index were included, it was felt that any possible bias in the mathematical conclusions of this paper would be negated.

Before examining thirteen different forecasts in some detail, there are two concepts of electrical power generation that should be explained. One is "utilization" and the other is "efficiency". Utilization is usually expressed in percent and is also referred to as "productivity" as well as "average capacity factor". Simply stated, utilization is the ratio of the actual energy output of a power plant over a period of time (usually a year) to the maximum possible energy output of the same power plant operating at maximum rated capacity without any interruptions over the same period of time. To illustrate, the utilization of the total nuclear utility industry in 1979 will be calculated.

Nuclear capacity at the end of 1979 was 54,594 x 10^3 kw,[1] and nuclear power output in 1979 was 255,155 x 10^6 kwh.[2]

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[1]Kilowatt is denoted by "kw", and 1,000 kw is equal to one megawatt.

[2]U.S., Department of Energy, Energy Information Administration, Monthly Energy Review, September 1980, p. 62.

Using this current information,

$$U = E_0/C_{mr}, \quad (1)$$

$$= (255{,}155 \times 10^6 \text{ kwh/yr})/(54{,}594 \times 8{,}760 \times 10^3 \text{ kwh/yr})$$

U = .53352, or 53 percent, where

U = utilization,

E_0 = energy output in kwh/yr, and

C_{mr} = maximum rated energy output in kwh/yr.

Utilization has varied considerably over the years but becomes more stable on the average as the number of power plants increases. It is a highly erratic figure when only a few power plants are involved and when they are intermittent in operation. For example, the utilization for a single power plant could be one hundred percent if it operated continuously at maximum capacity for one year, but only seventy-five percent if it had to be shut down a fourth of the time for repairs, safety checks, modifications, or refueling, as is periodically necessary with nuclear power plants. During 1978, of the five non-communist countries with ten or more reactors, the United States had the highest utilization factor.[1]

However, the United States did not likely retain this lead in 1979 because of shutdowns for safety checks and modifications. The first of these major shutdowns was at five east-coast plants starting the week of

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[1] Ibid., March 1979, p. 70.

March 19, 1979,[1] and the second major shutdowns followed the Three Mile Island incident and began on April 27, 1979.[2] To demonstrate the effect of these shutdowns on utilization in the United States, the utilization factor for the month of May 1979 will be calculated.

The capacity of the plants involved in the first shutdowns amounted to 4,107 Mw[3] and that of the second totaled 8,149 Mw.[4] The sum of all shutdown capacities is 12,256 Mw or twenty-two percent of all year-end 1979 installed nuclear capacity. The power output for May 1979, essential for the determination of utilization, will be calculated based on the operating plants having the same utilization factor as all plants had in 1979.

Data:

utilization factor in 1979 -- .53352

remaining capacity operating after shutdowns -- 54,594 Mw - 12,256 Mw = 42,338 Mw.

Utilization:

$(X \text{ kwh output})/(42{,}338 \times 10^3 \text{ kw})(8{,}760) = .53352$,

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[1]"Life: An Atom-Powered Shutdown", Time, 26 March 1979, p. 55.

[2]Eliot Marshall, "Assessing the Damage at TMI", Science, 11 May 1979, p. 596.

[3]"Life: An Atom-Powered Shutdown", Time, 26 March 1979, p. 55.

[4]U.S., Nuclear Regulatory Commission, Annual Report 1979, February 1980, pp. 301-311, and Eliot Marshall, "Assessing the Damage at TMI", Science, 11 May 1979, p. 596.

and X = 197,872 x 10^6 kwh.

Utilization for May 1979:

(197,872 x 10^6 kwh)/(54,594 x 10^3 kw)(8,760) = .41375, or 41 percent.

It is clear from the above calculations what this kind of interruption can do to the annual utilization factor for the entire nuclear power industry. Moreover, utilization will probably not increase significantly in the near future based on past trends and the current 1980 situation. Utilization has gradually decreased since March of 1979 - the month prior to the Three Mile Island event.[1]

The term "efficiency" refers to the ratio of the amount of energy output of a power plant to the quantity of energy used to produce that output. The energy output is usually expressed in kwh and must be converted to British Thermal Units (Btu's) if efficiency is to be expressed as a percent, because energy sources are usually expressed in Btu's. Throughout the calculations of this discussion, one kwh was equated to 3,414 Btu.[2] Another method of expressing this relationship is by Btu input per kwh of output (Btu/kwh). The ratio for the nuclear power industry

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[1]U.S., Department of Energy, Energy Information Administration, Monthly Energy Review, September 1980, p. 70.

[2]See appendix 1, pt. h for derivation.

in 1979 was 10,769 Btu/kwh.[1] Efficiency can be derived as a percentage by one of the two following methods.

Data:

efficiency = (energy out)/(energy in).

Calculate efficiency:

(3,414 Btu)/(10,769 Btu) = .3170.

or

Data:

total energy output in 1979 -- 255,155 x 10^6 kwh

total energy inputs in 1979 -- 2.748 x 10^{15} Btu.[2]

Convert energy output to Btu equivalent:

(255,155 x 10^6 kwh)(3,414 Btu/kwh) = .8710 x 10^{15} Btu.

Calculate efficiency:

(.8710 x 10^{15} Btu)/(2.748 x 10^{15} Btu) = .3170.

The efficiency of nuclear power plants has remained almost constant for the past several years, as the data and calculations on table 3 indicate.

Nuclear power forecasts can be expressed in several different ways. The various methods include expression in terms of (1) generating capacity, (2) percentage of total generating capacity, (3) generated electricity,

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[1]U.S., Department of Energy, Energy Information Administration, Monthly Energy Review, September 1980, p. 107.

[2]Ibid., p. 6.

TABLE 3

NUCLEAR POWER PLANT EFFICIENCIES 1970, 72-79

Year	Capacity[a] (Mw)	Energy In[b] (10^{15} Btu)	Energy Out[c] (10^{9} kwh)	Btu Equivalent[d] (10^{15} Btu)	Efficiency
1970	6,000	.24	21.8	.0744	(.0744)/(.24) = .31
1972	15,000	.58	54.1	.185	(.185)/(.58) = .32
1973	21,000	.91	83.5	.285	(.285)/(.91) = .31
1974	32,000	1.27	114.0	.3892	(.3892)/(1.27) = .306
1975	40,000	1.90	172.5	.5889	(.5889)/(1.90) = .310
1976	43,000	2.11	191.1	.6524	(.6524)/(2.11) = .309
1977	50,000	2.70	250.9	.8566	(.8566)/(2.70) = .317
1978	54,000	2.98	276.4	.9436	(.9436)/(2.98) = .317
1979	54,594[e]	2.75	255.2[f]	.8712	(.8712)/(2.75) = .317

[a] U.S., Department of Commerce, Bureau of the Census, Statistical Abstract of the United States 1979, September 1979, p. 608.

[b] U.S., Department of Energy, Energy Information Administration, Annual Report to Congress 1979, 3 vols., n.d., 2:5.

[c] Ibid.

[d] Calculated from "power out" data at 3,414 Btu/kwh.

[e] Melvin E. Johnson, telephone interview, U.S. Department of Energy, Energy Information Administration, Coal and Electric Power Statistical Division, Office of Data and Interpretation (Washington, D.C.), 17 December 1980.

[f] U.S., Department of Energy, Energy Information Administration, Monthly Energy Review, September 1980, p. 62.

(4) percentage of total generated electricity, (5) energy inputs to nuclear power, and (6) percentage of total energy inputs to the economy. In the following forecast analyses, if the forecast was not made in terms of simple generating capacity, the generating capacity was extrapolated from the data given, by procedures which will be shown. This standardization of forecast data was necessary in order to derive the measurements in chapter 7 which are the major purpose of this discussion.

There are several factors that have introduced a slight but not significant error in the validity of some of the forecasts. One is the fact that most if not all the forecasts were based on an assumption of higher utilization than has been actually experienced in the nuclear power industry thus far. For example, one forecast made the assumption of an eighty-five percent utilization factor,[1] and another, seventy-five percent.[2] Since expectations for these high utilization factors seem to have been common until recently, it has been assumed in this paper that the other forecasts, which did not specify a utilization factor, were estimating a similarly high

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[1]U.S., Federal Power Commission, National Power Survey, 2 pts., October 1964, 1:204.

[2]U.S., Department of the Interior, Bureau of Mines, An Energy Model For the United States, Featuring Energy Balances For the Years 1947 to 1965 and Projections and Forecasts to the Years 1980 and 2000, by Warren E. Morrison and Charles L. Readling, information circular 8384 (Washington, D.C.: Government Printing Office), 1968, p. 114.

one. Where utilization factors were specified in the forecasts, the forecasts were adjusted upward on the basis of the fifty-three percent utilization factor experienced by the nuclear power industry during 1979. The rationale here was that what is really being forecasted is the contribution of nuclear power to the total electrical needs of the United States, and the variable of utilization would have to be compensated for by greater capacity. Eleven of the thirteen forecasts do not specify utilization however, and therefore there was no way to adjust the forecasts for their probable high estimates. This variable would tend to render forecasts lower than they would otherwise be.

A second factor contributing to the margin of error is the expectation of an efficiency which is higher than has been experienced to date. For example, one forecast based its projected capacity on an assumption of thirty-eight percent efficiency or an output of one kwh for every 8,900 Btu input.[1] While other forecasts did not specify efficiency factors, it must be assumed that some of them also counted on a higher-than-experienced efficiency factor. To the extent that they did, the capacity forecasts would be lower than necessary to meet the contribution of electricity anticipated from the nuclear power industry in the various projections.

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[1] Ibid.

A third error factor that would tend to compensate somewhat for the other two is the slowing of the rate of growth of energy usage that has been experienced in recent years.[1] It seems that no widespread anticipation existed for the Arab oil embargo of 1973-74, and until that time a continued growth rate not much less than had been experienced in the past was expected in the future. The forecasts of nuclear capacity which were made before the Arab oil embargo reflect this expectation.

During and after the embargo, one would expect the forecasts to have dropped because of the higher costs of energy which would tend to encourage conservation and therefore reduce the need for additional power plants. The forecasts did not drop however, because of the commitment of the Federal government, in response to the Office of the President, to make the United States energy-independent by 1985. This was the thrust of the much touted Project Independence of 1974 that was shelved by the end of that year. Again, it is not felt that these three error factors are large enough to significantly affect the measurements of this investigation, especially since the third factor would seem to offset the first two.

The thirteen long-term nuclear power forecasts to be examined are for the year 1980. At the time of this writing however, year-end 1980 data was not available.

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[1]See appendix 2, table 7.

Because of the lack of availability of year-end 1980 data and the likelihood of subsequent 1980 data revisions, the forecasts will be analyzed against year-end 1979 energy data.

This comparison with 1979 data will not present a problem because of the high degree of correlation between almost all the major 1979 and 1980 energy parameters. In addition, the long-term nuclear power forecasts which were expressed in terms of capacity, did not always indicate whether they applied to the beginning of 1980 (year-end 1979) or the end of the year. This analysis will deal with them as if they applied to the beginning of 1980.

To illustrate the small variation between year-end 1979 energy data and the probable 1980 year-end data, several types of energy information are compared. First of all, total U.S. energy consumption in 1979 was 78.022 $x 10^{15}$ Btu.[1] As of December 1980, the preliminary projection for total U.S. energy consumption in 1980 was 77. $x 10^{15}$ Btu.[2]

Second, the total installed electrical generating

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[1]U.S., Department of Energy, Energy Information Administration, Monthly Energy Review, March 1980, p. 2.

[2]Information Specialist, telephone interview, U.S. Department of Energy, National Energy Information Center (Washington, D.C.), 17 December 1980. This preliminary data came from the in-house publication: "Short-Term Energy Outlook - December 1980".

capacity at the end of 1979 was 598,298 Mw.[1] The total generating capacity as of October 31, 1980 was 608,875 Mw.[2] The October 31 figure probably includes four newly 1980-licensed nuclear power plants,[3] two of which were not on-line, and the other two "not up to full power".[4] The two plants not on-line are classified in a new category following the ending of the Nuclear Regulatory Commission (NRC) moratorium on the licensing of new reactor units. Since the two units are not licensed for on-line operation, there is a question as to whether they should even be included in operating capacity figures. The other two nuclear units not up to full power, and licensed in August and September 1980, will not make substantial contributions during the year. Therefore the year-end 1980 total generating capacity should not differ to a large extent from that of 1979.

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[1]Johnson, telephone interview, U.S. Department of Energy, 16 December 1980.

[2]Ibid.

[3]Susan F. Gagner, telephone interview, U.S. Nuclear Regulatory Commission, Public Affairs Office (Washington, D.C.), 16 and 17 December 1980. Salem 2 (1,115 Mw) and Farley 2 (829 Mw) were issued "limited licenses" to begin low-power testing in April 1980 and October 1980, respectively; North Anna 2 (907 Mw) and Sequoyah 1 (1,140 Mw) were issued full-power operating licenses in August 1980 and September 1980, respectively; these four plants represent 3,991 Mw generating capacity.

[4]Loring Mills, telephone interview, Edison Electric Institute (Washington, D.C.), 16 December 1980.

Third, there were seventy-one nuclear reactors[1] with a combined capacity of 54,594 Mw[2] operating at year-end 1979. The addition of two new plants licensed to operate in August and September, as mentioned in the preceding paragraph, does not change this figure substantially.

Fourth, the total electricity generated in 1979 was 2,247,372 million kwh[3] compared to 1,911,622 million kwh through October 31, 1980.[4] This most recent total can be projected through the end of 1980:

$$(1{,}911{,}622 \times 10^6 \text{ kwh/10 mo.})(12 \text{ mo.}) = 2{,}293{,}946 \times 10^6 \text{ kwh.}$$

This 1980 projection is only 2 percent above 1979:

$$(2{,}293{,}946 - 2{,}247{,}372 \times 10^6 \text{ kwh})/(2{,}247{,}372 \times 10^6 \text{ kwh}) = .02, \text{ or } 2 \text{ percent.}$$

According to Edison Electric Institute projections, there will only be about a 1.3 percent increase in the total

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[1]U.S. Department of Energy, Energy Information Administration, Annual Report to Congress 1979, 3 vols., n.d., 2:153.

[2]Johnson, telephone interview, U.S. Department of Energy, 17 December 1980.

[3]U.S., Department of Energy, Energy Information Administration, Monthly Energy Review, September 1980, p. 62.

[4]Johnson, telephone interview, U.S. Department of Energy, 16 December 1980.

electricity generated in 1980 over 1979.[1] It therefore appears that there will only be a minor change in total electricity generated in 1980.

Fifth, the electricity generated from nuclear power plants in 1979 was 255,155 million kwh[2] compared to 208,077 million kwh through October 31, 1980.[3] This most recent total can also be projected through the end of 1980:

$$(208{,}007 \times 10^6 \text{ kwh/10 mo.})(12 \text{ mo.}) = 249{,}608 \times 10^6 \text{ kwh.}$$

This is only 2 percent below that of 1979:

$$(255{,}155 - 249{,}608 \times 10^6 \text{ kwh})/(255{,}155 \times 10^6 \text{ kwh}) = .02,$$

or 2 percent.

The rate at which nuclear power is providing electricity will probably increase slightly through the end of the year with the licensing for commercial operation of the two aforementioned units in August and September 1980. Hence, the difference between 1979 and 1980 electricity generated from nuclear may be even less than two percent. It can be seen from the foregoing five comparisons

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[1]Carl Tolby, telephone interview, Edison Electric Institute (Washington, D.C.) 16 December 1980.

[2]U.S., Department of Energy, Energy Information Administration, Monthly Energy Review, September 1980, p. 62.

[3]Johnson, telephone interview, U.S. Department of Energy, 16 December 1980.

that the long-term nuclear power forecasts for 1980 can be analyzed against presently available year-end 1979 data. The results of these analyses should be very similar to those obtained from using year-end 1980 data, not currently available. All thirteen forecasts will be examined in order, from the oldest in 1964 to the most recent one selected, which was published in September of 1975. There is an apparent trend from higher to lower forecasted capacities.

1964 Federal Power Commission Forecast

The first forecast to be examined is from a lengthy two-volume outlook for the total power industry prepared by the Federal Power Commission over sixteen years ago, in 1964.[1] While this survey dealt with all aspects of the power industry, there was a noticeably significant optimism and emphasis with regard to the future of nuclear power. The 1964 Federal Power Survey was the most detailed of any of the forecasts examined, and the forecast for nuclear power in 1980 was expressed in a variety of ways: (1) 70,000 Mw installed capacity with a utilization factor of 85 percent,[2] (2) as a percentage (13.3) of total generating capacity,[3] and (3) 19 percent of total generated electricity.[4]

The accuracy of each one of these expressions

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[1] U.S., Federal Power Commission, National Power Survey, 2 pts., October 1964, pt. 1.

[2] Ibid., p. 204. [3] Ibid., p. 207. [4] Ibid., p. 204.

of nuclear forecasting will be evaluated separately. It should first be mentioned, however, that the respectability of the _Federal Power Survey_ was very high. To demonstrate this point, the following is a comparison of some of the projections made in 1964 and the most recent data from the U.S. Department of Energy for year-end 1979.

Total energy inputs into economy: 1964 _Federal Power Survey_ -- 82 x 10^{15} Btu,[1] and year-end 1979 data shows -- 78.02 x 10^{15} Btu.

Percent of total energy into electrical power: 1964 _Federal Power Survey_ -- 30.5 percent,[2] and year-end 1979 data shows -- 31.3 percent.[3]

Energy into electric generation: 1964 _Federal Power Survey_ -- 25.1 x 10^{15} Btu,[4] and year-end 1979 data shows -- 24.4 x 10^{15} Btu.[5]

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[1] Ibid., p. 37.

[2] U.S., Federal Power Commission, _National Power Survey_, 2 pts., October 1964, 1:37.

[3] See appendix 1, pt. i for derivation.

[4] U.S., Federal Power Commission, _National Power Survey_, 2 pts., October 1964, 1:37.

[5] U.S., Department of Energy, Energy Information Administration, _Monthly Energy Review_, September 1980, p. 25.

Total electrical energy output:

1964 Federal Power Survey -- 2.8 x 10^{12} kwh,[1] and year-end 1979 data shows -- 2.2 x 10^{12} kwh.[2]

Total installed capacity:

1964 Federal Power Survey -- 525 x 10^{6}kw,[3] and year-end 1979 data shows -- 598 x 10^{6} kw.[4]

With the exception of the forecasted total installed generating capacity, these five parameters were remarkably accurate to have been made over sixteen years ago.

The first aspect of the Federal Power Commission forecast, i.e. 70,000 Mw installed capacity, differed from the year-end 1979 installed capacity of 54,594 Mw. However, the output (E_0) of 70,000 Mw at a utilization factor of eighty-five percent is much greater than the output of the same capacity at a utilization factor of fifty-three percent, the utilization factor experienced

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[1]U.S., Federal Power Commission, National Power Survey, 2 pts., October 1964, 1:35.

[2]U.S., Department of Energy, Energy Information Administration, Monthly Energy Review, September 1980, p. 62.

[3]U.S., Federal Power Commission, National Power Survey, 2 pts., October 1964, 1:35; the probable reasons for this low total capacity forecast were the expectations of much higher utilization of newer power plants with better technology, higher efficiency, and retiring of older equipment.

[4]Johnson, telephone interview, U.S. Department of Energy, 16 December 1980.

in 1979. The following calculations will demonstrate the difference utilization makes on total energy output.

Using equation (1) and the 1979 fifty-three percent U factor,

$$E_0 = UC_{mr}, \text{ therefore}$$
$$= (0.53)(70,000 \times 10^3 \cdot 8,760 \text{ kwh})$$
$$E_0 = 320 \times 10^9 \text{ kwh.}$$

For an eighty-five percent U factor,

$$E_0 = (0.85)(70,000 \times 10^3 \cdot 8,760 \text{ kwh})$$
$$E_0 = 520 \times 10^9 \text{ kwh.}$$

In order to make this forecast for 70,000 Mw capacity with a utilization factor of eighty-five percent valid, the capacity will have to be adjusted upward to achieve the forecasted power output at eighty-five percent utilization when the utilization in practice has only been fifty-three percent. The question therefore is: What capacity $(C_{mr}/8,760)$h would be required, operating at a utilization factor of fifty-three percent, to produce the same output as 70,000 Mw at a utilization factor of eighty-five percent?

Using equation (1),

$$C_{mr} = E_0/U, \text{ and capacity} = C_{mr}/8,760 \text{ hours}$$
$$\text{Capacity} = (520 \times 10^9 \text{ kwh})/(0.53)(8,760)\text{h}$$
$$= 110,000 \text{ Mw.}$$

It can be seen that the utilization factor is a very important part of a forecast since in this case it changed the capacity forecast from 70,000 Mw to 110,000 Mw, or an increase of fifty-seven percent. In order to apply this 1980 forecast to year-end 1979 installed capacity, a standard procedure will be employed throughout this discussion.

Nuclear shortfall:

110,000 Mw (nuclear forecast in 1964) - 54,594 Mw (year-end 1979 installed capacity) = 55,000 Mw (nuclear shortfall).

The second manner in which the Federal Power Commission expressed its forecast was as a percentage of total generating capacity, i.e. 13.3 percent.

Data: current total capacity is 598,298 Mw.

The forecast 1980 nuclear generating capacity is found by

(598,298 Mw)(.133) = 79,600 Mw.

Therefore the nuclear shortfall is

79,600 Mw - 54,594 Mw = 25,000 Mw.

The third method of expressing the 1980 forecast was as a percentage of total generated electricity, which was nineteen percent.

Data: year-end 1979 nuclear capacity was 54,594 Mw, total generated electricity was 2,247,372 x 10^6kwh, and the 1979 kwh generated per Mw of nuclear capacity was

4,673,682 kwh/Mw.[1]

The forecast 1980 nuclear power output is found by $(2{,}247{,}372 \times 10^6 \text{ kwh})(.19) = 430 \times 10^9$ kwh from nuclear, and the derived nuclear capacity forecast is found by $(430 \times 10^9 \text{ kwh})/(4{,}673{,}682 \text{ kwh/Mw}) = 92{,}000$ Mw.

Nuclear shortfall:

92,000 Mw - 54,594 Mw = 37,000 Mw.

The forecast of 92,000 Mw required to supply nineteen percent of the total electricity generated in 1980 is the forecast to be used in the conclusions of this chapter and Chapter 7. It best represents the intent of a nuclear forecast, i.e. to indicate the percentage contribution of nuclear power to the total power needs of the United States.

1968 Bureau of Mines Forecast

The second forecast appeared in 1968, and is a very detailed energy model for the United States prepared by Warren E. Morrison and Charles L. Readling of the U.S. Bureau of Mines.[2] Mr. Morrison lends a significant amount of credibility to his energy model because of his position as Research Coordinator in Energy Studies in the Bureau of

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[1]See appendix 1, pt. j for derivation.

[2]U.S., Department of the Interior, Bureau of Mines, An Energy Model For the United States, Featuring Energy Balances For the Years 1947 to 1965 and Projections and Forecasts to the Years 1980 and 2000, by Warren E. Morrison and Charles L. Readling, information circular 8384 (Washington, D.C.: Government Printing Office), 1968.

Mine's Division of Mineral Economics. He had no doubt learned from his experiences in preparing a similar report in 1964.[1] The 1968 report consisted of five "cases" and seventeen "composite cases" for a total of twenty-two different models for energy projections. The case selected for the nuclear forecast to be used here was the "conventional" energy model including all energy sources in the model.[2] In this model, a low and high nuclear capacity forecast was made along with accompanying energy inputs and outputs:

Low	High
70,000 Mw	110,000 Mw
4.076×10^{15} Btu in	6.434×10^{15} Btu in
458.0×10^{9} kwh out	723.0×10^{9} kwh out

total energy input to economy -- 88.0746×10^{15} Btu

As in the previous forecast, there are several methods of projection used. It would not be the best to use the capacities alone because first of all they are based on an assumption of a utilization factor of seventy-five percent.

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[1]U.S., Department of the Interior, Bureau of Mines, Summary Energy Balances for the United States: Selected Years 1947-62, by Warren E. Morrison, information circular 8242 (Washington, D.C.: Government Printing Office), 1964.

[2]U.S., Department of the Interior, Bureau of Mines, An Energy Model For the United States, Featuring Energy Balances For the Years 1947 to 1965 and Projections and Forecasts to the Years 1980 and 2000, by Warren E. Morrison and Charles L. Readling, information circular 8384 (Washington, D.C.: Government Printing Office, 1968), p. 114.

To demonstrate:

$(458.0 \times 10^9 \text{ kwh})/(70{,}000 \times 10^3 \text{ kw})(8{,}760) = .75,$

and

$(723.0 \times 10^9 \text{ kwh})/(110{,}000 \times 10^3 \text{ kw})(8{,}760) = .75.$

Nor would it be well to update these capacity forecasts on the basis of 1978 utilization because the 1968 forecast is based on an assumption of 88.0746×10^{15} Btu total energy into the economy, and the actual energy input to the economy in 1979 was 78.02×10^{15} Btu. This slowing down of total energy consumed in the United States was not anticipated by the writers of the 1968 forecast. It would also not be appropriate to derive a capacity forecast from the 1968 projections for "energy into" nuclear power for the reason of the total energy-growth slowdown, and also because the power plants were assumed to operate at an efficiency of thirty-eight percent.[1]

The best method of extrapolating a forecast from the 1968 forecast data would first be to determine what percent of the total energy consumed is forecast to be used in nuclear power plants. This percentage could be applied to the current updated expectation of total energy in 1980 and therefore updated nuclear energy inputs would be available, based on the overall decrease in energy growth in the United States.

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[1]Ibid.

The derived energy inputs to nuclear power can then be translated to kwh output, still using the assumed efficiency factor of thirty-eight percent. This new output should reflect the intent of the original forecast, incorporating the decrease in energy growth rate, and can be easily translated into capacity forecasts to attain the kwh-output derived by the procedure just described.

It would also be desirable to have a mid-range forecast from the 1968 projections since at the end of this chapter, an "average" shortfall in nuclear power will be determined from all of the forecasts, several of which have "low", "medium", and "high" divisions. A medium forecast was therefore extrapolated from the lower and upper projections of this 1968 forecast according to the following calculations:

6.434×10^{15} Btu - 4.0760×10^{15} Btu = 2.358×10^{15} Btu,

$(2.358 \times 10^{15}$ Btu$)/2 = 1.179 \times 10^{15}$ Btu,

and

1.179×10^{15} Btu + 4.0760×10^{15} Btu = 5.255×10^{15} Btu,

which is the mid-range forecast energy input.

Next is to determine what ratio of the total energy forecasted was projected to be diverted into nuclear power.

Low:

$(4.076 \times 10^{15}$ Btu$)/(88.0746 \times 10^{15}$ Btu$) = .04628$

Medium:

$(5.255 \times 10^{15}$ Btu)/(88.0746 $\times 10^{15}$ Btu) = .05967

High:

$(6.434 \times 10^{15}$ Btu)/(88.0746 $\times 10^{15}$ Btu) = .07305.

Then these results are applied to the year-end 1979 total energy inputs to the economy.

Low:

(.04628)(78.02 $\times 10^{15}$ Btu) = 3.611 $\times 10^{15}$ Btu

Medium:

(.05967)(78.02 $\times 10^{15}$ Btu) = 4.655 $\times 10^{15}$ Btu

High:

(.07305)(78.02 $\times 10^{15}$ Btu) = 5.699 $\times 10^{15}$ Btu.

The efficiency factor originally forecast was thirty-eight percent, and another way of expressing it is in Btu/kwh, i.e. 8,900.0 Btu input per one kwh output.[1] Therefore the energy output can be determined.

Low:

$(3.611 \times 10^{15}$ Btu)/(8,900.0 Btu/kwh) = 405.7 $\times 10^9$ kwh

Medium:

$(4.655 \times 10^{15}$ Btu)/(8,900.0 Btu/kwh) = 523.0 $\times 10^9$ kwh

High:

$(5.699 \times 10^{15}$ Btu)/(8,900.0 Btu/kwh) = 640.3 $\times 10^9$ kwh.

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[1] Ibid.

The kwh outputs can now be equated to nuclear capacity based on 4,673,682 kwh/Mw (productivity for 1979).

Low:

$(405.7 \times 10^9$ kwh)/(4,673,682 kwh/Mw) = 86,810 Mw

Medium:

$(523.0 \times 10^9$ kwh)/(4,673,682 kwh/Mw) = 111,900 Mw

High:

$(640.3 \times 10^9$ kwh)/(4,673,682 kwh/Mw) = 137,000 Mw.

Finally the various shortfalls can be obtained.

Low:

86,810 Mw - 54,594 Mw = 32,220 Mw

Medium:

111,900 Mw - 54,594 Mw = 57,310 Mw

High:

137,000 Mw - 54,594 Mw = 82,410 Mw.

1972 Interdevelopment Forecast

This forecast included projections for both 1975 and 1980.[1] The forecasts for electricity from nuclear power became larger as they projected further. This trend will be seen by evaluating the shortfall in both 1975 and

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[1] "World Energy Supply/Demand During a Period of Crisis", Interdevelopment, 1972, p. 67, cited by Environment Information Center, Energy Reference Department, The Energy Index, vol. 1 (New York: Environment Information Center, May 1974), p. 17.

1980 projections of this forecast. The 1975 projection will be reviewed first.

Forecast data for 1975: energy into nuclear was 3.340×10^{15} Btu, and total energy into the economy was 83.481×10^{15} Btu.

Actual data for 1975: energy into nuclear was 1.90×10^{15} Btu,[1] and total energy into the economy was 70.71×10^{15} Btu.[2]

Forecast nuclear ratio of total inputs:
$(3.340 \times 10^{15}\ \text{Btu})/(83.481 \times 10^{15}\ \text{Btu}) = .04001.$

Updated input based on results above:
$(70.71 \times 10^{15}\ \text{Btu})(.04001) = 2.829 \times 10^{15}\ \text{Btu}.$

Nuclear shortfall:
$(2.829 \times 10^{15}\ \text{Btu} - 1.90 \times 10^{15}\ \text{Btu})/(2.829 \times 10^{15}\ \text{Btu})$
$= .33$, or 33 percent.

Now the 1980 evaluation:

Forecast data for 1980: energy into nuclear was 9.490×10^{15} Btu, and total energy into the economy was 102.581×10^{15} Btu.

Actual year-end 1979 data: total energy into economy was 78.02×10^{15} Btu, and nuclear capacity was 54,594 Mw.

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[1] U.S., Department of Energy, Energy Information Administration, Annual Report to Congress 1979, 3 vols., n.d., 2:7.

[2] Ibid.

Forecast nuclear ratio of total inputs:

$(9.490 \times 10^{15}$ Btu)/(102.581×10^{15} Btu) = .09251.

Updated input based on results above:

$(78.02 \times 10^{15}$ Btu)(.09251) = 7.218×10^{15} Btu.

Energy output at .3170 efficiency (10,679 Btu/kwh):

$(7.218 \times 10^{15}$ Btu)/(10,769 Btu/kwh) = 670.2×10^{9} kwh.

Converting to capacity forecast:

$(670.2 \times 10^{9}$ kwh)/(4,673,682 kwh/Mw) = 143,400 Mw.

Nuclear shortfall:

143,400 Mw - 54,594 Mw = 88,810 Mw.

The shortfall based on the 1980 forecast is sixty-two percent while that of 1975 was thirty-three percent, as determined above.

1972 Atomic Energy Commission Forecasts

The fourth and fifth forecasts were prepared by the Atomic Energy Commission in early and late 1972.[1] Each of the forecasts have a "low", "most likely", and "high" projection.

The fourth forecast and the nuclear power shortfalls follow:

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[1]U.S., Atomic Energy Commission, Nuclear Power, 1973 - 2000, 1972, p. 1, cited by Environment Information Center, Energy Reference Department, The Energy Index, vol. 1 (New York: Environment Information Center, May 1974), p. 38.

Low:

127,000 Mw - 54,594 Mw = 72,000 Mw.

Most likely:

132,000 Mw - 54,594 Mw = 77,000 Mw.

High:

144,000 Mw - 54,594 Mw = 89,000 Mw.

The fifth and revised forecast, and the nuclear power shortfalls follow.

Low:

132,000 Mw - 54,594 Mw = 77,000 Mw.

Most likely:

151,000 Mw - 54,594 Mw = 96,000 Mw.

High:

166,000 Mw - 54,594 Mw = 111,000 Mw.

1973 National Petroleum Council Forecast

Forecast number six appeared in 1973 in a publication prepared by the National Petroleum Council.[1]

Forecast data for 1980: energy into nuclear was 11.349 x 10^{15} Btu, and total energy into the economy was 102.581 x 10^{15} Btu.

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[1]U.S., National Petroleum Council, U.S. Energy Outlook - New Energy Forms, 1973, p. 6, cited by Environment Information Center, Energy Reference Department, The Energy Index, vol. 2 (New York: Environment Information Center, December 1974), p. 61.

Year-end 1979 data: total energy into the economy was 78.02×10^{15} Btu.

Forecast nuclear ratio of total inputs:

$(11.349 \times 10^{15}$ Btu)/$(102.581 \times 10^{15}$ Btu) = .11063.

Updated input based on ratio above:

$(78.02 \times 10^{15}$ Btu)(.11063) = 8.631×10^{15} Btu.

Energy output at .3170 efficiency (10,769 Btu/kwh):

$(8.631 \times 10^{15}$ Btu)/(10,769 Btu/kwh) = 801.5×10^{9} kwh.

Converting to capacity forecast:

$(801.5 \times 10^{9}$ kwh)/(4,673,682 kwh/Mw) = 171,500 Mw.

Nuclear shortfall:

171,500 Mw - 54,594 Mw = 116,900 Mw.

1973 National Water Commission Forecast

Forecast number seven appeared in a 1973 publication prepared by the National Water Commission.[1] The forecast was expressed both in terms of capacity and percentage of total electricity. Percent of total capacity can be derived with the forecast total capacity. Both percentage of total capacity and percentage of total electricity generated will be used to derive the forecasts, although only the forecast derived from the percentage of total

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[1]U.S., National Water Commission, Water Policies for the Future, 1973, p. 172, cited by Environment Information Center, Energy Reference Department, The Energy Index, vol. 2 (New York: Environment Information Center, December 1974), p. 111.

electricity will be used in the conclusion. The purpose of evaluating the forecast in these two ways is to test the overall soundness of the forecast.

Forecast data for 1980: nuclear capacity was 140,000 Mw, total capacity was 665,000 Mw, and the ratio of nuclear generated electricity was .280.

Year-end 1979 data: nuclear capacity was 54,594 Mw, total capacity was 598,298 Mw, and the total electricity generated was 2,247,372 x 10^6 kwh.

Forecast nuclear ratio of total capacity:
(665,000 Mw)/(140,000 Mw) = .211.

Updated capacity forecast based on above ratio:
(598,298 Mw)(.211) = 126,000 Mw.

Nuclear shortfall:
126,000 Mw - 54,594 Mw = 71,000 Mw.

The second method using ratio of total electricity generated by nuclear will be calculated.

Energy output from nuclear:
(2,247,372 x 10^6 kwh)(.280) = 629 x 10^9 kwh.

Converting to capacity forecast:
(629 x 10^9 kwh)/(4,673,682 kwh/Mw) = 135,000 Mw.

Nuclear shortfall:
135,000 Mw - 54,594 Mw = 80,000 Mw.

It can be seen from the 9,000 Mw (eleven percent) difference resulting from applying two methods to the forecasts, that the projections were relatively consistent.

1973 Coal-Age Forecast

Forecast number eight appeared in the mid-April issue of Coal Age in 1973.[1] The forecast had three components: (1) energy into nuclear, (2) energy output from nuclear, and (3) percentage of total energy into nuclear. The forecast will be derived in terms of the percentage-of-total-energy-into-nuclear factor. No adjustments in the forecast are needed for a changed efficiency factor since the forecast implies an efficiency very close to the present experience of 31.70 percent.

Forecast data for 1980: energy into nuclear was 6.720×10^{15} Btu, nuclear energy out was 630×10^{9} kwh, and the ratio of total energy inputs was .070.

Determining the Btu equivalent of energy out:
$(630 \times 10^{9}$ kwh)(3,414 Btu/kwh) = 2.15×10^{15} Btu.

Calculating the efficiency:
$(2.15 \times 10^{15}$ Btu)/(6.72×10^{15} Btu) = .320, or 32.0 percent.

The energy into nuclear cannot be used for

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[1] "U.S. Energy Consumption by Source from 1971 to 2000", Coal Age, mid-April 1973, p. 59, cited by Environment Information Center, Energy Reference Department, The Energy Index, vol. 1 (New York: Environment Information Center, May 1974), p. 43.

extrapolating capacity because if 6.72×10^{15} Btu was indeed seven percent of total energy, then total energy in 1980 would have to be $(6.72 \times 10^{15}$ Btu)/(.070) or 96×10^{15} Btu. However, the year-end 1979 total energy inputs to the economy was only 78.02×10^{15} Btu. Therefore the forecast capacity will be derived from the forecast seven percent of the new total energy inputs to the economy.

Energy into nuclear:

$(78.02 \times 10^{15}$ Btu)(.070) = 5.46×10^{15} Btu.

Energy output at .3170 efficiency (10,769 Btu/kwh):

$(5.46 \times 10^{15}$ Btu)/(10,769 Btu/kwh) = 507×10^{9} kwh.

Converting to capacity forecast:

$(507 \times 10^{9}$ kwh)/(4,673,682 kwh/Mw) = 108,000 Mw.

Nuclear shortfall:

108,000 Mw - 54,594 Mw = 53,000 Mw.

1973 Citizen's Advisory Committee on Environmental Quality Forecast

Forecast number nine was published in 1973 by the Citizen's Advisory Committee on Environmental Quality.[1]

Data: year-end 1979 total energy inputs was

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[1]Citizen's Advisory Committee on Environmental Quality, "Sources of U.S. Energy Supply", Citizen Action Guide to Energy Conservation, 1973, p. 10, cited by Environment Information Center, Energy Reference Department, The Energy Index, vol. 1 (New York: Environment Information Center, May 1974), p. 16.

78.02×10^{15} Btu, and the forecast nuclear input as a ratio of total inputs was .070.

Energy in:

$(78.02 \times 10^{15}$ Btu)(.070) = 5.46×10^{15} Btu.

Energy output at .3170 efficiency (10,769 Btu/kwh):

$(5.46 \times 10^{15}$ Btu)/(10,769 Btu/kwh) = 507×10^{9} kwh.

Converting to capacity forecast:

$(507 \times 10^{9}$ kwh)/(4,673,682 kwh/Mw) = 108,000 Mw.

Nuclear shortfall:

108,000 Mw - 54,594 Mw = 53,000 Mw.

1974 Electrical World Forecast

This *Electrical World*[1] forecast was based on net additions of capacity per year through 1995. Since the actual forecast additions began with the year of publication, 1974, the additions were added to the known installed capacity at the end of 1973 to derive a 1980 forecast.

Data: forecast additions of nuclear capacity 1974-80 was 65,556 Mw, installed nuclear capacity at the end of 1973 was 21,000 Mw,[2] and the year-end 1979 installed

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[1]U.S., Federal Power Commission, *Electrical World*, 15 September 1978, p. 55, cited by Environment Information Center, Energy Reference Department, *The Energy Index*, vol. 2 (New York: Environment Information Center, December 1974), p. 116.

[2]U.S., Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States 1979*, September 1979, p. 608.

nuclear capacity was 54,594 Mw.

Capacity forecast:

65,556 Mw + 21,000 Mw = 87,000 Mw.

Nuclear shortfall:

87,000 Mw - 54,594 Mw = 32,000 Mw.

1974 Public Utilities Fortnightly Forecast

The eleventh forecast appeared in the September 26, 1974 edition of Public Utilities Fortnightly,[1] a public utilities industry journal.

Data: most likely was 132,000 Mw, high was 144,000 Mw, and year-end 1979 installed nuclear capacity was 54,594 Mw.

Shortfall for "most likely" forecast:

132,000 Mw - 54,594 Mw = 77,000 Mw.

Shortfall for "high" forecast:

144,000 Mw - 54,594 Mw = 89,000 Mw.

1975 Department of the Interior Forecast

Forecast number twelve was prepared in 1975 by the U.S. Department of the Interior and had two parts: a lower forecast based on petroleum being available at seven dollars a barrel, and a higher one being predicated

[1] "Nuclear Forecast", Public Utilities Fortnightly, 26 September 1974, p. 44, cited by Environment Information Center, Energy Reference Department, The Energy Index, vol. 2 (New York: Environment Information Center, December 1974), p. 115.

upon oil being sold at eleven dollars a barrel.[1] Since the price of oil could be fifty dollars a barrel by Spring of 1981,[2] the higher forecast will be the only one considered. The logic behind the forecasts is that the higher the price of oil, the higher the installed nuclear capacity is likely to be. If true, this nuclear forecast for 1980 is significantly understated. Nonetheless, an evaluation of the higher forecast will be used.

Data: forecast nuclear capacity for 1980 was 93,000 Mw, and year-end 1979 capacity was 54,594 Mw.

Nuclear shortfall:

93,000 Mw - 54,594 Mw = 38,000 Mw.

1975 Electrical World Forecast

The thirteenth and last forecast for nuclear power to be examined appeared in the September 15, 1975 edition of Electrical World[3] separated by one year from a similar

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[1]U.S., Department of the Interior, Energy Perspectives, February 1975, p. 171, cited by Environment Information Center, Energy Reference Department, The Energy Index, vol. 3 (New York: Environment Information Center, December 1975), p. 123.

[2]Statement made by Saudi Arabian Oil Minister, radio broadcast, United Press International, 18 December 1980.

[3]U.S., Federal Power Commission, Electrical World, 15 September 1975, p. 47, cited by Environment Information Center, Energy Reference Department, The Energy Index, vol. 3 (New York: Environment Information Center, December 1975), p. 116.

forecast made by the U.S. Federal Power Commission, cited earlier in this discussion. The forecast for installed capacity in 1980 was only increased by 2,000 Mw. The forecast again took the form of net additions per year.

Data: forecast additions of nuclear capacity 1975-80 was 61,796 Mw, installed nuclear capacity at the end of 1974 was 32,000 Mw,[1] and the year-end 1979 installed nuclear capacity was 54,594 Mw.

Capacity forecast for 1980:

61,796 Mw + 32,000 Mw = 94,000 Mw.

Nuclear shortfall:

94,000 Mw - 54,594 Mw = 39,000 Mw.

Summary and Analysis of Forecasts

Table on the following page is a summary of the various forecasts and shortfalls derived from the previous thirteen projections made during the years 1964 through 1975. It can be seen that the averages of the low, medium, and high nuclear power plant capacity shortfalls were 52,000 Mw, 64,000 Mw, and 84,000 Mw respectively.

Not only have there been significant nuclear forecast shortfalls in the past, but the gap between nuclear power forecast and what is likely to be installed in

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[1] U.S., Department of Commerce, Bureau of the Census, Statistical Abstract of the United States 1979, September 1979, p. 608.

TABLE 4

SUMMARY OF 1980 FORECASTED CAPACITIES AND SHORTFALLS
(In Megawatts)

			Forecasts			Shortfalls		
No.	Date	Source	Low	Medium	High	Low	Medium	High
1	1964	Federal Power Commission . .	79,600	92,000	110,000	25,000	37,000	55,000
2	1968	Bureau of Mines.	86,810	111,900	137,000	32,220	57,310	82,410
3	1972	Interdevelopment		143,400			88,810	
4	1972	Atomic Energy Commission . .	127,000	132,000	144,000	72,000	77,000	89,000
5	1972	Atomic Energy Commission . .	132,000	151,000	166,000	77,000	96,000	111,000
6	1973	National Petroleum Council .		171,500			116,900	
7	1973	National Water Commission. .		126,000	135,000		71,000	80,000
8	1973	Coal Age		108,000			53,000	
9	1973	Citizen's Advisory Committee		108,000			53,000	
10	1974	Federal Power Commission . .		87,000			32,000	
11	1974	Public Utilities Fortnightly		132,000	144,000		77,000	89,000
12	1975	Department of the Interior .		93,000			38,000	
13	1975	Federal Power Commission . .		94,000			39,000	
		Averages	106,000	119,000	139,000	52,000	64,000	84,000

future years seems to be increasing. For example the forecast published by Public Utilities Fortnightly,[1] mentioned earlier, anticipated an installed capacity of 87,000 Mw in 1978, 103,000 Mw in 1979, and 132,000 Mw in 1980. The shortfall was 33,000 Mw in 1978, 48,000 Mw in 1979, and may be considered to be between 73,000 Mw and 75,000 Mw at the end of 1980.[2] It seems that the question asked by Mr. Ken McKenna by the title of his article in Nation magazine in 1961 is still pertinent, i.e. "Whatever Happened to Atomic Power?"[3] The earlier forecasts for nuclear power were optimistically high as one would expect from McKenna's statement of history that "During the immediate post-World War II years, the subject of nuclear energy had a breathless fascination for public and industry alike.[4]

Yet there has been much concern expressed in the years since about the lack of development of nuclear power as was originally anticipated. This prompted President Kennedy to make the statement that the atomic program "has fallen far short of expectations."[5] It also prompted

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[1]"Nuclear Forecast", Public Utilities Fortnightly, 26 September 1974, p. 44, cited by Environment Information Center, Energy Reference Department, The Energy Index, vol. 2 (New York: Environment Information Center, December 1974), p. 115.

[2]See appendix 1, pt. k.

[3]Ken McKenna, "Whatever Happened to Atomic Power?", Nation, 14 January 1961, pp. 29-32.

[4]Ibid. [5]Ibid.

Senator Jennings Randolph of West Virginia in early 1974, in referring to the nuclear power shortfall, to comment that "It's one of those problems that we must solve..."[1] The optimistic attitude that existed toward nuclear power at the beginning of 1975 dimmed considerably by the end of the year, and during 1976, due to two judicial decisions, the U.S. Nuclear Regulatory Commission for the first time stopped issuing full-power operating licenses through the end of the year.[2]

Also, electric utility orders placed for nuclear reactors dropped from a high in 1973 of thirty-six to a low of three in 1979. Moreover, the forecast for numbers of nuclear power plants to be built by the year 2000 dropped from an estimated two thousand in the late 1960's to five hundred during President Ford's time in office to between 350 to 400 during the early part of President Carter's presidency.[3] The most recent outlook for total nuclear power plants to be installed by the year 2000 has no doubt been affected greatly by the April 1979 event at Three Mile Island and the escalating costs of building any new power plant - nuclear or coal.

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[1]"Energy Crisis: If We Delay We Court Disaster", U.S. News and World Report, 28 January 1974, pp. 67-69.

[2]Environment Information Center, Energy Reference Department, The Energy Index, vol. 4 (New York: Environment Information Center, December 1976), p. 12.

[3]Ibid.

The most recent annual report of the U.S. Nuclear Regulatory Commission[1] gives a good indication of what to expect for at least the next fifteen years or so (see table 5). Including the seventy-one currently operational power plants, there are at present only 193 nuclear power plants either operating, under construction, holding limited construction permits, announced or ordered, or under review for a construction permit. Unless both the current downward trend in development and the increasing public opposition to nuclear power changes drastically and very rapidly, the number of operating plants at the turn of the century will fall far short of the 350 to 400 anticipated during the early part of President Carter's Administration.

A final review of forecast operating capacity for 1980 has shown a significant drop in expectations between September 30, 1979, which was the date of the latest Nuclear Regulatory Commission forecast,[2] and year-end 1980.[3] The forecast in September 1979 for additional installed capacity by the end of 1980 was 18,866 Mw. However, only 2,047 Mw had come on line through December,[4]

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[1]U.S., Nuclear Regulatory Commission, Annual Report 1979, February 1980, pp. 301-311.

[2]Ibid.

[3]Susan F. Gagner, telephone interview, U.S. Nuclear Regulatory Commission, Public Affairs Office (Washington, D.C.), 16 December 1980.

[4]Ibid., North Anna 2 (907 Mw) and Sequoyah 1 (1,140 Mw).

TABLE 5

NUCLEAR POWER PLANT STATUS AS OF SEPTEMBER 30, 1979

Numbers of Plants With Announced Completion Dates[a]		Plants Without Announced Completion Dates[b]	Plants With Licenses
1979	7	10	71
1980	11		
1981	7		
1982	12		
1983	15		
1984	12		
1985	15		
1986	6		
1987	5		
1988	8		
1989	6		
1990	4		
1991	3		
1992	-		
1993	1		
Totals	112	24	71
Grand Total	193 plants		

SOURCE: U.S., Nuclear Regulatory Commission, Annual Report 1979, February 1979, pp. 301-311.

[a]Eighteen of these are under review for construction permits and four have been announced or ordered by the utility but application for construction has not yet been docketed by the NRC for review.

[b]Two of these have been announced or ordered by the utility, seven are under review for a construction permit, and one has been issued.

and only 4,202 Mw is expected to come on line in 1981.[1] This drop in forecast over a thirteen-month period of 16,819 Mw represents an eighty-nine percent decrease in forecast added capacity by the end of 1980. The fact is that none of the forecasts which have reflected an optimistic attitude toward the growth of nuclear power in the United States have come to pass. Most of the reasons were covered in the previous chapters.

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[1]Ibid., McGuire (1,180 Mw), Salem 2 (1,115 Mw), LaSalle 2 (1,078 Mw), and Farley 2 (829 Mw).

CHAPTER 7

NUCLEAR POWER TRANSLATED INTO OIL

Background for Translating Nuclear Power Into Oil

The previous chapter of this study attempted to measure the amount of the current nuclear power shortfall based on thirteen different forecasts made in past years. This chapter will attempt to translate the nuclear power shortfall in terms of imported oil, i.e. how much imported oil would be needed at oil-fired power plants operating in the United States, to generate the amount of electricity that could have been generated by the current 64,000 Mw nuclear capacity shortfall?[1]

There are several pieces of data that are essential to making this determination, some of which are not readily available. First of all it must be determined how many kilowatt-hours were generated per megawatt installed nuclear capacity in 1979. Secondly, it must be determined how much imported oil would have been required by 1979 oil-fired plants to generate the amount of electricity that was generated per megawatt of nuclear capacity. Finally,

[1]See table 4, Chapter 6.

this amount of oil can be used as a basis for determining total amounts of imported oil replaced by any given nuclear power plant or represented by any nuclear capacity forecast or shortfall. This amount of imported oil can also be expressed as a percentage of total oil imports during 1979.

It has been determined that the average number of kilowatt-hours generated per megawatt installed nuclear capacity in 1979 was 4,673,682.[1] Next, the Btu input required by an oil-fired plant to produce this amount of electricity must be derived, from which barrels of imported oil may be extrapolated. The problem of accurately determining Btu input per kilowatt-hour output of oil-fired plants is not an easy task, however. The reason is that although the kilowatt-hour output of oil-fired plants in 1979 is readily available from U.S. Department of Energy data, there is no highly accurate data available in aggregate form that tells the total Btu input used to produce this known kilowatt-hour output. The reason is that the public utilities are only required to report to the Coal and Electric Power Statistical Division of the Department of Energy the total barrels of oil and total tons of petroleum coke that were used in 1979, but are not required to list the types of petroleum products used or in what quantities of each. It is important to

[1]See appendix 1, pt. j for derivation.

have this information in order to determine the total Btu content of the oil products which, for example, range from 6,287,000 Btu per barrel for residual fuel oils to 5,670,000 Btu per barrel for kerosene. In addition, none of the Btu contents of the fuels used by the utilities are the same as the average Btu content of a barrel of imported crude oil, which is 5,802,000 Btu per barrel.[1]

Determining Btu of Oil Used by Utilities

The method employed to determine the Btu content of the oil products used by the public utilities in 1979 is not complicated. They report what the deliveries of all types of fuel- oil were. However, the amounts delivered are not the amounts consumed because of some drawing down of 1978 inventories and stockpiling a portion of the 1979 deliveries. Nonetheless, there should be a very close correlation between the percentage of total deliveries a particular fuel oil represents and its percentage of total oil products consumed during the same year, 1979. The deliveries to the oil-fired public utility power plants in 1979 are listed in table 6. Now some answers can be derived for 1979.

How much distillate fuel oil was used by the steam

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[1]U.S., Department of Energy, Energy Information Administration, Monthly Energy Review, September 1980, p. 107.

TABLE 6

DELIVERIES OF FUEL OIL FOR ELECTRIC GENERATION 1979

Steam Electric[a]			Gas Turbine/Internal Combustion[b]		
Type of Oil	Thousands of Barrels	Percentage[c] of Total	Type of Oil	Thousands of Barrels	Percentage[d] of Total
Distillate 2 . . .	19,599.3	4.00786	Distillate 2 . .	23,650.4	86.1860
Distillate 4 . . .	2,202.2	.45032			
Residual 5	2,397.5	.49026	Residual 6 . . .	619.0	2.256
Residual 6	464,017.3	94.88696	Kerosene	3,171.7	11.558
Unfinished Oils. .	804.8	.16457			
Totals	489,021.1	99.99997		27,441.1	100.000
(Total Distillate)	(21,801.5)	(4.45818)			
(Total Residual)	(466,414.8)	(95.05753)	(Total Residual)	(619.0)	(2.256)

SOURCE: U.S., Department of Energy, Energy Information Administration, Cost and Quality of Fuels for Electric Utility Plants - 1979, June 1980.

[a]Ibid., p. 42. [b]Ibid., p. 52.

[c]Calculated from data on table.

[d]Calculated from data on table.

electric plants?

Data: total bbl oil used for steam electric plants was 492,606 x 10^3 bbl.[1]

Calculation:

(492,606 x 10^3 bbl)(.0445818)[(2)] = 21,961.3 x 10^3 bbl.

How much residual fuel oil was used by the steam electric plants?

Calculation:

(492,606 x 10^3 bbl)(.9505753) = 468,259 x 10^3 bbl.

How much unfinished oil was used by the steam electric plants?

Calculation:

(492,606 x 10^3 bbl)(.0016457) = 810.6 x 10^3 bbl.

How much distillate fuel oil was used by the gas turbine/internal combustion electric plants?

Data: Total oil used for gas turbine/internal combustion plants was 30,691 x 10^3 bbl.[(3)]

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[1]U.S., Department of Energy, Energy Information Administration, Cost and Quality of Fuels for Electric Utility Plants - 1979, June 1980, p. 64.

[2]See table 6 for this and folllowing percentages.

[3]U.S., Department of Energy, Energy Information Administration, Monthly Energy Review, September 1980, p. 64.

Calculation:

$(30{,}691 \times 10^3 \text{ bbl})(.861860) = 26{,}451 \times 10^3$ bbl.

How much residual fuel oil was used by the gas turbine/internal combustion electric plants?

Calculation:

$(30{,}691 \times 10^3 \text{ bbl})(.02256) = 692.4 \times 10^3$ bbl.

How much kerosene was used by the gas turbine/internal combustion plants?

Calculation:

$(30{,}691 \times 10^3 \text{ bbl})(.11558) = 3{,}547.3 \times 10^3$ bbl.

How many barrels of petroleum coke were used by electric utilities for generating electricity in 1979?

Data: short tons of petroleum coke used for generation was 268×10^3 short tons,[1] and one short ton contains 6.65 bbl.[2]

Calculation:

$(268 \times 10^3 \text{ short tons})(6.65 \text{ bbl/short ton}) = 1{,}782 \times 10^3$ bbl.

The similar fuels used in each type of electrical generation are now added together.

Total distillate fuel oils:

$21{,}961.3 \times 10^3 \text{ bbl} + 26{,}451 \times 10^3 \text{ bbl} = 48{,}412 \times 10^3$ bbl.

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[1]Ibid. [2]Ibid., p. 107.

Total residual fuel oils:

$468{,}259 \times 10^3$ bbl + 692.4×10^3 bbl = 468,951 bbl.

The above series of calculations have determined how much of each type of petroleum product was most likely used for generating electricity in 1979. The next step is to derive the total Btu content of these various fuels. Table 7 is a compilation of the various fuels and a derivation of their total Btu contents, which is 3.2658×10^{15} Btu.

How Much Oil Does a Megawatt of Nuclear Replace?

In order to determine the barrels of oil it would have taken to generate the amount of electricity that was supplied by an average megawatt of nuclear capacity in 1979, the efficiency of 1979 oil-fired plants must be known, i.e. how many Btu/kwh?

Data: electricity from petroleum in 1979 was $303{,}525 \times 10^6$ kwh,[1] and the energy content of petroleum used was 3.2658×10^{15} Btu.

Calculation:

$(3.2658 \times 10^{15}$ Btu$)/(303{,}525 \times 10^6$ kwh$)$ = 10,760 Btu/kwh.

Since there were 4,673,682 kilowatt-hours generated for each megawatt of installed nuclear capacity in 1979,

[1] Ibid., p. 62.

TABLE 7

PETROLEUM PRODUCTS USED FOR ELECTRIC GENERATION 1979

Type of Product	Thousands of Barrels	Btu Content[a] per Barrel	Total Btu Content[b] For Each Type Fuel Used (10^{15} Btu)
Distillate Fuel Oils . . .	48,412	5,825,000	.28199
Residual Fuel Oils	468,951	6,287,000	2.94829
Unfinished Oils.	810.6	5,825,000	.0047217
Kerosene	3,547.3	5,670,000	.020113
Petroleum Coke	1,782	6,024,000	.0107
Totals.	523,503		3.2658[c]

[a]U.S., Department of Energy, Energy Information Administration, Monthly Energy Review, September 1980, p. 107.

[b]Derived by multiplying first two columns.

[c]Average Btu/bbl oil used by utilities is found by:

$(3.2658 \times 10^{15}$ Btu$)/(523{,}503 \times 10^{3}$ bbl$) = 6{,}238{,}400$ Btu/bbl.

this can be equated to Btu input required at an oil-fired plant.

Calculation:

$(4{,}673{,}682 \text{ kwh})(10{,}760 \text{ Btu/kwh}) = 50.289 \times 10^9 \text{ Btu.}$

Now the required 50.289×10^9 Btu can be expressed in terms of imported barrels of petroleum.

Data: Btu content of 1979 imported crude oil was 5,802,000 Btu per barrel.[1]

Calculation:

$(50.289 \times 10^9 \text{ Btu})/(5{,}802{,}000 \text{ Btu/bbl}) = 8{,}667.5 \text{ bbl.}$

This 8,667.5 barrels of oil is the amount of imported oil that would be required at a 1979 oil-fired plant in order to replace the amount of electricity that was generated by an average installed megawatt of nuclear capacity in 1979. On a daily basis this would amount to: (8,667.5)/(365), or 23.746 barrels of oil per megawatt of nuclear capacity.

How Much Oil Could Be Replaced by the Nuclear Shortfall?

Now the measurement that has been a central question of this study can be made, i.e. how much of the imported oil in 1979 can be attributed to the shortfall in nuclear power plant capacity discussed in the last chapter?

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[1]Ibid., p. 107

The low, medium, and high nuclear power shortfalls for 1979 are 52,000 Mw, 64,000 Mw, and 84,000 Mw respectively. Each of these shortfalls will be expressed as a percentage of total oil imports in 1979.

Data: oil imported in 1979 was 7,989,600 bbl/day,[1] and the daily imported oil necessary to replace one Mw nuclear capacity was 23.746 bbl/Mw.

Expressing as a percentage of 1979 oil imports,

Low:

(52,000 Mw)(23.746 bbl/Mw)day/(7,989,600 bbl/day) = .15, or 15 percent.

Medium:

(64,000 Mw)(23.746 bbl/Mw)day/(7,989,600 bbl/day) = .19, or 19 percent.

High:

(84,000 Mw)(23.746 bbl/Mw)day/(7,989,600 bbl/day) = .25, or 25 percent.

It has been demonstrated that the medium range nuclear power shortfall in 1979 can be equated to nineteen percent of all imported oil in 1979. This is certainly not an inconsequential amount. If the highest forecast examined in chapter 1 of 166,000 Mw had been met in 1979, the equivalent of energy from imported oil could have

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[1]See appendix 1, pt. 1 for derivation.

been reduced by an even greater amount as seen in the example that follows.

Data: highest nuclear forecast examined was 166,000 Mw with a shortfall of 111,000 Mw.

Calculation:

(111,000 Mw)(23.746 bbl/Mw)day/(7,989,600 bbl/day) = .33, or 33 percent.

An interesting question arises: If all electricity generated by nuclear power in 1979 had been supplied by oil-fired plants, how much additional imported oil would have been necessary?

Data: nuclear capacity in 1979 was 54,594 Mw, the oil imported in 1979 was 7,989,600 bbl/day, and the oil needed to replace one Mw nuclear capacity was 23.746 bbl/Mw/day.

Calculation:

(54,594 Mw)(23.746 bbl/Mw)day/(7,989,600 bbl/day) = .16, or a 16 percent increase in oil imports.

Another interesting question follows: How much added nuclear capacity over and above the 54,594 Mw installed in 1979 would be necessary to replace all the oil presently being imported to generate electricity in oil-fired plants?

Data: oil used to generate electricity in 1979 was $562,870 \times 10^3$ bbl,[1] and the oil replaced by energy of each Mw nuclear/yr was 8,667.5 bbl.

Calculation:

$(562,870 \times 10^3 \text{ bbl})/(8,667.5 \text{ bbl/Mw}) = 64,940$ Mw,

or a total nuclear capacity in 1979 of

54,594 Mw + 64,940 Mw = 119,534 Mw.

This capacity of 119,534 Mw needed to replace all oil used for electric generation in 1979 is almost identical to the medium-range nuclear capacity forecast (119,000 Mw) examined in Chapter 6, and is less than the high-range forecast (139,000 Mw) for 1980:

(119,534 Mw - 119,000 Mw)/(119,534 Mw) = 0.4 percent,

and

(139,000 Mw - 119,534 Mw)/(139,000 Mw) = 14 percent less.

It would also be interesting to determine how much of all imported oil is used for the generation of electricity.

Data: oil used to generate electricity in 1979 was $562,870 \times 10^3$ bbl, and oil imported in 1979 was $2,916,200 \times 10^3$ bbl.

Calculation:

$(562,870 \times 10^3 \text{ bbl})/(2,916,200 \times 10^3 \text{ bbl}) = 19.3$ percent.

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[1] See appendix 1, pt. m for derivation.

Of course, the oil used for electric generation in 1979 expressed as a percentage of all oil consumed in the United States, both domestic and imported, is less as seen below.

Data: oil energy used to generate electricity in 1979 was 3.2658×10^{15} Btu,[1] and the total oil energy consumed in 1979 was 34.984×10^{15} Btu.[2]

Calculation:

$(3.2658 \times 10^{15}$ Btu$)/(34.984 \times 10^{15}$ Btu$) = 9.3$ percent.

Immediately following Three Mile Island, there was a total of 12,256 megawatts of nuclear capacity shut down, consisting of the Babcock and Wilcox type - like installed at Three Mile Island, and the remainder belonging to a group that were closed for rechecking earthquake vulnerability.[3] This capacity can be expressed in terms of imported oil.

Data: oil needed to replace one Mw nuclear per day is 23.746 bbl, and the total oil imported per day, 7,989,600 bbl.

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[1]See table 7.

[2]See appendix 1, pt. b for derivation.

[3]"Life: An Atom-Powered Shutdown", Time, 26 March 1979, p. 55.

Calculation:

(12,256 Mw)(23.746 bbl/Mw)/(7,989,600 bbl) = .03643, or 3.6 percent of all imported oil.

Testing Some Statements in the Media

With the data that has been derived in this study one can evaluate some of the statements that appear in the media. Two published statements will be evaluated.

The first statement to be examined appeared in the April 26, 1979 issue of Public Utilities Fortnightly.[1] The writer in referring to six specific nuclear plants that could come on line in 1979, said that the plants could save an "estimated 240,000 barrels per day of oil". If he was referring to imported oil, which was clearly implied, the statement was twenty-six per cent too high. This was determined by obtaining from the NRC Annual Report 1979[2] the capacities of the nuclear plants referred to, which amounted to 7,518 Mw, and then calculating exactly what this capacity meant in terms of imported oil.

Data: oil needed to replace one Mw nuclear per day was 23.746 bbl.

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[1]Lucien E. Smartt, "The Means Are at Hand to Reduce Dependence on Foreign Oil", Public Utilities Fortnightly, 26 April 1979, p. 8.

[2]U.S., Nuclear Regulatory Commission, Annual Report 1979, February 1980, pp. 301-311.

Calculation:

(7,518 Mw)(23.746 bbl/Mw)day = 178,500 bbl/day, or twenty-six percent less than the stated 240,000 barrels per day.

A second statement to be evaluated appeared in a post-Three Mile Island article put out by Cox News Service.[1] It said that: "When a nuclear power plant the size of Three Mile Island is closed, it means the nation must import approximately another 30,000 barrels a day of foreign oil".

Data: oil needed to replace one Mw nuclear per day was 23.746 bbl, and the capacity of Three Mile Island Unit 2 was 906 Mw.[2]

Calculation:

(906 Mw)(23.746 bbl/Mw)day = 21,500 bbl/day, or twenty-eight percent less than the stated 30,000 barrels per day.

Reasons for the Measurement's Validity

It should be stated that the determination that nuclear power could have replaced nineteen percent of 1979 oil imports is not an uncomplicated conclusion because of three unknowns: (1) If the forecast nuclear

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[1] "Answers to Basic Questions About Nuclear Accidents", Cox News Service, 4 April 1979.

[2] U.S., Nuclear Regulatory Commission, Annual Report 1979, February 1980, pp. 301-311.

capacity had actually been installed, would it have replaced oil-fired power plants, or some other form of power generation resulting in less than a nineteen percent reduction in oil imports?; (2) Since there are 17,388 megawatts of private industrial generating capacity[1] not included in this study, is it not likely that had the nuclear forecasts been met, some of the private oil-fired capacity would not have been used in favor of the purchase of cheaper nuclear generated electricity, resulting in an even greater decrease in oil imports?; and (3) Since in 1978 an amount of fuel oil equivalent to 25.9 percent of oil imports was used for heating in the United states,[2] is it not likely that some of this heating would have been replaced by possibly cheaper nuclear generated electrical heat, thereby further decreasing dependence on imported oil?

The first unknown simply makes the nineteen percent conclusion somewhat uncertain, but the second and third unknowns allow the conclusion that had the nuclear forecasts been met, oil imports in 1979 would have been cut by at least nineteen percent.

Finally, this writer wishes to reiterate that this is not a "position paper" on the attributes or

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[1]Melvin E. Johnson, telephone interview, U.S. Department of Energy, Energy Information Administration, Coal and Electric Power Statistical Division, Office of Data and Interpretation (Washington, D.C.), 17 December 1980.

[2]See appendix 1, pt. n for derivation.

disadvantages of nuclear power. While it is entertaining to consider the Westinghouse Corporation executive's view that America will have "nuclear power or no power!",[1] compared to the feelings of the Union of Concerned Scientists who called for a shutdown of fifty-five nuclear plants where the now repudiated Rasmussen Report was used to justify operation,[2] the opinion of this writer lies in another direction.

It seems that a great amount of attention should be given to the ideas presented in a report of the U.S. Council on Environmental Quality called "The Good News About Energy". This encouraging report suggests that many more consumer goods and services can and should be urged out of each unit of fuel we use "whether it be a barrel of oil or a ton of coal or uranium", and that by pursuing a program of conservation technology the nation could get by with only an additional 125 new coal and nuclear power plants by the year 2000 instead of the 500 presently thought to be needed.[3]

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[1]Gordon C. Hurlbert, "The Anger of Decent Men", Public Utilities Fortnightly, 15 March 1979, p. 19.

[2]"NRC Review Affirms Licensed Nuclear Facilities' Safety", Public Utilities Fortnightly, 15 March 1979, p. 30.

[3]U.S., Council on Environmental Quality, "The Good News About Energy", cited in "Low-growth Rate in Energy Use Called Compatible With Economic Health", Public Utilities Fortnightly, 15 March 1979, p. 29.

SUMMARY AND CONCLUSIONS

The international market for nuclear power plants is growing. The growth is not uniform throughout all countries because of the varying degrees of economic development, energy intensiveness of major industries, existing networks for electrical power distribution, economic capacity to purchase fossil fuels in an increasingly competitive international market, and other reasons.

One of the strongest arguments in the international community for building nuclear power plants is economic. Nuclear power is today less expensive from a direct-cost standpoint than all fossil fuels priced in the international market. Most of the countries of the world that are pursuing the nuclear option do not have an abundance of fossil fuels, and some have practically none. The petroleum that must often be imported is much more useful in fueling the transportation sector than in generating electricity.

The amount of nuclear power needed in the world is increasing as the demand for energy grows. The demand for energy growth is in turn fueled by increasing population in many countries of the world, accompanied by development into more energy-intensive societies. In the European community, energy demand will have increased by the year 2000 by between 1½ and 2 times. Similar growth is expected in Japan. The growth in third-world nations will grow at an even more rapid rate, but because of a smaller base, the overall demand will not be as significant as the rate of growth might suggest.

A desire for energy self-sufficiency seems to be a major driving force behind nuclear power. Escalating fossil-fuel prices and the heavy dependence of an industrialized society on an uninterrupted supply of energy, are causing countries around the world to protect themselves from the effects of embargoes which could be brought about by either political or economic circumstances.

The United States is not the only country in the world interested in exploiting the international market for nuclear reactors, technology, and fuel. While the United States basically pioneered the nuclear power industry, its former customers are now competitors in what now appears to be a temporary "soft" market. As a result, the competition for reactor orders is increasing.

Because of U.S. concern over the nuclear weapons proliferation issue surrounding nuclear power plant expansion abroad, various policies have been implemented at the national and international levels to prevent such proliferation. However, these restrictive policies seem to be impacting more heavily on the U.S. nuclear manufacturing industry, and there is currently a need for greater freedom for the U.S. industry to compete in the international market by removal of various restrictive nuclear export policies.

There are three basic phases of concern in the nonproliferation issue: (1) use of a nuclear power reactor to generate weapons-grade material, (2) use of enrichment technology to produce uranium that is concentrated enough to form a "critical mass", and (3) use of reprocessing technology resulting in the formation of weapons-grade plutonium. The U.S. government has imposed restrictions on the sales of reactors to certain countries, and has supported international measures for monitoring the nuclear fuel cycle. However, the usefulness of these policies has been seriously questioned by both public and private interests. It would appear that there are better methods for acquiring nuclear-weapons capability than diversion of the nuclear fuel cycle. Moreover, the U.S. is foregoing what control it might have over potential nuclear power users by relinquishing sales to more eager competitors.

The growth of the nuclear power industry is dependent in the long run on the proper disposal of the nuclear waste products. There are more than three hundred radioactive substances created as a result of fission in nuclear power plants. However, the environmental concern centers around a handful of long-lined "transuranics". The most meticulous methods must be used for the disposal of these few long-lived waste products. Plutonium is one of the most toxic substances to be disposed of, and has a half-life of 24,600 years. The disposal of this and other similar wastes amounts to a million-year disposal challenge.

The nuclear waste disposal issue has had a history almost as long as the nuclear industry itself. At the beginning of the nuclear era, it was almost casually assumed by some scientists that nuclear wastes could be easily solidified in glass, encased in stainless steel containers, and placed in deep saltbed formations with complete safety. Technologically, this method of disposal is as viable as ever. However, the institutional hurdles have been insurmountable to date. The first attempt at such disposal was at Lyons, Kansas in 1970. However, due to political opposition instituted by the residents, the project was never carried out. As a result of this early successful opposing of a federal waste repository, institutional momentum was built up to prevent the selection of alternative sites. The net effect has been a continual build-up of nuclear wastes from both military and civilian sources that is being stored temporarily by methods not designed for the time period needed for the radioactive decay to safe levels.

The concern over waste disposal is not focused on the low-level wastes where the volume is much greater. Moreover, the public attention given to high-level waste disposal does seem to be out of proportion to other toxic waste disposal problems such as those accompanying the chemical industry. Nevertheless, as a result of public concern, various alternative methods of nuclear waste disposal have been researched. They include burial under the clay floors found in some areas of the ocean, disposal in holes drilled ten to fifty thousand feet into the earth, disposal in deep rock formations in sufficient radioactive concentration that the heat generated would melt the surrounding rock which would effectively seal it off from the environment, storage in mined areas on remote islands, disposal in ice sheets of the polar regions, deep-well injection disposal, and a transmutation process that would convert the long-lived transuranics into shorter-lived alternative isotopes.

A most insightful view into the choices surrounding nuclear power and how they may affect the future use of this technology falls in the realm of sociotechnical evaluation. After only limited investigation, it becomes clear that public perception of nuclear power has heavy psychological overtones and implications that have dramatically been reflected in the public regulatory policies regulating the nuclear power industry.

Public acceptance of nuclear power in the United States has declined over the years in spite of intensive effects to "educate" the public in nuclear power plant technology.

It has become clear to many students of this phenomenon that the problem is not with the risks associated with nuclear power alone, but rather with the problem of perception of the magnitude of the risks.

While it has been conceded in the Rasmussen Report that a "worst-possible" nuclear power plant accident could cost three thousand lives, this possibility is so low as to make it much safer than the best modern coal plant of comparable size. It can be argued with good reason that some of the public opposes nuclear power because of their realization that the risks are distributed differently by nuclear and coal plants, i.e., the risk of coal plants is widely distributed among the coal miners via mining accidents and "black lung", the railroad worker who ships the coal, and the public over thousands of square miles who breathes the one hundred or so carcinogens pouring out of the stacks in the fumes and particulate matter.

On the other hand, the risk from nuclear power, based on all past history is negligible in comparison, on both the broad society as well as those who live geographically close to nuclear power plants. The problem is that if the "worst case" nuclear accident did occur, its maximum impact would be felt locally. Those who oppose nuclear power on the basis of risk are acting upon the heavily studied "what if?" psychological phenomena. In a democratic society, individuals are certainly free to do so, unless they invest the federal government with the power to regulate how such risks are to be distributed.

A second problem uncovered in the sociotechnical evaluation of nuclear power is the public's inability to deal with different degrees of risk, i.e., anything other than one hundred percent safe, a fifty-fifty chance, or "extremely dangerous" is beyond the scope of most people's ability to evaluate. Nuclear power does not fall into any of the foregoing categories.

Before nuclear power will become accepted in any society, there must be a decision on the part of the public that the benefits to be derived are worth the risks (whatever the risks are perceived to be). The evaluation of the benefits seems to be most closely tied to the cost of energy in general, and the degree that national security could be threatened by disruption of energy flows from outside a country's borders. Nuclear power is no longer primarily a technical issue, but rather a political problem.

In Michigan, there is a capsule view of many of the same issues and choices that are being faced in other states, in the nation, and in other countries. The nuclear industry got an early and healthy start in the State, but has faced increased opposition in recent years. The problem of risk-perception was well capitalized on by the previously mentioned falacious book: The Day We Almost Lost Detroit. Nuclear waste disposal has been an issue in the State because of the need for such disposal for the local nuclear power industry, and also because of the various technologically feasible sites for such disposal within the State. So resistant are some citizens to the nuclear power industry that efforts have been made to prevent the continued operation of one nuclear power plant by legal opposition to the increased usage of existing spent fuel-rod storage facilities.

In spite of such opposition to existing plants and three new units under construction, the new plants are scheduled for completion in the next few years, and will place Michigan in a position of even greater dependence on nuclear power than the comparative lead it already has against the national average. Based on the discussions of the recent Michigan Legislature's special Joint Committee on Nuclear Energy from May 1979 to September 1980, it is doubtful that the State government will become any more involved in the nuclear power industry in the State than it already is via the Michigan Public Services Commission.

A model has been developed for determining the impact of past and present choices with regard to the building of a nuclear power industry on the energy economy of the United States. The "yardstick" for measuring this impact is the amount of imported oil energy-equivalent that could have been supplied by the nuclear power plant capacity that was forecasted to be installed by the end of 1980, but because of the various local, national, and international concerns which were discussed, was not installed.

It was determined, based on thirteen reputable forecasts made over the period from 1964 to 1975 that the medium forecast for nuclear capacity to be installed by 1980 was 119,000 megawatts. Based on actual installation, a 64,000 megawatt shortfall was observed.

It was then determined what this capacity could have replaced in terms of barrels of imported oil. The procedure followed was to first determine the number of kilowatt-hours that were generated per average megawatt of nuclear power in 1979. It was then determined how many Btu of oil at a 1979 oil-fired power plant would have been required to produce the same amount of electricity. Following this step, it was necessary to convert this Btu amount into barrels of imported oil, which could then be applied to the nuclear-capacity shortfall and expressed either in terms of barrels of imported oil per megawatt (23.746), or as a percentage of oil imports for 1979, which was nineteen percent. If the nuclear power plant capacity shortfall had not occurred, it could have generated approximately the energy-equivalent of all the oil-fired capacity in the United States during the same year. Of course, this would not eliminate the limited need of oil-fired plants during peak-load periods. However, it could have helped substantially by eliminating the necessity of operating oil-fired plants in the base-load, which has commonly occurred when there were low reserve margins.

The usefulness of this model is not in telling a society whether or not it should install more or less nuclear power, but rather to provide a tool for measuring the potential impact on the very strategic resource of oil and more specifically, imported oil. It is hoped that this process will help quantify the very complex decision making process with regard to nuclear power, so that one can more intelligently make the ubiquitous tradeoffs.

In conducting this study, various other worthy topics for research became apparent. One task might be to evaluate how amenable the American public would be to federal government control of the nuclear power industry (as in France and Japan). Another interesting study would be to evaluate just how effective different persuasive strategies are in gaining public acceptance for nuclear power, or if they are effective at all. A third study might be to evaluate the effectiveness of alternate types of educational information in achieving the goals of more knowledgeable public and private decision-making processes. A fourth study which would be dependent on completion of the first three mentioned above, would be an attempt to do a cost-benefit analysis of the nuclear industry in the United

States--considering the costs involved in gaining the acceptance of nuclear power via one of the above strategies of a predetermined percentage of the population.

The nuclear power issues and choices are among the most debated and formidable ones accompanying the phenomenon called the "energy crisis". There are no clear-cut right and wrong decisions regarding nuclear power, but there are a very large number of tradeoffs. It is hoped that this study has provided some additional tools and insights for making more intelligent choices among them.

APPENDIX 1

ADDITIONAL CALCULATIONS

Appendix 1, Part a

In order to obtain the most accurate answers possible throughout this paper, the standard method of rounding off numbers with each calculation to the maximum number of significant digits was used. Following are some examples:

$(24.\underline{1})(26.33\underline{3}) = 63\underline{4}$

$(24.22\underline{2})(13.9\underline{9} = 338.\underline{9}$

$(24.16\underline{8})/(22.\underline{1} = 1.0\underline{9}$

$1.684\underline{9} + 1.2\underline{3} = 2.9\underline{1}$

$1.2\underline{3} - 1.010\underline{3} = .2\underline{2}$

Appendix 1, Part b

Problem:

Determine the percentage of total dependency on foreign oil in the United States during 1979.

Data: domestic oil production in 1979 provided 18.064×10^{15} Btu[1] of energy, and imported oil in 1979 provided 16.920×10^{15} Btu[2] of energy.

Total oil utilized:

18.064×10^{15} Btu + 16.920×10^{15} Btu = 34.984×10^{15} Btu.

Percentage oil importation:

(16.920×10^{15} Btu)/(34.984×10^{15} Btu) = .484, or 48.4 percent.

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[1] U.S., Department of Energy, Monthly Energy Review, September 1980, p. 6.

[2] Ibid., p. 10.

Appendix 1, Part c

Problem:

Determine the percentage of total dependency on foreign oil in the United States through June of 1980.

Data: domestic oil production through June 1980 provided 9.176×10^{15} Btu of energy,[1] and imported oil through June 1980 provided 7.177×10^{15} Btu of energy.[2]

Total oil utilized:

9.176×10^{15} Btu + 7.177×10^{15} Btu = 16.353×10^{15} Btu.

Percentage oil importation:

$(7.177 \times 10^{15}$ Btu$)/(16.353 \times 10^{15}$ Btu$) = .438$, or 43.8 percent.

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[1]U.S., Department of Energy, Monthly Energy Review, September 1980, p. 6.

[2]Ibid., p. 10; this is a total of crude oil and refined petroleum products importation.

Appendix 1, Part d

Problem:

Determine what percentage of total energy inputs was provided by nuclear power in 1979.

Data: nuclear energy inputs was 2.748 x 10^{15} Btu,[1] and total energy inputs to the economy was 78.022 x 10^{15}Btu.[2]

Calculation:

(2.748 x 10^{15} Btu)/(78.022 x 10^{15} Btu) = .035, or 3.5 percent.

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[1]U.S., Department of Energy, Energy Information Administration, Monthly Energy Review, September 1980, p. 25.

[2]Ibid., March 1980, p. 2.

Appendix 1, Part j

Problem:

Determine what was the average amount of electrical energy in kilowatt-hours generated by each megawatt of nuclear capacity in 1979.

Data: installed nuclear capacity in 1979 was 54,594 Mw.[1] and the energy output from nuclear plants in 1979 was $255{,}155 \times 10^6$ kwh.[2]

Calculation:

$(255{,}155 \times 10^6$ kwh$)/(54{,}594$ Mw$) = 4{,}673{,}682$ kwh/Mw.

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[1]Melvin E. Johnson, telephone interview, U.S. Department of Energy, Energy Information Administration, Coal and Electric Power Statistical Division, Office of Data and Interpretation (Washington, D.C.), 17 December 1980.

[2]U.S., Department of Energy, Energy Information Administration, Monthly Energy Review, September 1980, p. 62.

Appendix 1, Part f

Problem:

Determine the percentage of total kilowatt-hours (kwh) generated by nuclear power plants in the United States during 1979.

Data: total electricity generated during 1979 was $2,247,372 \times 10^6$ kwh,[1] and the total electricity generated by nuclear in 1979 was $255,155 \times 10^6$ kwh.[2]

Calculation:

$(255,155 \times 10^6 \text{ kwh})/(2,247,372 \times 10^6 \text{ kwh}) = .114$, or 11.4 percent.

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[1] U.S., Department of Energy, Energy Information Administration, Monthly Energy Review, September 1980, p. 62.

[2] Ibid.

Appendix 1, Part g

Problem:

Determine the percentage of total kwh generated by coal, petroleum, and natural gas during 1979.

Data: total electricity generated in 1979 was $2,247,372 \times 10^6$ kwh,[1] electricity generated by coal in 1979 was $1,075,037 \times 10^6$ kwh,[2] electricity generated by oil in 1979 was $303,525 \times 10^6$ kwh,[3] and electricity generated by natural gas in 1979 was $329,485 \times 10^6$ kwh.[4]

Total fossil fuel electricity:

$1,075,037 \times 10^6$ kwh + $303,525 \times 10^6$ kwh + $329,485 \times 10^6$ kwh = $1,708,047 \times 10^6$ kwh.

Calculation:

$(1,708,047 \times 10^6 \text{ kwh})/(2,247,372 \times 10^6 \text{ kwh}) = .760$, or 76.0 percent.

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[1]U.S., Department of Energy, Energy Information Administration, Monthly Energy Review, September 1980, p. 62.

[2]Ibid. [3]Ibid. [4]Ibid.

Appendix 1, Part h

Problem:

Determine the number of British Thermal Units (Btu) in a kilowatt-hour (kwh).

Data: 453.6 grams in one pound of matter, 4.184 Joules per calorie, and 1 degree Fahrenheit is 5/9 degree Celsius.

(1 Btu is the energy input that will raise 1 lb of water by 1 degree Fahrenheit. This same energy will raise 1 lb of water (453.6 gm) by 5/9 degree Celsius. The amount of energy input would be 252 calories.)

Calculations:

(453.6 gm/lb)(5/9) = 252 calories,

(252 cal/Btu)(4.184 J/cal) = 1,054.368 J/Btu, and

(3.60×10^6 J/kwh)/(1,054.368 J/Btu) = 3,414.3676 Btu/kwh.

Appendix 1, Part k

Problem:

Demonstrate the trend toward increasingly larger shortfalls in nuclear power.

Data: forecast[1] for 1978 was 87,000 Mw, for 1979 was 103,000 Mw, and for 1980 was 132,000 Mw. Installed capacity for 1978 was 53,700 Mw,[2] 54,594 Mw at year-end 1979,[3] and could be considered to be either 56,641 Mw[4] or 58,585 Mw[5] at year-end 1980.

Calculate shortfalls:

87,000 Mw - 53,700 Mw = 33,000 Mw,

103,000 Mw - 54,594 Mw = 48,000 Mw, and

132,000 Mw - 58,585 Mw or 56,641 Mw = 73,000 Mw or 75,000 Mw.

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[1]"Nuclear Forecast", Public Utilities Fortnightly, 26 September 1974, p. 44, cited by Environment Information Center, Energy Reference Department, The Energy Index, vol. 2 (New York: Environment Information Center, December 1974), p. 115.

[2]U.S., Department of Energy, Energy Information Administration, Annual Report to Congress 1979, 3 vols., n.d., 2:139.

[3]Melvin E. Johnson, telephone Interview, U.S. Department of Energy, Energy Information Administration, Coal and Electric Power Statistical Division, Office of Data and Interpretation (Washington, D.C.), 17 December 1980.

[4]Added only North Anna 2 and Sequoyah 1 in 1980.

[5]Includes Salem 2 (1,115 Mw) and Farley 2 (829 Mw) issued "limited licenses" for low-power testing in April and October 1980; also includes North Anna 2 (907 Mw) and Sequoyay 1 (1,140 Mw) issued full-power licenses in August and September 1980.

Appendix 1, Part 1

Problem:

Determine the total barrels of oil imported to the United States in 1979.

Data: Btu content of oil imports in 1979 was 16.920×10^{15} Btu,[1] and the average Btu content per bbl imported crude oil was 5,802,000 Btu.[2]

Calculation:

$(16.920 \times 10^{15}$ Btu/yr)/(5,802,000 Btu/bbl) = 2,916,200 $\times 10^{3}$ bbl/yr, or

$(2,916,000 \times 10^{3}$ bbl/yr)/(365) = 7,989,600 bbl/day.

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[1]U.S., Department of Energy, Energy Information Administration, Monthly Energy Review, September 1980, p. 10.

[2]Ibid., p. 107.

Appendix 1, Part m

Problem:

Determine how many barrels of imported crude oil were necessary to generate the electricity from oil-fired power plants in 1979.

Data: Btu of oil used in generating electricity in 1979 was 3.2658×10^{15} Btu,[1] and the average Btu per bbl of 1979 crude oil imports was 5,802,000 Btu.[2]

Calculation:

$(3.2658 \times 10^{15}$ Btu)/(5,802,000 Btu/bbl) = 562,870,000 bbl.

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[1]See table 7 of Chapter 7.

[2]U.S., Department of Energy, Energy Information Administration, Monthly Energy Review, September 1980, p. 107.

Appendix 1, Part n

Problem:

Determine the barrels of imported-oil-equivalent for all the fuel oils used during 1978 for heating.

Kerosene:

44,090,000 bbl[1] at 5,670,000 Btu/bbl[2] = 250 x 10^{12} Btu.

Distillate fuel oil:

533,069,000 bbl at 5,825,000 Btu/bbl = 3,105 x 10^{12} Btu.

Residual fuel oil:

164,536,000 bbl at 6,287,000 Btu/bbl = 1,034 x 10^{12} Btu.

Total Btu for heating:

250 x 10^{12} Btu + 3,105 x 10^{12} Btu + 1,034 x 10^{12} Btu = 4,389 x 10^{12} Btu.

Convert to barrels of imported oil:

(4,389 x 10^{12} Btu)/(5,802,000 Btu/bbl) = 756 x 10^6 bbl.

Express as percentage of total imports:

(756 x 10^6 bbl)/(2,916.2 x 10^6 bbl)* = .259, or 25.9 percent.

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[1] U.S., Department of Energy, Energy Information Administration, Energy Data Reports: Fuel Oil Sales Annual, November 1979, p. 4; all other fuel amounts are from the same page.

[2] U.S., Department of Energy, Energy Information Administration, Monthly Energy Review, September 1980, p. 107; all other Btu values per barrel are from the same page.

*The total import amount is derived in Appendix 1, pt. 1.

APPENDIX 2

ADDITIONAL TABLE

TABLE 8

CONSUMPTION OF ENERGY 1949-1979

Year	Total Gross Energy Consumption (10^{15} Btu)	Change From Previous Year (Percent)
1949	31.08	-5.7
1950	33.62	8.2
1951	36.11	7.4
1952	35.83	-0.8
1953	36.78	2.6
1954	35.73	-2.8
1955	39.18	9.6
1956	40.76	4.0
1957	40.81	0.1
1958	40.65	-0.4
1959	42.42	4.3
1960	44.08	3.9
1961	44.73	1.5
1962	46.80	4.6
1963	48.61	3.9
1964	50.78	4.5
1965	52.99	4.4
1966	55.99	5.7
1967	57.89	3.4
1968	61.32	5.9
1969	64.53	5.2
1970	66.83	3.6
1971	68.30	2.2
1972	71.63	4.9
1973	74.61	4.2
1974	72.76	-2.5
1975	70.71	-2.8
1976	74.51	5.4
1977	76.39	2.5
1978	78.15	2.3
1979	78.02	-0.2

SOURCE: U.S., Department of Energy, Energy Information Administration, Annual Report to Congress 1979, 3 vols., n.d., 2:7.

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