Exporting nuclear power: Some ethical considerations and economic realities

John A. Baker

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EXPORTING NUCLEAR POWER
SOME ETHICAL CONSIDERATIONS
AND ECONOMIC REALITIES

By
John A. Baker
B.S. Chapman College, 1976
Prepared in Partial Fulfillment of the Requirements
for the Degree of

Master of Business Administration

UNIVERSITY OF MONTANA
1985

Approved by:

[Signature]
Chairman, Board of Examiners

[Signature]
Dean, Graduate School

9/22/85
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INTRODUCTION

Views on nuclear power are quite polarized and often there is more emotion than thought involved in the various opinions. I have also found in the course of my research that, in the last few years, some possible long term deficiencies in the economics of nuclear power may have surfaced. Every effort has been made to present all sides of each issue.

In the wake of the Three Mile Island accident and the less than expected growth of demand for nuclear power, the nuclear industry in the United States seems to be faltering. The industry has already invested approximately $230 billion to construct, operate, and maintain commercial nuclear generating stations and their supporting infrastructure. The federal government has funded an additional $40 billion -- used principally for R&D on light water reactor technology. This United States light water reactor technology has formed the basis for all of the successful light water nuclear programs in the world.

The Japanese, the Germans and the French are all using the contemporary U.S. light water reactor technology as the foundation for their nuclear programs.¹
The Industry

The nuclear power industry is made up of 24 giant multinational corporations and may constitute the single largest and most powerful business enterprise in history. In 1981, they sold $400 billion worth of products. All but five of these behemoths rank among the one hundred fifty biggest companies in America. The enormous influence that they have in the United States is amplified by their close association with eight of the nine largest banks, the seven largest insurance companies and many top investment and law firms, not to mention the strong support of the government. These factors combine to assure access to large pools of capital.²

The day when nuclear power will be the world's leading electricity source now seems to have been postponed indefinitely. Nuclear power is plagued by many serious issues that remain unresolved, including safety, waste disposal, and nuclear weapons proliferation. Something much simpler, however, is giving the industry most of its current problems. In most countries, nuclear power is no longer economically attractive. Years of cost overruns have destroyed the economic underpinnings of many programs, and much slower growth in electricity use has called into question the need for many nuclear plants now being built. All indications are that nuclear power's economic competitiveness continues to deteriorate and could lead to
further cutbacks. Indeed, the development of nuclear power may come to a complete standstill by the late eighties.\(^3\)

In Chapter One, I will explore the questions of Why Nuclear Power? and How Much Nuclear Power is required? We will examine what the international market looks like. I will list and explain in layman's terms the types of technology used and the safety precautions and concerns in each of the countries that presently use nuclear energy.

Chapter Two will explain why Third World countries want nuclear technology and why the major suppliers of nuclear technology envision these Third World countries as being important customers.

Chapter Three will examine the Nuclear Proliferation issue (To export or not to export?). Some of the dangers of nuclear proliferation will be examined from the standpoint of the nation states and terrorists. We will show some of the reasons why nation states want to acquire nuclear weaponry. Additionally, this chapter will give some insight into where the world is in regard to nuclear proliferation. We will look at the proliferation problem from the point of view of: The U.S. government's position, the U.S. nuclear industry's position, the position of the U.S. allies and the Third World position.

Chapter Four will evaluate nuclear power from the
sociotechnical standpoint. We will get a perspective of public attitude and what the total social cost of nuclear power is. The externalities of nuclear power will be examined and what those would mean to the countries receiving the exported technology. A comparison will be made of "normal emissions" of radioactive gasses versus background radiation, in terms of dosage and danger. We will take an in-depth look at what the "Worst Case Nuclear Accident" in a light water reactor would be like; how that differs from what the public perception is and why. Other public perceptions of nuclear externalities will be examined and analyzed. A comparison will be made of the hazards associated with working in the nuclear industry versus working in other vocations. The discussion will include what nuclear waste is made of; how this waste has become an issue and how that issue has progressed. We will explore what methods are the most promising for waste disposal and how those methods relate to the reality of Third World capabilities or the lack thereof. Some alternative disposal methods will be examined along with environmental and institutional considerations.

In Chapter Five, the economic costs of nuclear, coal-fired and solar energy will be contrasted. Then, some of the environmental impacts of the alternative technologies will be enumerated. We will examine some of the more salient aspects of conservationism and how they apply to
the Third World nations.

Chapter Six will contain my conclusions and recommendations as to the exportation of Nuclear Power.

The Appendix will contain a brief history of Nuclear Power for those who have an interest in such matters. Of course, it is always a good idea to know where we have been, as we consider where we are going.

**Preview**

A recent article in the Wall Street Journal indicates a grim assessment of the nuclear industry's condition. "Nuclear power cannot at this time be considered a viable option on which to base new electric generating capacity in the U.S.," said the 31 member panel headed by Robert Smith, retired chairman of Public Service Electric & Gas Co., Newark, N.J. The panel said:

"Until there is more certainty and stability in the licensing and regulation of nuclear power and construction lead times have been reduced, and until there is a greater public consensus in favor of nuclear power, the private sector cannot take on the open-ended financial risks that now attend the nuclear power option."

It is interesting to note that this report was commissioned by the Atomic Industrial Forum, the nuclear industry's own promotional arm! The panel was made up of top utility, industry and financial figures.  

Today, contraction has replaced expansion as the rate of investment in nuclear power has slumped around
the world. What could be termed a "deep recession" in nuclear power, has had some advantages to the world as a whole. It has dealt a severe, if not mortal blow to the fast breeder reactor and thus to the surplus of fizzle (nuclear material that has been enriched with excess neutrons to the point that it is capable -- under the right circumstances -- of sustaining an uncontrolled chain reaction -- Weapons grade) material. This in turn, has slowed down the spread of nuclear technologies and materials to countries that may wish to develop nuclear weapons. The recession also brings with it problems. The suppliers are threatened with the possibility of losing their productive and technological capabilities.5

Unless quite dramatic changes occur in the outlook for nuclear power in the United States, its decline as a leading producer and developer of nuclear power plants would appear irreversible. By the 1990s, other nations -- most likely West Germany and Japan -- may have replaced it at the hub of the industrial system. During the 1990s, the combination of economic revival, rising energy prices and the need to replace aging power plants of all types may bring some recovery to the nuclear industry. The possibility of revival, however remote, is one of the primary reasons that the manufacturers are going to such lengths to stay in the business. It is also why governments are, for the most part, subsidizing their efforts.6
The five leading producers, the U.S., Canada, France, West Germany, and Japan have differing prospects. Regarding domestic demand, the U.S. vendor's position seems least favorable. After over a decade of losing money, the utilities will take a lot of convincing before they invest in nuclear power again. On the good side, it seems that the political and regulatory climates may be changing.

General Electric and Babcock & Wilcox have effectively withdrawn from making offers for nuclear orders for the time being. Combustion Engineering may have to follow suit if foreign orders cannot be secured soon, most notably in Taiwan; and even Westinghouse is showing signs of strain. 7
Introduction Notes


6 Ibid.

7 Ibid.
CHAPTER ONE

Nuclear Power: Why and How Much?

Discussion

The central issues of this chapter:
1) Why there is a need for nuclear power.
2) How much nuclear power is needed?
3) The international market for nuclear power.
4) An insight into present nuclear technology.
5) Safety precautions and concerns regarding nuclear power.

Why Nuclear Power?

Internationally, the market for nuclear power plants is growing due to several factors. Some nations do not have the diversified energy resources that are available to the United States and the Soviet Union. They lack domestic supplies of coal, oil or natural gas, and many do not have hydroelectric options. These nations have had to import large supplies of fossil fuels to meet their energy needs in the past, or alternatively, they have not been able to take advantage of their growth potential. Many industrialized countries have found that it is highly
undesirable to be dependent upon fuel from outside sources, and this has made the nuclear option quite appealing. The Third World countries find that nuclear power may be the best route into the modern era. In any case, the question of justifying nuclear power introduction or expansion is unique to each country. Statistically, nuclear power worldwide is a fast-growing industry (See Figure 1-1 to 1-6). Figure 1-1 shows the percentage of nuclear electrical generation by the Third World countries.

Figure 1-2 gives a comparison of nuclear generation by Third World countries and the rest of the non-communist world minus the U.S. Note that, in this comparison, the Third World volume of generation is generally not significant.

Figure 1-3 compares U.S. nuclear generation with that of other non-communist countries. Note that growth for the other countries has been nearly linear to slightly exponential while that of the U.S. has basically stopped.

Figure 1-4 shows the third world, the non-communist industrialized nations and the U.S. nuclear growth within the context of total nuclear growth for the period. Note that all of the graphs show a distinct growth except that of the U.S.

Figure 1-5 shows an expanded view of what nuclear generation growth has been like for the Third World countries. Note that the growth shows an exponential tendency
Fig. 1-1 Nuclear Electrical Generation of Third World Countries

- Argentina: 9 (27%)
- India: -2.9 (9%)
- Brazil: -2 (1%)
- Pakistan: -2.5 (7%)
- South Korea: 18.9 (56%)
- Taiwan: -.2 (1%)
Fig. 1–2 Nuclear Electrical Generation

Third World Vs. Industrialized Non-communist countries - U.S.

Nuclear Generation Growth 1973 to 1983
Fig. 1-3 Nuclear Electrical Generation
Total Non-Communist Nuclear Generation Minus U.S.

- United States
- Total Non-Communist - U.S.

Nuclear Generation Growth 1973 to 1983
Comparison of Growth in Non-communist Countries
but that this may be due to a number of nuclear generation plants coming on line at the same time (this does not necessarily indicate a growth in demand for the nuclear energy).

Figure 1-6 shows an expanded view of nuclear growth for all of the non-communist countries; it appears quite linear with a tendency to be exponential. This depicts a healthy growth pattern for the industry for the period 1973 - 1983 in the non-communist world. ²

American suppliers, American constructors and American engineers are building American-designed nuclear power plants throughout the world. In many countries such as Japan, and soon China, these plants are built in just five or six years for a total cost of less than a billion dollars. It takes 12 years in the U.S., and as much as $4 billion to build the same kind of plant to the same safety requirements. Obviously, the question is, "Why?"

Philip Bray, of General Electric, states:

"We did a study of a typical nuclear power project and found that in countries such as Japan, France and Taiwan, the total cost of building a nuclear plant is less than $1 billion. In the U.S., we found that the original cost estimates grew by more than $3 billion - a billion for regulatory changes, a billion for the escalation of costs over the lengthy construction period and a billion for the interest on the bonds issued throughout the construction period." ³

Given the growth in world population since mid-century, the percentage rise in per capita oil consumption
Fig. 1-6 Nuclear Electrical Generation
Total Worldwide Non-Communist Nuclear Generation Minus U.S.

(In Billions of Kilowatt Hours)

Nuclear Generation Growth 1973 to 1983
Between 1950 and 1979, the average individual's use of oil climbed from 1.56 barrels per year to 5.48 barrels, a gain of nearly fourfold. Since 1979, however, with world oil consumption declining while the number of people continued to increase, the per capita decline has been precipitous. Falling nearly 20 percent in four years, it has affected every facet of human existence from diets to transportation. The substantial adjustments of the last few years will continue for decades to come. "In retrospect, the world may be heavily indebted to OPEC for having raised the price of oil."  

Demand for all forms of energy has not been increasing, as was previously forecasted. Could this indicate a new worldwide energy awareness that could change the energy marketplace in the long term?

Some would argue that, even if nuclear power is expensive, it is still essential as a replacement for imported oil. Although it is true that nuclear power has helped lower oil imports in some nations -- particularly France and Japan -- in most countries its contribution has been negligible, dwarfed by increased use of coal and by energy efficiency. In the United States, oil imports have fallen 50 percent since 1973. Today, a small and shrinking fraction of the world's oil is used to generate electricity, and the oil versus nuclear equation is largely moot.  

Economically, nuclear power is often hard to
justify. In many countries, an efficient size nuclear power plant would overtax the power grids of the country. Therefore, the power grids often have to be rebuilt; this sometimes drives the costs of nuclear power above those of fossil fuels. The economies of nuclear power are unique to each country.

Probably the major reason for using nuclear power is to free petroleum for other purposes; transportation is the most notable of these. The view also exists that burning oil for electricity is too wasteful since only about one-third of its energy content is captured in conventional power plants.

Spurred by the oil price hikes of the 1970s, France and Japan are using nuclear power to make rapid strides toward energy self-sufficiency. France obtains the highest proportion of its electricity from nuclear generation in the world. It is estimated that France will generate 75% of her needs through nuclear power by 1990. Japan received 21% of its electricity from nuclear plants in 1983. Determined to reduce its dependence on foreign oil, Japan has committed to building 27 new nuclear plants over the next ten years. This will more than double the amount of electricity generated by nuclear plants in Japan. Their long-term commitment to nuclear energy includes plans for a new $4 billion facility for uranium enrichment, fuel reprocessing and permanent waste disposal.⁶
National security is a goal that most nations feel they must attain. Energy self-sufficiency, elusive by any standard, is an important part of that security and is best approached by some countries through nuclear power by using their own supplies of uranium. Japan has no deposits of uranium and still opts for nuclear power as one of its chief sources of energy. Even the United States has pursued other forms of energy since the 1973 oil embargo (albeit not to the degree necessary to achieve true energy independence).

Prestige enters into the question of, "Why?" in that many countries seemingly have decided to pursue nuclear power chiefly as a symbol of entry into twentieth century technology. Table 1-1 gives a breakdown of the nuclear commitment by each of the major nuclear generating countries.

Finally, a significant motive for acquiring nuclear power is the enhancement of the country's scientific community's expertise in the field of nuclear technology. A country may not have plans to build nuclear weapons, yet might want to have the technology available should the need for the weapons arises. Indeed, there are definitely some countries that want the weapons. This aspect will be discussed at length in Chapter Three.
Table 1-1

WORLD WIDE NUCLEAR POWER COMMITMENT, by END OF 1983*

<table>
<thead>
<tr>
<th>Country</th>
<th>Plants Operating</th>
<th>Plants Ordered and Under Construction</th>
<th>Total Commitment</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Megawatts</td>
<td>Number</td>
</tr>
<tr>
<td>United States</td>
<td>77</td>
<td>50,026</td>
<td>64</td>
</tr>
<tr>
<td>France</td>
<td>31</td>
<td>21,778</td>
<td>31</td>
</tr>
<tr>
<td>West Germany</td>
<td>12</td>
<td>9,806</td>
<td>17</td>
</tr>
<tr>
<td>Japan</td>
<td>25</td>
<td>16,652</td>
<td>15</td>
</tr>
<tr>
<td>Soviet Union</td>
<td>34</td>
<td>18,915</td>
<td>11</td>
</tr>
<tr>
<td>Canada</td>
<td>12</td>
<td>6,622</td>
<td>12</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>34</td>
<td>9,273</td>
<td>8</td>
</tr>
<tr>
<td>Spain</td>
<td>6</td>
<td>3,820</td>
<td>7</td>
</tr>
<tr>
<td>Sweden</td>
<td>10</td>
<td>7,300</td>
<td>2</td>
</tr>
<tr>
<td>South Korea</td>
<td>1</td>
<td>556</td>
<td>8</td>
</tr>
<tr>
<td>Belgium</td>
<td>5</td>
<td>3,450</td>
<td>2</td>
</tr>
<tr>
<td>Switzerland</td>
<td>4</td>
<td>1,940</td>
<td>3</td>
</tr>
<tr>
<td>Taiwan</td>
<td>4</td>
<td>3,110</td>
<td>2</td>
</tr>
<tr>
<td>Czechoslovakia</td>
<td>2</td>
<td>880</td>
<td>8</td>
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<tr>
<td>Italy</td>
<td>3</td>
<td>1,285</td>
<td>3</td>
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<tr>
<td>Brazil</td>
<td>-</td>
<td>-</td>
<td>3</td>
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<tr>
<td>East Germany</td>
<td>5</td>
<td>1,830</td>
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<tr>
<td>India</td>
<td>4</td>
<td>804</td>
<td>6</td>
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<tr>
<td>Argentina</td>
<td>1</td>
<td>335</td>
<td>2</td>
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<tr>
<td>The Rest of the World</td>
<td>12</td>
<td>5,205</td>
<td>21</td>
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<tr>
<td>World Total</td>
<td>282</td>
<td>173,587</td>
<td>227</td>
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(7) *Preliminary estimate.

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How Much Nuclear Power?

A study of worldwide investment in nuclear power indicates that, between now and the year 2010, investment in nuclear power could amount to about one trillion dollars.8

The World Energy Conference suggests a program for the installation of nuclear capacity, worldwide, by the year 2020 of between 3,200,000 Mw. and 5,500,000 Mw.9

Demand for energy is increasing worldwide, and with that increase, there is a corresponding demand for nuclear capacity. In the European community, demand for energy by the year 2000 will have increased between 1.5 and 2 times. The anticipated growth is similar in Japan, and in the remaining parts of the world, it may well increase by three times by the start of the next century.10 Contrast this to Douglas Cogan's (an energy analyst with Investor Responsibility Research Center) assessment in the November 8, 1984, issue of the Wall Street Journal in which he said,

"A survey by us indicates that conservation and load management programs being developed by utilities could cut future power needs in the U.S. by the equivalent of 30 new nuclear plants. If utilities really 'put their money where their mouths are,' energy-conserving programs could stave off the need for virtually any new plant construction this century -- and cost less than half as much as new construction."11

What we have here is an indication that not only is the nuclear power industry in trouble in the United States from the standpoint of public opinion, but also its capabilities

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may not be needed in the U.S. when viewed in the light of conservationism. This leads one to believe that there is an imperative for the nuclear industry to use every means at its disposal to find projects for its technical personnel in other countries in order to keep them on staff and to remain viable for the long haul.

It is not just in the United States that nuclear power faces a less secure future than was expected just five years ago. Although most governments with major nuclear programs -- including France, Japan, and the Soviet Union -- remain strongly committed to nuclear power, there is a growing gap between rhetorical and monetary support and the actual achievements of the nuclear programs. Behind the lagging pace lie diminished growth in electricity demand and a long list of technical, economic and political problems.\(^1\)

**National Experience**

**Canada**

Canadians tend to be more trusting of their utilities and more confident about nuclear power than their U.S. counterparts. Indeed, the Canadian nuclear industry has not been plagued with the problems that have dogged the U.S. industry. Five of the world's most efficient reactors are in Canada; no planned reactors have been cancelled there, and they take half as long to build there as they
do here. In fact, Canada is even exporting nuclear power to the United States. The Canadian nuclear industry has a major advantage over the nuclear industry in the U.S. in that Canada's 13 completed reactors and the nine under construction follow the same design. This makes technical problems easier to solve and licensing merely a matter of inspection and power-up monitoring. Although the Canadian industry has had its minor problems of small cost overruns, its nuclear program has been successful mainly because the nation took one product, the Candu -- for Canadian deuterium uranium (it uses both deuterium and uranium to create nuclear fission), and they perfected it. In the U.S., on the other hand, every one of the sixty odd utilities want a custom plant, and so the learning curve that is so important to an industry never has a chance to run. The U.S. and most other nations use light water reactors, which rely on the heat of uranium fission to boil water. The steam produced turns a turbine to generate electricity. Canadian technology was controlled from the very start by two levels of government that approved designs and plans. These were then handed to the nuclear power industry which relegated the industry in Canada to that of a manufacturer. When a problem surfaced, government and industry got together to solve it. The Candu uses hundreds of small pressure tubes rather than a large core contained in one large pressure vessel, as with the light
water reactors. Thus, if one of the small tubes should rupture, there is little likelihood of serious contamination. In August of this year, there was a rupture of a pressure tube that did cause a minor loss of coolant accident. Upon investigation, it was found to be due to an alloy that is no longer used in newer reactors.

Canadians learned early on to regard training and safety as crucial.13

Ten years ago, someone suggested that the U. S. finance a line of Candus along the border and pump the energy south much like milking a giant power cow. This is not likely; however, New England states already import about one-third of the output of New Brunswick's reactor, and the Canadians would like to see that increase so they can build another reactor in the province. What is involved with Canada is the antithesis of this paper, in that we are in this case importing -- not exporting -- nuclear power.14

France

France has made the most notable shift to nuclear power; they set a goal of 36,200 Mw. of added nuclear capacity to be installed between 1970 and 1985. Earlier delays are being overcome, and by 1985, they anticipate that electricity from nuclear power will provide fifty-six percent of their total requirements.15
The scarcity of coal, oil and natural gas has made it necessary for France to rely on nuclear energy and to develop an ambitious program that encompasses nearly all types of nuclear installations from uranium mines to waste repositories, including uranium-enrichment facilities, irradiated fuel reprocessing plants and various types of reactors. With the first oil crisis in 1973, the French government decided to launch a massive construction program of pressurized-water reactors (PWRs) of which twenty-six 900 Mw. units are presently in operation and twenty-five more (900-1300 Mw.) are under construction. There are two important characteristics of French nuclear power. They are: standardization of technology and the fact that France has only one utility, Electricité de France (EDF), which also acts as its own architect-engineer for nuclear power plants. There is but one contractor for their nuclear plants, FRAMETOME (Societe Fronco-Amricaine de Constructions Atomiques, Puteaux, France), which is a Westinghouse Electric Corporation licensee. This limited number of partners in the French regulatory procedure should be kept in mind when considering the economies of nuclear power in this country.

When France embarked on a PWR program, the authorities decided in the beginning that U.S. experience should be used to minimize costs and delays and also to allow competent teams to be progressively formed. Each of the
three partners used U.S. experience.

Gradually, a French safety philosophy took shape, but it should be kept in mind that the French philosophy started with the U.S. Nuclear Regulatory Commission (NRC) regulations, which were always used for reference.  

Economic realities have proved much more hazardous to the French nuclear program than political opposition. Growth of electricity demand has been gradually showing since the late seventies, and in 1982, the government reduced its forecast of growth in the eighties by 50 percent. This means that France would have at least 13 percent too much generating capacity in 1990. Even many of the strongest supporters of nuclear power in France now admit that, from an electrical demand standpoint, no additional plant orders are needed for at least several years.

Germany

In contrast to the governmental nuclear energy programs in Canada, France, the United Kingdom and the U.S.S.R., the introduction of nuclear power plants in the Federal Republic of Germany was left to the existing public utilities. The first few nuclear power plants were constructed under licenses of U.S. vendors. The role of government was restricted to that of promoter of research and development.
At first, two large German electrical corporations developed and constructed two separate and independent lines of nuclear power plants. The Boiling Water Reactor (BWR) was built in cooperation with General Electric Company. The Pressurized Water Reactor (PWR) was built in cooperation with Westinghouse Electric Corporation. Later, another PWR was introduced in cooperation with the U.S. firm, Babcock & Wilcox Company.\(^{19}\)

In addition, the government sponsored the development and construction of other reactor types -- heavy water reactor, pressure tube reactor, sodium cooled reactor, fast sodium-cooled reactor, gas cooled high temperature reactor, nuclear steam superheater, and a ship reactor. Some of these were through independent development and some due to close international cooperation. Presently, there are five BWR units operating in the Federal Republic of Germany with a total of 3299 Mw. and three units with 3936 Mw. under construction. Of the PWR type, there are seven units with a total of 6965 Mw. in operation and seven more with a total of 9363 Mw. under construction.\(^{20}\)

Opponents of the German nuclear power program have been successful in raising issues of safety, environmental damage, and cost effectiveness in licensing hearings and in the courts. Project delays and cost overruns have been common. Meanwhile, electricity demand growth rates have dropped substantially, and the country has been under
increasing economic pressure, which makes investment in capital intensive projects much less attractive.21

Sweden

Sweden faces the situation of depending heavily on nuclear power in the near term, while having decided to abandon the nuclear option in the long term. This is as a result of an early commitment to a substantial nuclear program and an intensive political debate during the late 1970s, which ended in a referendum on the nuclear power issue. Concerns about reactor safety, waste management, and proliferation risks played an important role in the debate and the decision by the Parliament in 1980 after the referendum.22

The nuclear power program in Sweden is based on the use of 12 light water reactors (LWRs), 9 of which are BWRs of Swedish design. When the last two units are commissioned in 1985-1986, nuclear power will supply 50% of the nation's electricity needs.23

Britain

The government is in the midst of a major decision on the future of its nuclear program. The nationwide government-owned utility has proposed that the country begin building a new generation of light water nuclear plants based on the American Westinghouse design. Considerable controversy surrounds the economic soundness of the
proposal. The utility now admits that the country's most recent gas-cooled nuclear plants cost twice as much to build as coal-fired plants, but it still argues that light water plants can be produced at an attractive price.\textsuperscript{24}

Beyond the 8,500 Mw. of nuclear capacity that now supply 13 percent of the country's electricity, only another 5,500 Mw. worth are under construction, much of which is near completion. The high cost of the plants built so far and the forecasts that electricity demand will grow little, if at all, in the next decade provide ample economic hurdles to a revitalized nuclear construction program. Without the proposed new LWR program, the nuclear industry in Britain would soon wither.\textsuperscript{25}

Europe Overall

The total commitment to nuclear power in Europe has risen only 10 percent since 1978, and almost all the gain comes from France. The number of British and West German projects has risen slightly, while the numbers in Spain, Sweden, Switzerland, and Italy have fallen. Nuclear capacity projections have been lowered by nearly two-thirds since 1970.\textsuperscript{26}

Japan

Japan's experience with nuclear energy began with technology from the United Kingdom. The Japanese had to modify the U.K. reactors to take into account the
possibility of earthquake that was not considered by the British. The next generation of nuclear technology came from the U.S. and, in particular, from Westinghouse in the form of a PWR and from General Electric as a BWR. The commitments by these two companies influenced the electric utilities and introduced the era of the LWR in Japan.  

Public concern for nuclear safety grew and resulted in a policy decision to address problems immediately, no matter how insignificant they might appear to be, so that those problems would not lead to serious accidents, and then to incorporate the solutions into actual reactor operations.

To date, Japanese LWR technology, which is based on American technology with input from Japanese experience, has been aimed at continually improved reliability and safety to establish the "Japanese type" LWR. The capital cost of nuclear power is 60% of the total energy costs and basically represents construction costs. The increase in nuclear power plant construction costs in Japan exceeds that of the general wage scale and the price index because of increased costs for safety and reliability measures as well as inflation during long construction periods.

Conclusions to be drawn from Chapter One:
1) Many countries do not have the options of alternative resources such as coal, nor do they have topography that
will allow hydroelectric power development. The only way for many of them to enter the realm of modern civilization is through nuclear power. Nuclear energy frees many countries from the dependence on oil imports and bolsters their national security accordingly. Finally, another reason for pursuing the nuclear option is gathering the wherewithal to have a nuclear weapons capability.

2) Conservation has slowed the growth in demand for nuclear energy significantly; however, the population continues to increase. With that increase eventually will come a time when rising expectations will demand more electrical power. The question of, "how much nuclear energy?" remains clouded since there are many unresolved technical, economic and political problems.

3) Many countries have embraced nuclear technology and have developed or are developing the capability to generate their energy with it. Most of the world's technology is based on the United States Light Water Reactor. In most cases, the countries become generally self-sufficient regarding the technology required to operate their plants rather quickly but remain dependent on the suppliers for fuel reprocessing and enriched uranium, or for expansion of their nuclear facilities. The more advanced countries have themselves become exporters of nuclear technology.

4) The trend in nuclear safety is toward a walk-away reactor. The concept is that, when a condition occurs
that threatens the reactor's operation, the reactor has safety features that rely on the laws of physics rather than on man-made devices. This eliminates the need for decisions made under stress to right the situation and allows the operator the opportunity to research the problem properly before taking corrective action.
Chapter One Notes


12 Flavin, p. 126.


14 R. Atchison, F. Boyd and Z. Domaratzki, "Canadian


16 Flavin, p. 127.

17 Ibid.


19 Ibid.

20 Ibid.

21 Ibid.

22 Flavin, p. 126.


24 Flavin, p. 128.

25 Ibid., p. 126.

26 Ibid.


28 Ibid.
CHAPTER TWO

Nuclear Power and the Third World

Discussion

The central issues of this chapter:
1) Why the Third World nations want nuclear technology.
2) Why the suppliers of nuclear technology see the Third World as an important customer.

The forces behind the energy situation that confront the Third World countries are: the exploitation of the world's low cost fossil energy resources; development of nuclear power; growth of energy interdependence on a global scale; and emergence of environmental constraints on energy resource development and use.¹

Developing countries have quite different growth patterns than industrialized nations. This growth is characterized as exponential and stems from the fact that, when you have very little, as growth occurs the rising expectations of the populace require even more growth. Once a country becomes industrialized, the growth becomes generally more linear. Countries that are developing have a psychology of acceptance with regard to nuclear power that is based somewhat on a desire to enter the world of
twentieth-century technology with all of its perceived advantages of a higher standard of living. Latin America is a good case in point. Brazil has extensive nuclear power growth plans because their increased requirement of electricity cannot be solved by coal or hydroelectric power alone. The projected growth of nuclear power in Brazil is not unique; Latin America appears to offer the greatest external market for exporters of nuclear reactors, technology and services for the next ten years.²

In addition to accelerating expectations, the population of Latin America is growing at a rate that should see it nearly double by the year 2000 (See Table 2-1).

There is no question that vast quantities of energy would be required to bring the developing countries from their low standards of living to the standards of much of Europe, let alone the standards of the United States. These developing nations are looking for the industrialized nations to provide them with ways of producing more energy. As they develop, and as personal income increases, the people will want more lighting and appliances.³

Prestige, a consuming interest for any politician, is normally defined in terms of an accepted theory for national welfare. Reality has debunked the fantasy that nuclear power would make deserts bloom and villages prosper. The estimated cost of a $3,500 - per kilowatt for Brazil's Angra II reactor, which is at least four times the cost of
<table>
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<tr>
<th>Country</th>
<th>Number of Reactors</th>
<th>Planned or Announced</th>
<th>Possible</th>
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<th>Est. 2000</th>
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<td>10-30</td>
<td>110</td>
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<td>17</td>
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<tr>
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<td>0</td>
<td>1-2</td>
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<td>35</td>
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<td>1-2</td>
<td>29</td>
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<td>48</td>
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<tr>
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<tr>
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<td>2</td>
<td>2-10</td>
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<td>75</td>
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<tr>
<td>Totals</td>
<td>17</td>
<td>10-57</td>
<td>340</td>
<td></td>
<td>600</td>
</tr>
</tbody>
</table>

local central station power alternative, must now strike Brazilian national planners as less than seductive. 4

The predicted growth in nuclear reactors, as shown in Table 2-1 does not appear to be forthcoming due to economic factors that will be discussed later. Notice the date of the source.

Internationally, less than ten percent of energy consumption is by the Third World countries; however, as mentioned above, their growth of consumption will be far greater than the industrialized nations, and it is postulated that consumption may reach as much as twenty percent of the world total by the year 2000. 6

Contrast this to what a State of the World article says in 1984. During the sixties and seventies, developing countries had some of the brightest hopes for nuclear power, which Third World leaders viewed as a way to boost national prestige and reduce crippling oil import bills. Industrialized countries dispatched experts to promote the economic merits of nuclear power.

A deteriorating world economy since 1980 has led to a significant trimming of the Third World's most active nuclear programs. The capital intensity of nuclear power plants makes them a burden to debt-strapped developing countries, particularly since much of the money must be spent abroad, draining scarce foreign exchange. Substituting nuclear import bills for oil import charges is not seen by most Third World leaders as much of a gain. 7

Latin America was a booming market for nuclear
power in the seventies, but it, too, has fallen on hard
times. Argentina has had a small plant operating since
the early seventies and two more are being built. Wrapped
in the cloak of nationalism, Argentina's nuclear program
has enjoyed strong government support, and the country
hopes to have six operating plants by the end of the
century. Crippling debt problems, however, have cast doubt
on these goals and anything beyond the two now being built
is unlikely.®

Brazil, the world's sixth most populous country,
has one plant complete and two under construction. The
country planned to have eight plants operating by the early
nineties, largely relying on West German technology, but
major technical problems and a lack of capital have ren­
dered these goals meaningless. Brazil will be lucky to
complete the two now being worked on.®

Current plans indicate that developing countries
will have at most 20,000 Mw. of nuclear capacity by 1990,
which is only one-seventh as much as the International
Atomic Energy Agency had projected in the early seventies.
Yet, even these numbers overrate the economic viability of
nuclear power in developing countries. All the nuclear
sales in the Third World so far were subsidized by indus­
trial country governments or manufacturers. The day when
nuclear plants are sufficiently cost-effective that
developing countries will buy them at the full price is
Beyond these problems lies the more fundamental question of whether nuclear power is a wise use of scarce resources for a developing country. Nuclear power creates fewer jobs and requires more dependence on foreign companies and governments than does almost any other investment a Third World nation can make. Along with the economic issue is the growing realization that nuclear power plants are inviting targets for military and terrorist attacks in politically unstable regions.

The nuclear industry is looking quite favorably at prospects outside of the United States. Bechtel Group, Inc. is trying to stay alive until the day comes when nuclear power comes into its own. They are constructing fossil fired plants and drumming up nuclear construction jobs outside of the U.S. through the use of "financial engineering" much like a car dealer who helps with the financing. Bechtel now searches the globe on a far larger scale for billions of dollars so that their cash strapped customers can build their projects. "It's almost typical now," says Alden Yates, Bechtel's President. "In much of the Third World, you can't get a job unless you bring the money." Another form of financial engineering Bechtel is exploring is barter. A spokesman of Bechtel said that the company has offered to swap nuclear power plant construction management services for unspecified Yugoslavian
commodities, but no deal has been made yet. He acknowledges that such a course suggests strains on the world finance system. Still, he is optimistic about the future. "The world's population is growing and expectations are growing. Things are going to get built."¹²

Importing of fuel seems to be the only answer for most of the Third World nations along with hydroelectric development when possible. Oil will, most likely, be used chiefly for transportation, leaving coal (the primary sources of which are the U.S. and Australia) as the fossil fuel alternative. Considering shipping costs and aforementioned desire for self-reliance, nuclear and hydroelectric power will be the technologies to receive most of these countries' investments.¹³ This means that enriched uranium will be increasing in importance as an import for these countries since the only way to circumvent its importing would be to develop breeder reactors, which is considered a technology too high for developing nations to achieve or to maintain. An exception to this might be India where, with the aid of France, they are constructing a 15 Mw. fast breeder reactor.¹⁴

The National Academy of Sciences feels that nuclear power will play a significant role in developing nations. They state:

"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."15

There can be little doubt that, for industrialization to occur at all, sizable energy resources must be available to a country. Many developing countries already face unfavorable and often potentially devastating balance of payments problems which could force them to adopt nuclear power at a rate that is not socially nor technologically sound.

There are other problems with nuclear power. One is the inability of power grids in many Third World countries to carry the output of a modern nuclear power plant. This problem increases the costs of adopting nuclear power since grids have to be updated. The significant economies of scale associated with the larger plants would be lost to many countries if they developed reactors that were of a size more aligned with their power requirements and grid constraints. Thus, there are tradeoffs, but most countries have opted for the larger plants in the past. A happy note is that there are several suppliers who are beginning to tailor their designs to the less capital and power intensive needs of developing nations. (See modular High Temperature Gas Reactors, Chapter Five.)

Another concern is that, since the technology of
nuclear power is imported and these countries little understand it nor do they have competent regulatory agencies to control it, the nuclear power plants may not be built nor operated in a safe and efficient manner. The mere use of electricity over other forms of energy (manpower, animals, etc.) may well require a lengthy period of transition for many countries.¹⁶

Conclusions to be drawn from Chapter Two:
1) Growth in demand for electrical energy is generally exponential in developing countries. Many of these countries do not have the alternative energy resources available to the industrialized nations. Politically there is much to be gained by being able to claim that the efforts of a particular administration is bringing a country into the twentieth century.
2) The suppliers see developing countries as potentially lucrative customers because these countries do not possess the expertise to build their own nuclear facilities. There are many problems to be overcome regarding the exportation of nuclear technology, but at least there is a potential market, whereas, in the United States and in many industrialized countries, the market has withered. Being able to use their expertise elsewhere allows the suppliers to keep essential staff.
Chapter Two Notes


5 Temple and Hennelly, p. 59.


8 Ibid., p. 131.

9 Ibid.

10 Ibid., pp. 131-132.

11 Ibid., p. 132.


13 Mitre Corporation, p. 67.


15 National Academy of Sciences, pp. 76-77.

16 Mitre Corporation, p. 16.
CHAPTER THREE

Nuclear Proliferation

Discussion

The central issues of this chapter:
1) Whether or not to export nuclear technology.
2) Some of the dangers of nuclear proliferation.
3) Why some of the nation states would want nuclear weapons.
4) Where the world is in regards to nuclear proliferation.
5) The nuclear proliferation issue from the industry's, the government's, the allies' of the United States and from the Third World's point of view.

In 1972, while in the Air Force, I flew with some Israeli pilots and, after becoming friends with one, he said, pointing to the nuclear weapons delivery panel in the cockpit, "One day soon we shall have these in our aircraft."

A world in which many more countries acquire nuclear weapons could be a much less pleasant one. Wars that today kill thousands might instead kill millions; wars that now are averted might instead be launched simply because each side preemptively hastened to use its weapons, feeling that it dared not hesitate.1

The Nuclear Non-proliferation Treaty demands that all
but five of the nations of the world renounce nuclear weapons; the authors of the treaty naturally are among the privileged five.²

National Nuclear Club

The nuclear "club" which evolved in the 1960s included the U.S., the Soviet Union, Britain, France and China. India joined after shocking the world with its 1974 "peaceful nuclear explosion." (At that time India said, "We wanted to keep ourselves abreast of all aspects of the possibilities and benefits of peaceful nuclear explosions.") Most western analysts believe that Israel quietly acquired a nuclear arsenal in the late 1960s or early 1970s. Now, there is concern that a number of others may be nearing the threshold; among them Argentina, South Africa, Libya, South Korea, Taiwan and Iraq. These countries have developed the nuclear fuel reprocessing capability that can only be associated with massive nuclear generation or an ongoing weapons program.³

Argentina

One of the key policies of the current U. S. Administration is to ensure that Argentina does not construct nuclear weapons. Last November, Admiral Carlos Castro Madero, the head of the Argentina National Atomic
Energy Commission, announced that his country had succeeded in enriching the content in uranium of the isotope U-235 to 20%. This is the enrichment level required for Argentina's reactors. Foreign experts note that bridging the gap between 20% enriched uranium and fizzle material (90% enriched) is relatively inexpensive and not problematic technically. (Fizzle material is essentially weapons grade nuclear fuel, enriched with added neutrons and capable of -- under the right circumstances -- sustaining an uncontrolled chain reaction.) A concern that the U.S. has and one that cannot be entirely discounted is that, sometime in the future, the Argentines may be governed by lunatics who, in an effort to display their national patriotic fervor, may build "the bomb".

Foreigners control the technology that has been introduced into Argentina, including the three nuclear power reactors now in operation. However, installations built in Argentina with Argentine technology are another concern.

During the late 1970s, the Canadians were negotiating with Argentina to build a nuclear power plant. The Canadians were eager for the Argentines to accept full scope safeguards, since it was one of their reactors from which the Indians had diverted spent fuel for its "peaceful" explosion; however, when they required the Argentines to renounce the right to acquire a plutonium-reprocessing
capability, the Argentines broke off negotiations. That did not keep the plant from getting built.\(^5\)

Time and time again, the Argentines have seen the principles underlying the non-proliferation policies of the industrialized nations crumble in the way of commercial considerations. They say that they can import anything they want by demonstrating that they have the capability to develop the technology themselves. Should that fail, they buy from someone else.

There is every indication that Argentina intends to join the ranks of purveyors of nuclear energy services and technology.\(^6\)

**Pakistan**

Israeli analysts estimate that Pakistan may have an operational nuclear capability of 10 Hiroshima-sized bombs by 1986. U.S. and Indian estimates are more cautious, although they agree that Pakistan is close to becoming a nuclear weapons state. If Pakistan is close, can others be far behind?\(^7\)

The specter of an armed confrontation between India and Pakistan looms since, if India believes that Pakistan indeed is approaching weapons capability, she may decide a preemptive strike is in order. Israel has much to be concerned about -- a "Moslem bomb" -- and they, too may decide to unleash a strike such as they did under similar
circumstances against Iraq in 1981.\textsuperscript{8}

The weapons effort in Pakistan has been getting a lot of help from many sources. The Netherlands has furnished high strength steel of the type used in nuclear centrifuges. A West German company sold Pakistan a fluoridation plant which is required to make uranium hexafluoride. Conversion into this gas is a necessary stage in the uranium enrichment process. A Swiss company supplied a special gas system that could pump the gas into and out of the centrifuge, and U. S. companies have sold radiation-resistant thermometers and airconditioning equipment necessary to complete the process.\textsuperscript{9}

The Pakistanis claim that they are doing all of this to enhance their power production capabilities and that the enriched uranium is to fuel reactors for the generation of electricity. Western experts are more than skeptical about that claim since Pakistan does not have a nuclear power plant that uses enriched uranium fuel and may not for years. Should, as expected, Pakistan face a strong Western political rebuff, India believes she may well accept a "basement capability" which is the ability to make a weapon quickly without testing. European intelligence reports that China may have given Pakistan the weapons technology in exchange for centrifuge enrichment technology.\textsuperscript{10}
India

Obviously, India has weapons technology -- she has proven it -- but fizzle material is another matter. Most of the plutonium 239 that India now produces (about 10 kilograms per year) is consumed in research. A weapon of the Hiroshima/Nagasaki class requires 6-8 kilos. India is about to put a fast breeder reactor on line, designated the R-5. This reactor will produce up to 100 kilos of U-239 per year, enough to build 12 nuclear weapons. The Institute of Defense Studies and Analysis believes that it would require only a matter of weeks to fabricate bombs, once a decision had been made to do so. India's nuclear technology has been oriented toward generation of energy, not weapons; the weapons capability has been a spinoff. Money is not seen to be a problem in the production of weapons. India's first bomb, in 1974, cost about $400,000 to build. After the fast breeder reactor is producing plutonium in India, the estimates of weapons cost vary from $30,000-$180,000. In contrast, India is spending $20 million a copy for the French Mirage 2000 fighter aircraft.11

Before her death, Mrs. Gandhi told the annual conference of naval commanders that a Pakistani bomb would pose a great threat to India. With this in mind, it might seem that India may make a preemptive strike to remove the Pakistani threat. However, the "surgical" strike is not
considered a reasonable option by Indian officials since the Pakistani nuclear facility is some 70 miles from the Indian border, whereas Indian facilities are far closer to the Pakistani border. Thus, India offers many more "nuclear hostages" than Pakistan. Major General D. K. Palit, now retired and a writer on strategic affairs believes that Pakistan is doing in 1984 what India did in 1974, telling the world that it can make a bomb. He says:

"Pakistan doesn't have to go the whole route, because the scientific and intelligence grapevines have picked up evidence that it can succeed. Both countries now have the capability to make it, but I don't think either will. They don't need to, the state of uncertainty suits their strategic needs well enough." 

Israel

Barbed wire fences, no trespassing signs and sentries on hilltops keeping passers-by at a distance -- these are all part of what is believed to be the heart of the Israeli nuclear weapons facility, known as the Dimona nuclear reactor. If one is to believe that the Israelis have in fact developed nuclear weapons, then they have done so without all the trouble of international uproar and regardless of all the international safeguards provided by the Nuclear Non-Proliferation Treaty. It would seem that France is the culprit that has passed the atomic secrets to the Israelis in the form of plans for a reprocessing plant.
They may also have agreed to reprocess fuel from the Dimona reactor and ship it back to Israel. Meanwhile, the Israelis may have acquired some highly enriched uranium from a U.S. company during the late 1960s. With what would then be a wealth of fizzle material, it is postulated by many experts (and Israeli officials obliquely allude to the fact) that Israel may have acquired an arsenal of perhaps 20 nuclear warheads by now. (This is based on conservative estimates as to what would be possible if production were conducted on a nominal basis over the last two decades at Dimona.)

Some advocate that the Israelis overtly build and stockpile nuclear weapons. They say that this would tend to stabilize the Middle East. Yet, the Israeli people see it differently. They feel that this course may keep the U.S. from being so free with military aid during times of crisis. More importantly, they have a hard time envisioning using the nuclear weapons in a border war of attrition. In the meantime, there are very real economic pressures for them to do something pretty dramatic to reduce the cost of maintaining such a large conventional standing force.

South Africa

South Africa, like India, is not a signatory of the Nuclear Non-proliferation Treaty and, like India, it seems that they too, have developed a nuclear weapon capability.
The country's Koeberg nuclear power plant (a breeder reactor), opened this year and produces enough plutonium for a nuclear bomb every one or two weeks. Another such plant is being built, and South Africa also has a pilot nuclear fuel enrichment plant in addition to mines that make it the third largest producer of uranium in the world. At first blush, one may ask, "So what?" What are they going to use a bomb for even if they have one? Good point, and the South African official echo the refrain. "South Africa wants nuclear technology for peaceful purposes only. We do not possess nuclear weapons." South Africa probably has the most advanced nuclear program in the developing world. Their principle threat lies from within -- the twenty million strong disenfranchised black population. "Where would we drop a bomb anyway?" asks a government spokesman. Some outsiders believe that the government is slightly paranoid in that it continually warns of an imminent onslaught being orchestrated by the Soviet Union. This obsession has caused the government to be the brunt of much humor. A joke being circulated in the country has the President going to a fortune teller and asking if whites will still be ruling South Africa 50 years from now? "Yes," the fortune teller reassures him, "and what will be the price of a loaf of bread fifty years from now?" he asks. "Not much," reassures the fortune teller, "only 10 rubles." If jokes of government paranoia abound, can we
take lightly the fact that that same government may have its finger on the nuclear trigger. 16

Analysts say that a nuclear bomb may be viewed as a deterrent in the worst case scenario where a combination of outside forces are attacking South Africa at the same time that there is internal unrest. 17

Again, as with the Indians, the Pakistanis and the Israelis, we have a situation where the fear of the unknown (keeping their foes guessing) is more useful politically and diplomatically than definitely and overtly having the nuclear weapons. And, again, the government can wring concessions out of the Western countries who do not want the South Africans to openly build and stockpile nuclear weaponry. The Western countries have little leverage over the South Africans since what few pieces of the nuclear puzzle they may have lacked have been given or sold to them by either the U.S., France or West Germany. It was in 1961 that South Africa built its first nuclear reactor, using U.S. technology. Later, South Africa, which is vulnerable to an embargo by OPEC, hired a French company to build two more nuclear reactors for them. 18

The U.S. has tried to keep control over the enrichment process by taking South African uranium, enriching it and shipping it back. However, in 1975, the South Africans opened their own enrichment plant; they apparently got the technology from the West Germans. The U.S. then
suspended supplies of enriched uranium. As a result, the 
South Africans were not able to fuel their new nuclear 
power station (the enrichment plant can produce enough 
enriched fuel for two to three bombs a year, but not enough 
for the commercial power plants.) Since then, the Reagan 
Administration has quietly eased rules on nuclear coopera­
tion with South Africa and sales of enriched uranium have 
resumed, albeit not U.S. uranium (That would be against 
the law passed in 1978.) This uranium sold to South Africa 
was enriched in France. 19

The U. S. Impotence

Until the mid-1970s, there was little effort to 
achieve an international consensus on handling nuclear ex­
ports. In both fuel-cycle and reactor manufacture, the 
United States was so dominant that its policies alone 
seemed to count.

Other countries engaging in nuclear trade did not 
seem to raise many eyebrows; for example, France with 
Israel and Spain, West Germany with Argentina, and Canada 
with India and Pakistan. The thought that developing 
nations might one day have the ability or the desire to 
possess nuclear weapons was not taken too seriously. 20

This laissez-faire atmosphere continued even when 
those same suppliers began to challenge the U.S. nuclear 
industrial supremacy in the last 1960s and early 1970s.
The rise in anti-nuclear sentiment coincided with a series of events that caused an abrupt change in U.S. policy (proposed U.S. deals with Israel and Egypt, the Indian explosion in 1974, the French and West German agreements to sell reprocessing technologies to Pakistan, South Korea and Brazil). As a result, Congress passed the 1978 Nuclear Non-Proliferation Act. Total bans were placed on the transfer of enrichment and reprocessing technologies. Countries that refused to accept total safeguards were warned that they would receive no further trade. Even existing contracts were subject to cancellation retroactively. Thus, the United States attempted to unilaterally put a halt to the spread of nuclear capabilities and bring other supplies into line with its restrictive policies.  

Prior to the Act of 1978, the United States attempted to influence the suppliers of nuclear technology when it hosted the London Suppliers Club meeting in 1975 by attempting to seek unanimity on future export policy. The Club initially consisted of Canada, France, West Germany, Japan, the United Kingdom, the United States and the Soviet Union. They were later joined by Belgium, Czechoslovakia, East Germany, Italy, the Netherlands, Poland, Sweden and Switzerland. Canada had already unilaterally imposed its own self-restrictions on trade (since Canada felt responsible for India's bomb). The main task was to convince the Western Europeans that restrictions
were necessary. The U.S. was only partially successful, and the Club finally drew up a list of sensitive items and "guidelines" which were agreed to by the members. The force of this agreement was basically that of an honor code.  

The Library of Congress Congressional Research Service voiced concern over the NRC's ability to stand up to Presidential pressure when U.S. nuclear aid is promised to a country as a carrot to gain their cooperation with U.S. foreign policy. Would White House pressures force the NRC to approve the required licenses without delay?  

Reagan's China Policy  
The Administration's delay in forwarding the cooperative agreement which was announced by President Reagan during his visit to China in April, 1984, leaves Congress in suspense, the Chinese piqued and U.S. nuclear companies stalled as to their plans and aspirations. The major hitch seems to be whether the Chinese have given assistance to Pakistan in its program to develop nuclear weapons. Reports have indicated that the Chinese have aided Pakistan's uranium enrichment efforts. This would, of course, violate the premises of the Nuclear Non-proliferation Treaty and would, therefore, provoke strong opposition in Congress to the cooperative agreement with China. A key question has been the degree to which the U.S. negotiators
obtained Chinese assent to safeguards to prevent the transfer of nuclear materials and technology to countries that do not have nuclear weapons.

A statement from the Chinese foreign ministry indicated that the Chinese have no intention to make formal commitments to non-proliferation.24

When President Reagan announced that the agreement would be initialed, he indicated that the way was being cleared for American companies to win contracts to build a dozen nuclear power plants, worth some $20 billion over the next two decades. Enthusiasm was voiced by the top U.S. vendors, Combustion Engineering, General Electric, Bechtel, Stone & Webster and Westinghouse, but they were not so optimistic about the market potential. Westinghouse executives estimate that China's purchases will not exceed $6 billion to $7 billion.25

In the background is the awareness that China has every intention of achieving nuclear self-sufficiency and the capability to be an international supplier of nuclear technology. Westinghouse officials have expressed confidence about competing for Chinese business. The company's pressurized water reactor has been the dominant design in the nuclear export market, and the Chinese are said to regard Westinghouse as technologically the strongest organization in international nuclear trade.26

The non-proliferation issue may be out of the hands
of the United States or its contractors in the case of China, since Westinghouse faces strong competition both domestically and particularly from the French and the West German vendors. In addition to the nuclear technology, financing is expected to be an important factor, and the U.S. companies worry that, with the aid of their governments, the French and the Germans may be able to offer a more attractive package.  

Senator William Proxmire complains that the Chinese have given nuclear help to nations like South Africa. He says,

"The Reagan Administration has turned a blind eye toward the long record of Chinese disregard for nuclear non-proliferation. What we have here is an agreement by wink and by nod. This is the worst kind of agreement-one that is given orally, subject to translation problems, not even clear as to tense or timing."  

Senator Jesse Helms states, "I have a suspicion this whole thing is being orchestrated to bail out the nuclear power industry from its own foibles. I just don't think that Red China is the appropriate vehicle."

The industry seems to think that the Chinese will play the U.S. companies off against the French and the Germans. "They may buy a plant or two, plus engineering and technical assistance, enough to start manufacturing their own plants." The French have negotiated with the Chinese for six years now and are about to close a deal. The Chinese know how hard up the U.S. nuclear industry is and
says one nuclear manufacturer, "I imagine they'll be looking for pretty good terms."  

The French Nuclear Industry

The recession in the nuclear industry has hit France quite hard, economically and politically. This is causing the French to act irresponsibly in the area of nuclear proliferation. The industry has become a significant part of their economy, and reductions in its activity has a strong impact on other sectors such as steel and construction. Since the industry is largely state owned, it is less flexible and reducing its capacity has many political ramifications.

Finding new reactor orders on the international market has understandably become increasingly important to the country. France's nuclear industry derives considerable strength from the scale of its domestic nuclear program; yet, in some ways, this puts it at a disadvantage internationally. Partly as a result of making its technology uniquely French, France has placed its customers outside of the network of technological alliances that have evolved around U.S. and West German power plant producers.

France's market share since 1965 has been small: six reactors sold to Belgium, South Africa and South Korea, compared to the 50 units the United States has sold to 11
countries. It is not well positioned to play the multi-national game in the international market place and faces considerable barriers to entry in export markets where local industries have already been captured by other suppliers. Consequently, France has increasingly been turning to the Third World nations that have not yet been technologically influenced by other suppliers and has disregarded the London Club guidelines and (since it never was a signatory) the Nuclear Non-proliferation Treaty full-scope safeguards.\(^3^3\)

Since the 1978 Nuclear Non-proliferation Act, the U.S. has not had its traditional sway in the international market, and considerable erosion of its market strength has occurred. Pockets of industrial expertise have sprung up in places such as in Belgium, Italy, South Korea and Spain. These will tend to use joint ventures to expand into the void left by the U.S. nuclear industry's forced withdrawal. Should the U.S. re-emerge as a factor in this market, these countries will likely trade without hesitation in the gray area of the world market.\(^3^4\)

The Soviet Block

By the 1990s, the Soviet Block countries will have invested a tremendous amount in nuclear technology and will be ready and willing to export it. It is interesting to note that the Soviets have shown no compunctions about
offering reactors and nuclear fuels to countries outside the Non-proliferation Treaty when it suited their foreign policy interests, as in the recent case of Pakistan.\textsuperscript{35}

The Third World

The more advanced Third World countries are developing their nuclear technology at a rapid rate and, as their capacity grows, so does their propensity to export their new found knowledge. Most notable is China and the six quasi-nuclear countries outside of the Treaty which have attracted so much attention among proliferation watchers. These countries will not be competitive in the area of large reactor systems but will soon be able to offer a fairly comprehensive range of nuclear goods and services. After all the threats and denied assistance in developing their nuclear capability, they are unlikely to embrace the London Suppliers Club guidelines much less U.S. policies.\textsuperscript{36}

The Arms Race

The U.S.-Soviet arms race continues to make attempts at non-proliferation seem hypocritical, at best. So long as Article VI of the Non-proliferation Treaty, in which the signatories pledged themselves to arms control and disarmament, is being so blatantly violated there seems little hope that the Third World rejectionists of that treaty will be persuaded to join.\textsuperscript{37}
Article VI of the Non-Proliferation Treaty: "Each of the Parties of the Treaty undertakes to pursue negotiations in good faith on effective measures relating to the cessation of the nuclear disarmament, and on a treaty on general and complete disarmament under strict and effective international control."

Indeed, the concern now is not so much the expansion of the treaty but the prevention of its collapse. If the international community could agree on a truly comprehensive test ban treaty, there would be some hope of ending the massive nuclear proliferation that is occurring in the world. However, since the U.S. and the U.S.S.R. do not seem to be able to stop the arms race, what credibility can a test ban have with other countries. It seems that the most promising of all non-proliferation measures -- a comprehensive test ban treaty -- has run into a brick wall in Moscow and Washington. (Note, as of this writing, there seems to be a thawing of East/West relations.)

To Show and Tell or Not?

There may be a ray of light in the unhappy thought of nuclear proliferation, the fact is that six countries have apparently attained their goal of nuclear weapons options and are clearly in a quandary as to what to do with them. Israel and South Africa show no sign of wanting to test or to deploy them -- they are apparently content to be able to threaten to do so. The relations between India and Pakistan have improved, and both countries are understandably reluctant to engage in a regional nuclear arms race.
The government of Argentina has decided to bring their nuclear power program under civilian control, which may open the way for stronger nuclear arms control accord in Latin America.

We have a situation that is unstable but not beyond recall. 40

Subnations

What about terrorists and the concerns for nuclear non-proliferation? These concerns are real and must be addressed: First, the technology required to detonate a nuclear weapon is on the streets, but the availability of fizzle material is what keeps nuclear weapons out of the hands of terrorists, gangsters or rogue nations. Clearly though, as commercial nuclear power is being placed in the hands of more and more countries, the availability of fizzle material is more readily at hand. If we consider the general availability of information about weapons, it is prudent to assume that anyone who has weapons grade material is capable of using it. For this reason, international and national entities take measures to make acquisition of weapons materials difficult, either diplomatically or physically. The effectiveness of these measures is the question. 41

There is concern that, sooner or later, terrorist groups will construct atomic bombs clandestinely for their
own purposes, or criminals may divert nuclear materials for radioactive blackmail. Associated with this problem is the prospect of living in a police state designed to minimize the annual number of cities destroyed by terrorists' A-bombs. Furthermore, by selling nuclear technology to all comers, we assure that dozens of countries will possess enough nuclear material to manufacture bombs by the end of the century. At least 20 percent of these countries will actually develop weapons from the materials we have supplied. If the ultimate threat to public health is nuclear war, we may be writing a death warrant for society by boosting nuclear reactor sales worldwide.  

The problem for a nation or terrorist group is not so much being able to get the weapons grade material. Under agreements that allow nations the use of nuclear technology, they also have legal or extralegal rights of access to the material to fuel them. Terrorist groups or gangsters would only have to embezzle or raid to get hold of the material. For these groups to have the rather elaborate facilities and highly skilled personnel necessary to refine the reactor fuel or the spent fuel (which does contain plutonium) is difficult to imagine. It is not so difficult to imagine a nation having such capabilities. Normal reactor fuel is not sufficiently enriched to allow the formation of a super critical mass. However, if a nation owns an enrichment plant or a reprocessing plant, it
clearly has at its disposal both the materials and the facilities to produce weapons grade material. The proliferation of reprocessing plants adds to the danger but seems necessary in light of each recipient's desire to maximize uranium utilization. 43

Conclusions to be drawn from Chapter Three:
1) It seems that the question of whether to export nuclear technology is moot. The fact is that once a country has developed the resources necessary to support the technology, invariably there is insufficient demand in that country to fully utilize these resources. The only alternative then that will allow the country to keep the industry going is to export the technology. The United States was the first to export nuclear technology, but had that not been the case, others would have developed it and exported it.
2) Some of the dangers of nuclear proliferation include increased likelihood of rogue nations or terrorist groups using nuclear blackmail to get their way. Another danger is that nuclear war may erupt where a country is about to be overwhelmed by a neighboring country.
3) Some countries are apparently developing a nuclear weapons capability in an effort to quietly intimidate their neighbors with their potential might and thus reduce the likelihood of incursions by those neighbors into their territory. Of concern to the rest of the world is the
question of national responsibility in the restraint of its use.

4) There has not been meaningful effort by the "Nuclear Club" to restrain proliferation of technology to developing countries. Efforts to do so have been diluted by the unrestrained arms race between the United States and the Soviet Union. The world is just not taking the proliferation problem seriously and is unlikely to do so until the superpowers do. Each of the Club members seem more intent on their own immediate profit from the sale of technology.
Chapter Three Notes


2 Ibid.


5 Ibid.

6 Ibid.

7 Fialka, pp. 1, 32.

8 Ibid.

9 Ibid.

10 Ibid.


12 Ibid.

13 Ibid.


15 Ibid.

17 Ibid.
18 Ibid.
19 Ibid.
21 Ibid.
22 Ibid.
25 Ibid.
26 Ibid.
27 Ibid.
29 Walker and Lonnroth, p. 32.
30 Ibid.
31 Ibid.
32 Ibid.
33 Ibid.
34 Ibid.
35 Ibid.
36 Ibid.
37 Ibid.
38 Ibid.
39 Ibid.
40 Anthony Nero, Jr., *A Guidebook to Nuclear Reactors* (1980), Chapter 12.

41 Ibid.


CHAPTER FOUR

Sociotechnical Issues

Discussion

The central issues of this Chapter:

1) The public attitude about nuclear power.
2) What the social cost of nuclear power is.
3) The externalities of nuclear power for the countries receiving the technology.
4) A comparison of "normal emissions" of radioactive gasses compared to background radiation in terms of dosage and danger.
5) What a "worst case" nuclear accident in a reactor would be like.
6) Other public perceptions of nuclear externalities.

Radiation

The accidents at Three Mile Island (TMI) and Browns Ferry left many wondering about the safety of nuclear energy worldwide. The long term damage to the health of the population in the vicinity of TMI is still not fully known. (This is due to the less than perfect understanding of the effects of low level radiation on the human body.) Radiation, even in the smallest doses, can
cause cancer. It can produce genetic defects that could be passed on for all the generations of human beings to come. It can act as a virtually permanent pollutant -- one that can never be "cleaned up." It is being added to the environment deliberately through ordinary operation of nuclear plants and their attendant fuel cycle. Nuclear power and weapons production is the second biggest source of man-made radiation. (The greatest cause of man-made radiation is nuclear weapons detonations.) At every step of the nuclear fuel cycle, cancer-causing poisons escape into the air, water and soil. Radioactive fallout -- the permanent calling card left behind by atmospheric nuclear explosions -- is now factored in as part of the "natural background radiation."  

In addition to an accident such as occurred at TMI, the long-term effects of nuclear stations affecting our environment requires consideration. Table 4-1 shows the probable whole-body dose from a typical nuclear power plant on a seashore. In the United States, the upper limit of the dose on the boundary of nuclear power stations is now limited to at most 5 mrem (millirems) per year. Because nuclear power stations are point sources of radiation, this limits the dose to the population within 6 miles of nuclear power stations to approximately .6 mrem/yr and within 50 miles to approximately .01 mrem/yr.
Table 4-1
Probable Dose from Nuclear Power Station

<table>
<thead>
<tr>
<th>Activity</th>
<th>Dose (mrems/yr.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>At boundary of station</td>
<td>5</td>
</tr>
<tr>
<td>Population within 6 miles of station</td>
<td>0.6</td>
</tr>
<tr>
<td>Eating fish and shellfish, 50 grams/day</td>
<td>2.5</td>
</tr>
<tr>
<td>Swimming 3 hrs/day, 120 day/yr. in effluent condenser discharge canal</td>
<td>0.03</td>
</tr>
<tr>
<td>Swimming 3 hrs/day, 120 day/yr. at shore areas on either side of nuclear power station</td>
<td>0.006</td>
</tr>
<tr>
<td>Average natural background radiation in the United states</td>
<td>105.00</td>
</tr>
</tbody>
</table>


Doses calculated for Millstone Point, Connecticut, a power station containing two reactors about 1300 Mw. on the north shore of Long Island Sound. Doses at the boundary of the station and to the population within six miles are doses accumulated by individuals remaining for 24 hrs/day and 365 days/yr at the boundary or in the open within 6 miles of the station.
As seen from Table 4-2, the risk of death by auto
is about 1000 times that of leukemia under the uppermost
limits of radiation after 35 years of exposure from the
nuclear power station. After 35 years of exposure, the
risk of death under the average conditions of the popula-
tion within 6 miles of the plant; i.e., the population at
the greatest risk, is one ten-thousandth that of being
slain by an automobile. Since the total risk of dying
from cancer at those doses is approximately five times
that of the incidence of leukemia, the total risk of dying
from cancer at those doses is then still infinitesimal.
Moreover, even taking into account that a fetus may be
approximately 10 times more susceptible to the oncologenic
effects of radiation than the average member of the popu-
lation, one appreciates that the fetus normally remains
un utero for less than one year. Thus, the risk to a fetus
will be approximately one-third that calculated for the
general population after a 35-year exposure.³

Probabilistic Risk Assessment

The actual quantitative results on the estimated
public risks of nuclear power, while important, are per-
haps the least useful results of Probabilistic Risk
Assessment (PRA). Enough studies have been completed by
now to tell us that the estimated risks from nuclear
reactor accidents are quite small.
Table 4-2
Risk of Death
Per Year for an Individual

<table>
<thead>
<tr>
<th>Risk</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidental Death*</td>
<td>57 out of 100,000</td>
</tr>
<tr>
<td>Death in Motor Vehicle*</td>
<td>26.7 out of 100,000</td>
</tr>
<tr>
<td>Death from Heart Disease*</td>
<td>364 out of 100,000</td>
</tr>
<tr>
<td>Death from cancer</td>
<td>157 out of 100,000</td>
</tr>
<tr>
<td>Death from all spontaneous Leukemias*</td>
<td>67 out of 1,000,000</td>
</tr>
<tr>
<td>Leukemia after 1000 mrems Whole Body Radiation**</td>
<td>1 out of 1,000,000</td>
</tr>
<tr>
<td>Leukemia after natural radiation (35 years)**</td>
<td>3.7 out of 1,000,000</td>
</tr>
<tr>
<td>Leukemia after living near power reactors (35 years at boundary site eating fish and swimming)**</td>
<td>2.6 out of 10,000,000</td>
</tr>
<tr>
<td>Leukemia after living near power reactors (35 years-general population within 6 miles of site.)**</td>
<td>2.1 out of 100,000,000</td>
</tr>
</tbody>
</table>

* Risk of death per year from an individual in the United States.
** Risk of leukemia represents an additional risk of death to be added to that from "all spontaneous leukemias". Similarly, risk of death from all additional cancers would be about five times the data shown for cancer above.

Engineering insights are the most important benefits of PRA studies. The most general of these is the entirely new way of thinking about reactor safety in a logic structure that transcends normal design and regulatory processes. PRA thinking introduces much-needed realism into safety evaluations. Deterministic thinking, in contrast, although it has served society well, often masks important matters.5

Figure 4-1 depicts an event tree such as would be used by engineers to evaluate the consequences of a pipe break that might lead to a release of radioactivity. Analysts assign probabilities to each possible event in the sequence. Then, having satisfied themselves that all the probabilities in a sequence are independent of each other, they multiply them to obtain the overall chance that a particular sequence will occur.

PRA concepts can help improve understanding in many applications across a broad spectrum of activities, including engineering, licensing, and operations. The following are among its most important general insights:

1) Contrary to what was previously thought, core meltdowns would not necessarily be catastrophic in terms of public risk. In fact, PRAs show that, if a core meltdown occurs, there is only a small chance that the containment building will also fail in such a way that a large
PROBABILISTIC RISK ASSESSMENT FOR NUCLEAR REACTORS

Figure 4-1

PIPE BREAKAGE | ELECTRIC POWER | EMERGENCY CORE COOLING SYSTEM | FISSION PRODUCT REMOVAL | CONTAINMENT INTEGRITY | SEVERITY OF ACCIDENT | COMPOSITE PROBABILITY
---|---|---|---|---|---|---
| | | | 1-p5 | Very Small | | p1
| | | | 1-p4 | Available | | | p1 x p5
| | | | 1-p3 | Available | | | p1 x p4
| | | | p4 | | | | p1 x p4 x p5
| | | | 1-p2 | Available | | | p1 x p3
| | | | p1 | | | | p1 x p3 x p4
| | | | p2 | | | | p1 x p2

Breaks

Available

Fails

Available

Fails

Available

Fails

Available

Fails

Available

Fails

Available

Fails

Available

Fails
amount of radioactivity will be released.

2) The notorious "China Syndrome," in which the nuclear fuel melts through the containment basemat beneath the reactor, does not pose a significant risk to the public. Not only is this scenario unlikely, an analysis shows that, even if it happened, most of the dangerous materials would be retained in the concrete and the soil. Releases of radioactive materials from this event would be very much smaller than if the building itself had been ruptured.

3) Current reactor designs provide great capability to reduce the consequences of potential accidents that are more severe than those considered in the licensing process.

4) The most significant accident sequences in pressurized-water reactors in common use in the United States do not result from large pipe ruptures, as previously assumed. Breaks in large coolant pipes are unlikely, and reactors have been specifically designed to cope with them. The overall risk of accidents that result from ruptures in small pipes and subsequent failures of safety systems turns out to be greater.
5) "Transient events," when the power output of the reactor is being changed, also pose potentially significant risks when combined with additional failures in safety systems.

6) The most significant accident sequences in boiling water reactors do not involve loss of coolant, but stem rather from transient events.

7) The importance of strong containment buildings and reliable safety features, such as the emergency coolant-injection and heat-removal systems, has been highlighted and quantified by PRA.

8) In general, human factors — errors in testing, maintaining and controlling plants — account for a significant, but not dominant, part of the public risk that might arise from reactor accidents.

Worst Case Accident

The worst case accident is postulated to result in instant death for all exposed within ten miles downwind of the accident, heavy contamination of the land within 200 miles downwind of the site and loss of use of crops and animal products within 1,000 miles downwind. Depending upon the location of population centers in relation to the
wind pattern, this could result in 3,000 immediate fatalities and 45,000 cancers or radiation sicknesses.

This study of the likelihood of a nuclear accident, which was accomplished by the Oak Ridge Laboratory, has been updated in draft form on July 1983. The report concludes that the chance of a severe core damage accident was 1 in 4,000 per reactor-year of operation. The Nuclear Regulatory Commission (NRC) director, Robert Minogue, said, "Even at this improved frequency rate, there is still a roughly 10 percent chance that a severe core-damage accident will happen in the next five years."  

The Sandia National Laboratory released its report on the possible consequences of an accident at 91 reactor sites in the United States in November 1982. These figures indicated that, for example, 100,000 persons might die within a year from a worst-case accident at the Salem plant in New Jersey, or that property damage might reach $300 billion in the area near the Indian Point plant in New York. The NRC countered this with a study that showed the probability of an accident at Indian Point that would kill only one person immediately (not a worst case accident) is only 1 in 1.7 million years of operation. 

It appears that the industry and the NRC seem to be trying to convey a sense of security to the public that cannot be justified. The fact is that the likelihood of a serious accident cannot yet be precisely determined.
Recall that the types of accidents occurring at TMI and at Browns Ferry, Alabama, were officially deemed "not credible." 10

Ironically, anti-nuclear people show much apprehension for workers in the nuclear industry but little for workers in other industries. The hollowness of the protestations of the self-styled "concerned" persons is shown by the following death statistics: e.g., coal-face workers (actual dead 420... expected 12 = 35.00 times the expected amount). Company Directors (actual dead 425... expected 54 = 7.87 times the expected amount). This compares to surprisingly low deaths for workers in British nuclear reactors where deaths from all causes were only .75 percent of expected.11

Dr. Robert L. DuPont, M.D., after the TMI accident, at the invitation of the Media Institute, a non-profit organization devoted to improving the quality of media coverage of business and economic affairs, reviewed 13 hours of TV news videotapes. These tapes contained all the news stories regarding nuclear power broadcast between August 5, 1968, and April 20, 1979 -- one month after the TMI accident. After the review, Dr. Dupont's impression was that fear was the motif of the entire series of nuclear news broadcasts. The driving force in the nuclear energy issue is not economics, not technology, not energy production. It is fear! He stated that the public debate will certainly
hinge on fear and that, right now, the tide appears to be running with those who are encouraging that fear. He felt that a phobic is at the roots of the fear, a malignant disease of "what ifs." The phobic thinking process is a spiraling chain reaction of "what ifs." Each "what if" leads to another. Moreover, phobic thinking travels down the worst possible branchings of each of the "what ifs" until the person is overwhelmed with the potentials for disaster. Often these worst-case eventualities remain only partly articulated, even to the phobic himself. When Dr. DePont reviewed the tapes, he noted time and again that the newscasters would continually go down those "what if, worst-case" branches. An example that Dr. DuPont gave of this attitude was when a reporter talked about a study in Washington State which reported of one scientist's estimation that, of persons who worked at a nuclear facility over many years, there were 30 to 50 "extra" deaths from cancer out of 4,000 deaths from all causes, which may have been due to something -- probably radiation -- at the nuclear plant.¹²

The reporters who covered the story asked questions and used a tone of voice which carried the message: "Well, my God, isn't that terrible?" The scientist said,

"No this is the risk that comes from that activity. People ought to know the facts but you should not close the plant because of that additional risk. . . . The point is that people need straight forward
information about nuclear plants and alternative sources of energy including the positive and negative aspects of those sources.\textsuperscript{13}

Dangers of Other Technology

Not in an effort to minimize the real or perceived dangers of a nuclear plant, but instead to put those dangers into a perspective with other forms of energy currently in use, we must look at what happened at Mexico City on the 19th of November, 1984. That disaster is unusually germane to our discussion. An article from The Wall Street Journal is filled with so much information relative to this chapter that I will take the liberty of quoting it verbatim.

The explosion of four tanks containing liquefied gas on the outskirts of Mexico City Monday morning was most importantly a human tragedy, the kind of disaster that strikes suddenly and unexpectedly, leaving us all in shock as we contemplate its horrors. As of midweek, the death toll had risen above 300 and the numbers of injured and homeless were much larger still. (Business Week, December 24, 1984, fixed the toll at 452 people killed.)

But beyond this reminder of the capriciousness of fate, there seems to us another lesson to be drawn. Although we take precautions in the use of all technologies, older technologies often pose greater danger to human life than new ones. This is exactly the reverse of the argument we hear so often from those intellectual elites who make it their business to raise fears about where advances in technology are leading us.

Liquefied gas is a relatively simple technology when compared with, let us say, nuclear energy. Liquefied petroleum gas (LPG) is propane or butane kept liquid under pressure. This so-called bottled gas is ubiquitous, particularly in rural areas. It is an extremely convenient way of storing fuel, and the safeguards built into handling equipment keep it well within the realm of acceptable risk.
Liquefied natural gas (LNG) presents somewhat greater difficulties, in part because a very low temperature is required for liquefaction and because the usual goal of this technology is to store and transport large quantities of gas in circumstances where it is not possible or practical to distribute it directly from the wells by pipeline.

As the Mexico City explosion demonstrated, there is real risk and quite obviously, a need to review safety precautions in large-scale storage facilities. The U.S. General Accounting Office, an arm of Congress, in July 1978, issued a three-volume report discussing the risks of storage and transportation of liquid gases, even going so far as to suggest that such facilities be restricted, as nearly as possible, to lightly populated areas.

This report created no great hysteria, certainly nothing on the scale of the uproar that followed the Three Mile Island nuclear power facilities accident in March, 1979. Yet the TMI accident, which was the product of incredible operational ineptitude, resulted in no loss of life and not even any risk to life from the small amounts of radioactive material released. The record shows that liquid gas occasionally kills, but nuclear generation, a much more complex technology, has harmed almost no one. Obviously, there is much more to the anti-nuke movement than mere considerations of safety. [Note: a January 10th, 1985, newscast indicated that the cancer rate near TMI is seven times the national level.]

Other comparisons are available. Space pioneers had a far better safety record than pioneers of the air age. Modern technology, partly because of its complexity and difficulty, requires elaborate organization, a far cry from the single-handed adventures of the early technological pioneers. Computers have made it possible to simulate real-world accidents and to thus remove risks. The great concentrations of capital and manpower on single ventures have made it economically feasible to over-design equipment to build in fail-safe "redundancies".

In short, modern industrial technology on the whole yields greater safety along with its other benefits. Disasters such as the one in Mexico City should thus be a spur to, not a brake on, technological development. 

Not related to energy, but certainly related to
older technology, was the horror of the India poison gas release that occurred on the 3rd of December, 1984. The gas, closely related in its effects on the body to the war gas, Phosgene, kills by causing the lungs to fill with fluid. At 1:00 a.m., the methyl isocyanate gas had begun leaking from an underground storage tank at a Union Carbide pesticide plant in a poor area of Bhopal India. The leak was stopped after only 40 minutes but, by that time, as many as 200,000 people were affected. Twenty-five hundred were dead before two days passed, and at least 20,000 may suffer serious after-effects such as sterility and loss of eyesight. 15

What the Mexico City and the Bhopal accidents point out loud and clear is that most technologies have the potential to be dangerous and, given the right circumstances, can certainly kill. We need to be quite aware of this possibility and review existing as well as proposed siting and procedures for all potentially dangerous industries as they relate to exposure and risk. Perhaps the nuclear industry has been singled out for scrutiny for too long, at the expense of other (more dangerous?) technologies.

An Indian government official expressed an emerging concern recently. "There has been competition to have an atomic reactor or a Union Carbide unit in as many areas as possible without considering the consequences. The entire
policy toward aligning with multi-nationals must be reconsidered."¹⁶

Russian Nuclear Disaster in the Urals

In 1958, there was a nuclear disaster of some magnitude in the Soviet Union. It was an explosion involving concentrated waste produced by military reactors and stored somewhere underground. The radioactive fission products which had accumulated over many years were released explosively to the surface of the earth and carried by the wind for dozens of kilometers.

There were no large cities in the main contaminated area, but there were villages and workers' settlements. Because of the suddenness of the explosion and the dispersion of the radioactivity, the levels of contamination in the various localities were only determined after some delay. The secrecy surrounding nuclear activities hampered timely radiation monitoring. The first serious evacuation attempts were made after several days, and then only in the settlement closest to the site of the explosion. Subsequently, symptoms of radiation sickness began to appear in the more distant areas. Necessary treatment techniques had not been adequately developed at that time. The evacuation affected several thousand persons (possibly tens of thousands), but the number who died of radiation sickness remained unknown. The immediate effects of
such exposure may not be apparent but may be carried to future generations as the strontium-90 in the bones of the exposed affects the reproductive cells.\textsuperscript{17}

This Urals disaster represents the only nuclear accident of great proportion to have occurred thus far. It was (as far as can be determined at a distance) due to unsophisticated storage of nuclear waste. The explosion was really a release of radioactive contamination with explosive force, not a nuclear explosion, since such materials are not capable of sustaining an uncontrolled chain-reaction. We might assume that the heat of radioactive decay in an underground chamber combined with subterranean waters and generated steam whose pressure caused the release. Alternatively, there could have been a hydrogen explosion caused in a similar manner.

**Nuclear Waste**

In addition to the possible contamination from a nuclear accident, we should examine the nuclear waste problem in depth. How serious is this problem? Is it a problem?

In fact, radioactivity cannot be artificially destroyed, in contrast to other well known poisons which can be burned or rendered harmless by chemical methods. Radioactivity decays at a rate determined by its own law of half-life. The half-life of radioactivity is the time
taken for the substance to decay to half of its original strength; that is, for half of the atoms in it to disintegrate. This may take seconds or thousands of millions of years, depending on the type of materials.

This waste problem has become one of the most volatile issues surrounding the nuclear fuel cycle. A nuclear reactor will build up an enormous inventory of radioactive fission products during its operation. Although most of this radioactivity will decay quite rapidly after reactor shutdown and removal of spent fuel elements, a significant fraction of the high-level radioactivity induced in the fuel will remain for many years.\(^\text{18}\)

Six methods have been proposed for dealing with high level nuclear waste: 1) shooting them into space, 2) burning them in breeder reactors, 3) burying them in the Antarctic ice sheet, 4) drilling holes 20,000 or so feet into the earth and burying them, 5) burying them in subseabed deposits, and 6) placing them in underground cavities.

Rocketing waste into space is a handy solution -- assuming that the launch is successful and excluding costs. The breeder reactor concept died in the U.S. for the time being at least, with the Clinch River reactor. Besides, breeders still generate waste (albeit, not as much as other reactors). The ice sheet burial concept has fallen into disfavor because the deposits might not be
stable over the time periods required. After all, plutonium has a half life of 24,360 years. Deep drilling with the necessary large diameter hole is not now within our technological capabilities. In fact, only two of the suggested methods seem worthy of further examination as solutions in the immediate future.

Subseabed Disposal

Between the mid-ocean ridges and the continental margins, there exists an area that is quite stable geologically, and studies have been made of burying waste under about 15,000 feet of water and approximately 100 feet into the sediments there. This would be an extremely stable area, seismically. The containers presently available for this procedure are estimated to be able to hold their contents for as much as 1,000 years, after which time the sediments into which the containers were placed would have to contain the waste. It has not been established how well the sediments would be able to do that and thus keep the radioactive waste out of the ocean eco-system. This question is being studied, but the best estimate of its resolution is about 2020. By that time, the nuclear waste problem will be greatly magnified over what it presently is.

Continental Geological Disposal

The construction of the first mined dump for high
level nuclear waste is already under way near Carlsbad, New Mexico. The $1 billion Waste Isolation Pilot Plant (WIPP) will be a disposal site for military waste and could, over the strident objections of New Mexico's Governor, Toney Anaya, be used for experimentation with more radioactive spent fuel. A salt bed is being used and, ultimately, the extent of the underground labyrinth will be about 120 acres. There are several problems associated with this location and the concept of using salt beds in general, but there are problems associated with any concept so far. This seems to be the concept that, for the time being, will give us direction. However, the site will not be operational until about the year 2000, and this still leaves us with a serious disposal problem. 21

The Geologic Isolation System

Related to the continental geological disposal previously described is geologic isolation. This system is the primary method of waste disposal being pursued by the Department of Energy (DOE). Conceptually, the geologic repository, as a waste isolation system, consists of three functionally distinct subsystems that interact to provide multiple natural and man-made barriers to the release of the contained waste into the accessible environment. These subsystems or components are the waste package, the repository, and the site. 22
The waste package includes the waste form itself and a system of engineered barriers consisting of a filler material (in the case of spent fuel), a high-integrity canister, and one or more layers of protective materials selected to minimize interactions among the waste, host rock, and ground water. During the repository operational phase, the waste package provides safe containment of the waste material during handling and emplacement operations and helps ensure that the waste can be safely retrieved, if necessary, from the repository. During the time that fission product decay is dominant and radiation and thermal output are high (i.e., 400 to 600 years), the waste package will continue to provide containment of the waste, delaying initiation and retarding the rate of radionuclide release into the ground-water environment. After the thermal period, the repository and the site, in conjunction with the waste packages, provide long-term waste isolation.\textsuperscript{23}

The repository will be much like a conventional mine. It incorporates structures to access the underground corridors and rooms for waste emplacement and man-made barriers to contain and isolate wastes. All site activities from initial studies and construction through closure will be performed in a manner that preserves the containment and isolation capabilities of the sites selected.\textsuperscript{24}

Edwin Wiggin of the Atomic Industrial Forum,
headquartered in Bethesda, Maryland, worries about the cost of delays due to "political and social matters" rather than technical problems. He feels there is a tendency for "DOE to research a problem to death." Wiggins said, "Most of the basic research has been accomplished. We can make a mistake in looking for the perfect answer when an adequate answer is enough."

In Germany and the U.S., efforts are being made to deposit nuclear waste in deserted salt mines or rock salt formations. However, nobody can predict with any certainty what sort of effects concentrated radioactivity will have on the rock salt formations over a long period of time. Apart from this, the radioactive material could come into contact with subterranean waters, or tectonic changes might take place.25

A Department of Energy Study has been completed that was quite exhaustive and indicates that invasion of a properly conceived subterranean storage facility by an outside force (earthquake, etc.) is so minimal as to not deserve consideration in the selection of this alternative. The most likely cause of such intervention was postulated to be man, but even this possibility was too low to be of concern.26

The government has just released the top candidates to become the nation's nuclear waste depository. The sites are near Santa Rosa and Ogallala, Texas, in the panhandle;
Yucca Mountain, on the western edge of Nellis AFB and the Nuclear Weapons Test Site in the Southern part of Nevada; and finally, Hanford nuclear reservation near Richland, Washington. Of these, the Nevada site seems to be the one that is ranked first by the government. I can recommend the Nevada selection, too. I have flown over it many times; the nuclear craters are awesome, and the whole area is already contaminated.

The multibillion-dollar underground repository will become the final grave for some 70,000 metric tons of highly radioactive wastes that will not decay to safe levels for at least 10,000 years. Acknowledging that none of the potential sites are supported by popular opinion, the government feels that once the magnitude of the safety precautions to be taken are understood, the site (as selected) will be accepted. The program is scheduled to cost on the order of $20-25 billion.

The top three sites will be put through four to five years of intensive "characterization" studies each costing $500 million to $1 billion after they are finally approved by the President.

Based on the results of the study, whoever is the President in 1991 will have the final choice. At that point, current law allows the chosen state to veto the selection.
Conclusions to be drawn from this chapter:

1) The public attitude about nuclear energy is distorted by the fact that nuclear energy somehow has the same connotation as nuclear weapons. This negative attitude by the public has been heightened by the impressions that a nuclear plant might explode like a weapon. The worst-case accident involving a nuclear plant is significantly less dangerous than a nuclear detonation. Valid concern exists over the problem of radiation associated with nuclear waste material, radiation associated with an accident or radiation associated with proximity to daily nuclear plant operations.

2) The social cost of nuclear power is essentially fear of the unknown. If it could be stated that a low dose of radiation was definitely going to cause a particular effect in a certain portion of the population, then that risk could be assessed in view of need, and it would be either acceptable or not. There are few certainties regarding nuclear side effects.

3) The externalities of nuclear energy for countries receiving the technology are many. The fact that the facility, in itself, does not generate jobs for the local population is one. There is the dilemma of what to do with the nuclear waste. Power grids often have to be rebuilt to handle the output of the plants. A dependence is established on sources of nuclear fuel. The danger of accident
or radiation exposure to the population of the country is feared. In the case of developing countries, the population often is not ready to benefit from the wonders of electrical power. This often results in unused capacity for nuclear plants. Nuclear energy is highly capital intensive, and the countries that are trying to expand the use of that source of power are often debt ridden to begin with. The nuclear option does little to improve the situation.

4) Working in the nuclear industry seems to be little more dangerous than working at many other vocations. The major thought here is that life in general is hazardous in one way or another.
Chapter Four Notes


3. Ibid.

4. Ibid.


6. Ibid.


8. Ibid.


10. Ibid.


20 Ibid.

21 Ibid.


23 Ibid.

24 Ibid.


CHAPTER FIVE

Salient Aspects of the Alternatives

Discussion

The central issues of this chapter:
1) The economic costs of nuclear and alternative energy sources will be contrasted.
2) The environmental impacts of the nuclear alternatives will be evaluated.
3) Conservationism and how it applies to the Third World nations.

Nuclear Power

The Secretary of Energy, Don Hodel, has consistently maintained that we must work toward a balanced and mixed energy resource system and avoid over-reliance on any single energy resource such as the dependence on oil which prevailed during the 1970s. Surely, nuclear power must join with fossil fuels and renewables such as hydro and solar, as an essential element of that mix. Under virtually any growth projection, we will need all of the power plants currently under construction just to meet demand in 1995. In addition, if we are going to replace obsolete facilities, even more new generating plants will
be needed.\textsuperscript{1}

In the interim, with the reduced rate of growth in demand for electricity coupled with the "de facto" moratorium on nuclear development in the U.S., we should give further consideration to improved reactor designs and technology.\textsuperscript{2}

One of the chief reasons that nuclear power has been so appealing to Third World countries in the past is the fact that it is relatively insensitive to spatial relationships of fuel or topography such as hydroelectric power is. Thus, countries that could not in the past hope to have sufficient electrical power for their needs may now have it, provided they can afford it! This last point is where the system is breaking down since many of these countries cannot service their debt as it is.

Hard, cold economics is now doing to nuclear power what thousands of hot blooded demonstrators never could. It is slowly, painfully shutting down the world's nuclear industries. The only countries in which development is proceeding at close to the pace planned a decade ago are those where there is no semblance of a market test and where nuclear power is pushed single-mindedly by a strong central government. Private investors who have a choice and who must bear the financial responsibility for their decisions are steering clear of nuclear power.

Important additional costs may further tip the
economic scales. The disposal of nuclear wastes and decommissioning of old plants are critical problems that have yet to be effectively resolved in any country. (Note: Both of these aspects present significant residual radiation problems.) Each presents enormous health and safety concerns that could affect societies for generations. Providing remedies will inevitably add to the cost of nuclear power. So far waste disposal and decommissioning are "uncounted costs," and their potential size can only be guessed. Official figures generally show the disposal and decommissioning adding 5-10 percent to the cost of nuclear power though unofficial estimates range up to an additional 50 percent or more.³

**Nuclear Alternatives**

There are a number of new technologies developing in nuclear power itself that should be explored, contrary to what Philip Bray of General Electric says. Granted, he may be correct when he says that the light water technology is like a thoroughbred horse and only needs a well prepared surface to run on rather than a steeplechase full of water hazards. Then, again, his views could be considered proprietary.⁴

At present, there are two well thought out ideas for inherently safe reactors: the "Process Inherent Ultimately Safe" (PIUS) reactor being developed in Sweden
and the modular High Temperature Gas Reactor (HTGR) proposed by the U.S. and Germany. Several other concepts have been proposed in addition, but none have been taken as serious or developed as fully as the PIUS and the modular HTGRs. Some of the more salient features of each are shown.

**PIUS.** Protection against core meltdown in the PIUS reactors would be gained through passive physical principles without the intervention of active safety systems or reactor operators. The protection is effective not only against conceivable accidents caused by equipment or operator failures but also against external events such as earthquakes, sabotage, or attack with conventional explosives. A number of technical problems must be resolved to prove its operability and commercial worth. A demonstration plant could be put into operation in approximately 12 years.5

**HTGR.** Without getting too technical, the principal advantages of the HTGR are its ease of refueling and economical modular design. Refueling may be done while the reactor is powered up which is a significant safety advantage. (During a transient condition, such as loss of coolant, instead of possible core damage, there is no danger at all.) This latter feature is why the HTGRs are often referred to as "walk away reactors," since an operator does not have to make an immediate decision under
stressful conditions and take the chance that it may not be the right one.

Economically, the HTGRs may prove to be feasible since they allow modular off-site production and incremental installation. Utilities may add an increment of power capability when needed and not pay the interest on capability that will be needed years hence.

An advantage to this modular concept is that the suppliers of HTGR technology would be able to control quality standards more easily than would the suppliers of LWRs.

Thus, modular HTGRs can, in principle, help remedy the current woes of U. S. utilities. The reactors also hold considerable promise for use in developing nations, which would appreciate their safety and reliability as well as their suitability for increasing electrical generation incrementally to match demand.6

The Candu

The Canadian Candu reactor also has automatic control devices which relieve the operator of the need to make quick decisions under stressful conditions. Adjustments required by transient conditions are made automatically by the regulating system, which can bring the plant from shutdown to the demanded power at a safe and controlled rate without intervention by the operator.
Therefore, the operator is free to make full use of his diagnostic abilities. The major endorsement for the Candu as an alternative is that the technology is proven.  

Renewables  
Promising renewable sources of electricity include small-scale hydropower, geothermal energy, biomass energy, wind power, and photovoltaic solar energy. In addition, cogeneration, the combined production of heat and power, is a rapidly growing alternative to central power plants. The relative costs of these alternatives compared to nuclear and coal power are shown in Table 5-1.  

Table 5-1  
Projections of Estimated Cost of Electricity for 1990 (in 1982 dollars)  

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Cents per kilowatt-hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass</td>
<td>7 - 10</td>
</tr>
<tr>
<td>Coal</td>
<td>8 - 10</td>
</tr>
<tr>
<td>Cogeneration</td>
<td>4 - 6</td>
</tr>
<tr>
<td>Conservation</td>
<td>3 - 5</td>
</tr>
<tr>
<td>Nuclear</td>
<td>14 - 16</td>
</tr>
<tr>
<td>Photovoltaics</td>
<td>10 - 20</td>
</tr>
<tr>
<td>Small Hydropower</td>
<td>10 - 12</td>
</tr>
<tr>
<td>Wind Power</td>
<td>6 - 10</td>
</tr>
</tbody>
</table>

Environmental Impacts of the Alternatives

The questions of acid rain pollution and carbon dioxide pollution of the upper atmosphere have to be compared to the dangers of nuclear pollution. This comparison, to be complete is outside the scope of this paper. The effects of the fossil fired pollution in the upper atmosphere is unknown but is postulated to be either of two, the "greenhouse effect" or "perpetual winter." The greenhouse effect is that a layer of carbon dioxide would seal in the heat from the sun and cause a gradual rising of the earth's atmospheric temperatures to the point wherein the ice caps would begin to melt. This would cause widespread flooding and the loss of much of our land mass. The perpetual winter effect is that the haze from burning the fossil fuels would block the sun's rays and cause a gradual but devastating decrease in the world's temperatures. These two possibilities are dichotomous and no one knows which might be the result of massive use of fossil fuel burning. The one thing that does seem certain is that something will happen, the effects of which will be far reaching and irreversible. Thus, we have a situation where many of the alternatives (particularly coal power) seem as bad, or worse, than the nuclear contamination. 10

Federal Environmental officials have decided to
force the utilities to comply with a 1983 federal court ruling that would reduce sulfur dioxide pollution by about 10 percent. The pollution control devices would cost the utilities over $4 billion by the early 1990s. The impact of this effort would be to reduce sulfur dioxide emissions that we pump into the air by approximately three million tons of the twenty-four million tons of pollutant emitted each year. Acid rain would thus be reduced but not eliminated. The action was forced by the Sierra Club and the Natural Resources Defense Council when they successfully challenged the Reagan Administration's rules in court, arguing that they didn't sufficiently protect the environment.\textsuperscript{11}

\textbf{Anti-Alternatives}

As far as energy is concerned, we're not going to end up with what we choose to have or even what we want to have. When it comes to energy, we are going to be left with what is possible. In other words, we don't have much of a choice.

Oil has become too valuable to use for electrical generation. Coal has its problems, too: acid rain, sulfates, and all the rest. There are all kinds of figures for the number of deaths every year that are a result of mining and burning coal. It is in the tens of thousands if you include both deaths from respiratory ailments caused by
coal (including black lung disease) and from mine accidents. One thing is certain: burning coal is not safe or clean. Even if you burned it as cleanly as possible, eliminating all the sulfates by using stack scrubbers, you would still have the problems of the ash that contains toxic elements and the CO$_2$ that is being put into the atmosphere.$^{12}$

Hydroelectric power is the most efficient and least polluting, but there are limits to how much hydro we can count on. In some parts of the country, virtually all of the hydro available has been tapped. It floods valuable farm land. Also, many environmentalists are less happy with a dam than with a nuclear power plant, especially dams that block big, wild rivers -- the dams that make the most power.$^{13}$

That leaves the "soft energies" -- solar, geothermal, wind and biomass -- all of those technologies that looked so promising and have delivered so little. Most of them will never be large-scale producers of power because the gathering and conversion process is inefficient and requires too much large-scale energy intensive technology. Solar, for instance, requires large amounts of high-purity silicon, which is expensive and requires a lot of energy to make it commercially available. That is one reason we haven't seen the kind of boom in the solar-generated production of electricity that was predicted ten years ago. Solar advocates, likewise, never mentioned
how expensive the requisite materials would be or how much space the reflectors would take up -- thirteen square miles of land to produce the same amount of power that comes from an atomic plant the size of a city block.\textsuperscript{14}

Every technology has environmental drawbacks. Wind power, for instance, requires windmill farms on the tops of mountains. Roads must be built to service them, and transmission lines are needed to get the power from the generating site to where it will be used. Additionally, wind power, so far, has not proved very efficient.\textsuperscript{15}

The biggest change in the utility industry in recent years has been the new role of "end use" energy efficiency as an alternative to new power plants of any kind. By increasing the amount of light delivered by a light bulb or the work performed by an industrial motor for every kilowatt-hour of electricity used, the same energy services are gained at less than it would cost for new generating facilities.\textsuperscript{16}

**Thoughts on Nuclear Power**

U. S. industry and government studies have been slow to recognize the declining economic competitiveness of nuclear power. Careful analysis of the utilities own data for the 30 odd U.S. plants scheduled for completion in the mid-eighties shows that the electricity they produce will cost on average 65 percent more than coal fired power and
25 percent more than oil fired energy (the high cost of which has often been cited as a major reason for building nuclear plants). 17

Outside the United States, the picture is somewhat murky but appears to show high and growing costs for nuclear power, worldwide. J. W. Jeffrey, a retired University of London professor, conducted a thorough economic assessment of British nuclear plants and concluded that nuclear power is considerably more expensive than coal-fired power. Said Professor Jeffrey, "Nuclear power has not been economic, is not economic and is likely to get more uneconomic in the future." 18

In Germany, nuclear electricity costs at least 60 percent more than coal-fired electricity. Even in France, nuclear power does not seem to be cheaper than coal-fired power. The Soviet Union released figures in the latest Five-Year-Plan that nuclear power plants are 80-100 percent more expensive to build than coal plants. Data released on Canada's CANDU nuclear power plants show that construction costs went from $400 per kilowatt of capacity in 1972 to $1,700 in the early eighties, a real rate of increase of 6 percent after accounting for inflation. In India, the government now admits that nuclear power is more expensive than coal-fired electricity. 19

Comparisons of nuclear economics in strictly quantitative terms seems hopeless considering the lack of
comprehensive and reliable data. However, substantial cost increases appear to have been near universal. Most disturbing is that the situation seems to worsen with time. Many countries appear poised to repeat the disappointing economic experience of nuclear power in the United States.

Conclusions to be drawn from this chapter:
1) The relative cost of nuclear power is rising due to delays in construction time, the fact that the plants often are not as dependable as they have been portrayed to be, high interest rates, the decrease in growth of demand for electricity and the fact that alternative sources of energy are not increasing in cost as anticipated.
2) Many of the alternatives for nuclear energy have frightening environmental side effects. These must be considered when we are establishing the proper mix of energy sources.
3) Conservationism does not seem to be an option for the developing countries since their energy consumption is based on real need and has little in the way of frills that may be reduced.
4) The spatial relationship of coal to many of the consumers of energy will one day cause increases in price for that commodity that may make the nuclear alternative more appealing. In many countries, the high cost of nuclear
power is justified by the fact that they are not hostage to the oil cartel and would have supplies of energy even if there were major political upheaval in the Middle East. 5) It is not clear whether many of the nuclear alternatives will ever become commercially feasible. At this time, there is insufficient emphasis being placed on their development for them to be considered a threat to the long-term viability of the nuclear industry. However, technological breakthroughs for many of these alternatives may be expected over the extended period of time involved in the nuclear predicament.
Chapter Five Notes


8Flavin, p. 134.

9Ibid.


13Ibid.

14Ibid.

15Ibid.
16 Flavin, p. 133.
17 Ibid., pp. 120-125.
18 Ibid.
19 Ibid.
CHAPTER SIX

Conclusions and Recommendations on
Exporting Nuclear Power

Discussion

The central issues of this chapter:

1) A brief recapitulation of salient points from previous chapters.

2) Conclusions reached by the author as to nuclear energy.

3) Recommendations by the author for the nuclear industry.

The kind of fundamental changes that are necessary for nuclear power to continue as an alternative in the world's industrialized nations do not seem to be in the offing. Those would be: a guaranteed reduction in nuclear construction costs and a major surge in electricity growth. Both are far from likely. The continued financial crisis caused by the remaining nuclear projects hardly creates a climate conducive to major new investment programs.\(^1\)

The ability of U. S. suppliers to survive a long drought, in the sense of retaining the skilled manpower to allow market re-entry when demand returns, if it does, should not be underestimated. Servicing and fueling the stock of operating reactors has become a substantial and
lucrative business, and the upgrading of existing nuclear plants will keep the technology moving to some degree. More significant still in terms of international viability, Westinghouse and General Electric can exploit their ties with licensees in Spain, Italy and particularly Japan to keep abreast of technical development, compete in joint ventures and extract a rent from licensees' home markets.²

Projected Growth of Demand

A world of eight billion people is almost surely going to demand more energy than we use today, assuming the energy can be found. The most recent projections by the U. S. government and the electric-power industry suggest that demand will grow by between 2.5 and 3.2 percent per year from now to the end of the century. In the recent past, official forecasts almost invariably overestimated growth in demand. But, even if the growth rate turns out to be significantly lower than this -- under 2 percent -- the world will still require new plants, with a combined capacity of several thousand megawatts per year, to come on line starting in the late 1990s.³

The above projection compares favorably with the one by Ralph M. Rotty of the Institute for Energy Analysis and Wolf Haefele of the International Institute for Applied Systems Analysis. They visualize a world that uses three to four times as much energy in 2030 as we use today. Were
most of this to come from coal, the world would have to
mine 25 billion tons of coal each year. We have discussed
some of the problems with coal-fired energy in previous
chapters, and I would imagine that, given the volume of 25
billion tons per year, the dangers of nuclear energy would
pale by comparison.

Even if only one-half of this proposed energy
were produced by nuclear reactors, we would be speaking of
a world of 7,500 reactors. Is this credible?

The demand for utility central station electricity
is projected to continue to grow after 2000, but at lower
rates than that projected through the mid-term. Average
annual growth in electricity demand is projected to be 2.6
percent from 1980 through 2000. This compares with an
average 2.9 percent annual growth from 1973 to 1980. In
addition, both coal and nuclear generating stations are
projected to generate larger shares of total electricity in
the year 2000 and thereafter through 2020.\(^4\)

These two independent estimates of future growth
of demand for electricity are both similar, and it does
seem reasonable to assume that there will be some growth.
The real question is, "What role will nuclear power play
in that growth?" The technology of nuclear power must
change and, also, the economics for it to become an accept-
able part of the long term energy mix. On the good side,
if demand for nuclear energy does return in the late 1990s
as some have projected, there should be an available nuclear waste repository to meet the challenge of further nuclear energy production.

Worldwide, the nuclear alternative will survive only if it has an advantage over other forms of energy. That advantage may be as simple as the fact that, for some, nuclear power is the only form of energy they can turn to if they intend to emerge from their primitive lifestyles. For most, the question will hinge on the economics of the nuclear option. In the last five years, there has been a dramatic change in world demand for nuclear energy. As the factors that caused that change themselves change, we could see a reversal in the downward spiral of nuclear power. We must not lose sight of the fact that there is some risk that the nuclear power industry will not remain commercially viable in a climate of uncertain and variable markets. The fact is that markets of any kind are becoming increasingly rare for the nuclear industry.  

The risks of a descent into nuclear anarchy, akin to that prevailing in the conventional arms trade, should not be exaggerated. There is a general awareness of the dangers to political and economic relations that would result from reckless nuclear trading. China's recent sale of unsafeguarded materials to Argentina notwithstanding, suppliers around the world may have stumbled on a de facto agreement; namely, that all new sales to non-nuclear weapon
states be safeguarded by the International Atomic Energy Agency, even if those safeguards do not amount to the full-scope safeguards of the Nuclear Non-proliferation Treaty. Membership in the Agency is not compatible with any other conduct. There also appears to be a general climate of restraint over the transfer of sensitive technologies and materials. India and Pakistan, for instance, have given no grounds for believing that they will behave uncautiously in the international market.6

Conclusions

Economics

In the short term, the nuclear industry worldwide is going to have to accept severe contraction of its operations. This is due primarily to economics surrounding the technology, not the technology itself. There is room for improvement in the technology but little hope that the suppliers of nuclear reactors will be willing to spend more than they have to improve something that is not selling well to begin with. Investors in the United States will not soon allow themselves to get burned again, so in this country, the nuclear option is essentially dead for the foreseeable future. Conservationism has surfaced as the dominant force in world energy, and many feel that the extent to which energy can be conserved has not really been explored yet. However, conservation in Third World
countries amounts to not being able to move into the twentieth century (soon to be the twenty-first century) and, as expectations rise, that option will not be very tasteful.

Ethics

My research has not brought out any earth shaking ethical dilemma regarding the exporting of nuclear technology to the Third World countries, other than proliferation and the fact that they, too, have suffered from uneconomical nuclear power. These countries have not paid for their capability to generate nuclear power. For the most part, it has been financed by suppliers and the governments of various industrialized countries, subsidizing their country's nuclear industry. It has been claimed that nuclear power does little to provide jobs for the citizens of these developing countries and certainly there are ethical overtones to that claim. The fact is that, when a country has power, it has the ability to create industries (other than nuclear) that could and would employ the citizens.

The question of weapons proliferation has been addressed at length and makes anyone nervous. The entire world community must become concerned and cooperate to prevent countries such as Pakistan from attaining a weapons capability. This is due to the obvious fact that
often these smaller countries are threatened by their neighbors in wars that we look upon as small, but which to the contestants are life and death matters. When a country is about to lose and the present government is about to be put on trial, can we doubt for a minute that they would use any weapon at hand to survive. Of course, as we saw, there is an element of deterrence in the possibility of a country having nuclear weapons, but can we rely on that deterrence in countries where there are far fewer cross checks and balances of power than in the major countries? It is well and good to talk about the fact that the countries suspected of having a weapons capability are presently acting responsibly -- but for how long? Ironically, there does not have to be a proliferation of weapons capability for countries to enjoy the fruits of nuclear power. All that is necessary is to withhold the fuel reprocessing or enrichment technology. Can this be done? I doubt it. Can we go back from where we are? I doubt it. My personal answer is -- I worry a lot.

There is no turning back. The United States started the whole thing by exporting its nuclear technology to the industrialized countries. However, if we had not, someone else would have. Nuclear power was a thing whose time had come. For the time being, it appears that its time has gone. The United States and the other industrialized countries that have nuclear power are all trying to
export it to the Third World countries. This is in order to keep their nuclear industries flourishing and technicians at the cutting edge of technology.

In the long run, I feel that new technology will emerge that is both safe and economically sound. This will not happen any time soon, but eventually, population, pollution, and rising expectations will overcome the malaise of the nuclear industry, and it will re-emerge as an important part of the energy mix.

Another factor to be considered is the spatial relationship of coal to the consumers. The major free world deposits are located in America and Australia. How long will these countries supply this resource at a bargain price that allows economical use even considering extensive shipping costs. Oil is obviously too expensive to be used for anything except transportation, so it seems that nuclear energy will have to come into its own once again. There is a possibility that another form of technology will emerge. However, the present alternatives do not have the broad application for central station utility power that nuclear power has.
Recommendations

1) BUILD ON THE TECHNOLOGY. The nuclear industry is holding out as best it can. Conservation will likely reduce demand for new nuclear facilities for at least the next decade. Emerging nations are presently in serious financial difficulties, and that will not be resolved in the near future. In this environment, the sunk costs of various suppliers, utilities, investors and governments are the focus of attention. This should not be the case. When there are other opportunities that may be more advantageous, the sunk costs of previous projects should not be considered. I do agree that these costs should in this case, encourage building on a technology that has obvious long term applicability. Mr. Bray, of General Electric, is probably right in his statement that the present light water technology is sound -- the problem is, it doesn't seem to be economical. Many things have changed since the LWR technology was developed, and those factors (such as the fact that there is now a relative abundance of uranium) should be considered in advancing the technology toward economic viability. I recommend that the industry hold its technical staff together in a research and development effort to find a standardized, flexible, cheap, reliable,
available and safe method of generating nuclear electricity. This would have to be financed by the nuclear aftermath market since few new orders are forthcoming.

2) DEVELOP AFFORDABLE NUCLEAR POWER. I feel that the best new market for nuclear power will be in the Third World nations. The industrialized nations will require more nuclear power at some point but have a long way to go in their ability to conserve. Additionally, they are generally in a position to provide that power themselves. For the Third World market to become a reality, the suppliers must refine their ability to deliver tailor-made power units that will fit the financial and power needs of each country. There must be no more cost overruns. That is easy to say, yet, somehow it must be accomplished. If we can develop technology as intricate as nuclear power, we should be able to find a way to build it so that it is affordable. Perhaps modular units will allow the control and standardization necessary. Construction cost overruns have been the chief reasons for curtailment of nuclear projects, along with the Third World countries' inability to service their debts. The fear of the unknown has caused cancellations of many nuclear projects. To make the nuclear option appealing, the suppliers must guarantee construction costs. There can be no surprises. Five to six hundred percent overruns make potential customers nervous. If these countries are to prosper and pay off their debt,
they must have power. What we are obviously talking about is International Monetary Fund help in restructuring their debts in such a way that financing of needed nuclear power is still possible.

3) ELIMINATE DELAYS AND INCREASE RELIABILITY. The problems of delays in delivery combined with unreliable reactors, causing costly down time, must be resolved for nuclear energy to become or remain competitive with present forms of electricity. Whatever resources are necessary to meet schedules must be expended by the industry. The financial implications of this are obvious. Only the top engineers can be assigned to construction projects, and quality control must be very tight in order to assure reliable and safe reactors. Sloppy workmanship and inferior materials must never again be associated with nuclear power. In the Third World, the environmentalists are not really a factor. These emerging people are quite pragmatic about their needs, and nuclear power could fulfill many of those needs if it was affordable and reliable. The environment must be considered in every case, and to do so, will not only make nuclear power more attractive to the Third World, but it will enhance the image of the industry worldwide.

4) BE SERIOUS ABOUT STOPPING PROLIFERATION. The United States and the Soviet Union should take advantage of the recent warming of relations and push forward on a broad front to stop the spread of weapons technology. This
has been pretended to in the past, but it was obvious to
the world that the major players did not take it seriously.
There must not be any more looking the other way.

5) MULTILATERAL EFFORT REQUIRED. Nuclear power
is certainly not a panacea, as has been shown by the reduc-
tion in demand for new facilities worldwide. However,
there is no doubt in my mind that it must remain an impor-
tant and growing part of the energy mix in the long term.
Every effort should be made to hold the technology together
for the long haul.

In order for the nuclear industry to survive in the
United States, the market in the United States must survive.
Otherwise, the industry will migrate to other countries
where the climate is more favorable. It is not a question
of whether nuclear energy will survive, the question is,
"Where?" Survival in the United States does not seem to be
possible under the present circumstances. Changes must be
made. This may mean further government involvement in cen-
tralizing management of the utility operations, standardized
reactor plans, reducing unfounded litigation (such as is
now done in Canada) and, in extreme cases, subsidizing of
the industry might be justified. The utilities must develop
the technical expertise to recognize their needs and be able
to articulate them to the suppliers. This ability has
always existed insofar as other forms of energy were con-
cerned but has been noticeably lacking in the nuclear area.
The nuclear industry in this country must realize that it too will have to progress if it is to remain competitive with emerging nuclear technologies being pursued by other countries. This is not the time for the industry to sit back and rest on its laurels. Few countries would buy a LWR when an operational PIUS or HTGR could be purchased.
Chapter Six Notes


2. Ibid.


5. Flavin, p. 132.

APPENDIX "A"

A History of Nuclear Power in the United States

In 1939, two Austrian physicists, Otto Hahn and Fritz Strassman, split the uranium atom's nucleus for the first time. This produced the release of tremendous power, and the military significance was immediately recognized. Germany was hard at work to develop an atomic weapon, and the allied powers knew it. Einstein persuaded President Roosevelt to embark on a massive project to develop an atomic bomb, and thus was born the Manhattan Project. Teams of the free world's top scientists came to participate in this project by the hundreds of thousands. The first nuclear reactor was developed, built and tested only three years after the discovery of the fission process and only three years after that an atomic bomb was successfully detonated in the New Mexico desert. Then followed, of course, the demonstrated devastation at Hiroshima and Nagasaki which effectively brought Japan to her knees.

After World War Two, the expected diversion of effort from the "war atom" to the "peace atom" did not materialize. In 1946, Congress passed the Atomic Energy Act which established the Atomic Energy Commission (AEC). From the beginning, the AEC gave priority to military...
applications and, in the minds of many, the difference between war atoms and peace atoms remained small.

In 1953, the Eisenhower administration announced the Atoms for Peace Program. This allowed for the sharing of technological and scientific expertise with other countries. Domestically, however, several major obstacles hindered the transfer of the peaceful atom to the private sector. First, much of the nuclear technology remained highly classified, and companies not involved directly in military research had restricted access to important information. Second, vast engineering problems had not yet been solved; it was extremely difficult to create an entirely new technology of steel and rare metals which could withstand the blistering conditions of intense radiation, temperatures and pressures found in reactors. Third, the utilities were not convinced that reactors could generate electricity competitively with proven technologies like coal and oil. For the utilities, one crucial question remained: "Could the atom generate profits?"¹

In 1954, Congress revised the Atomic Energy Act to allow for private ownership of nuclear facilities under AEC license and, in 1957, passed the Price Anderson Act that protected utility companies from full financial liability for a serious nuclear accident.

Admiral Rickover was instrumental in the successful launch of the first atomic submarine and the first
atomic aircraft carrier; this technology (light water reactors) resulted in the first full scale nuclear generating plant in 1957 in Shippingport, Pennsylvania. This was a 60 megawatt demonstration reactor and was a scaled-up version of the small submarine reactor. When the power of this reactor came on line, commercial nuclear power appeared to many to be a reasonable alternative to coal or oil powered plants.\(^2\)

During the 1960s, the gold rush to produce nuclear power began. General Electric lead the way, followed by the other three reactor manufacturers (Babcock and Wilcox, Westinghouse and Combustion Engineering) in offering the utilities reactors at a fixed cost that would only escalate in response to inflation during the period of construction. This, plus the low costs of operation, caused many utilities to go nuclear. From the beginning, it was obvious that G.E. and Westinghouse were the dominant firms in the industry (Indeed, Babcock and Wilcox and Combustion Engineering had entered the field only to protect their market share as boilermakers.)\(^3\)

G.E. and Westinghouse had what might be termed a corporate nuclear war at this time. Westinghouse emerged as the front runner by offering uranium to the utilities at a guaranteed rate of $10 per pound. This proved to be disastrous for Westinghouse as the increased demand for the fuel and the limited supplies drove the price of uranium

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to $26 per pound. Westinghouse was faced with potential losses of $2 billion which would be unthinkable for the company. Ordered to find a way out of the quagmire, company lawyers discovered an arcane doctrine of "commercial impracticality," a legal device that excuses companies from financial liability for circumstances beyond their control. This left a very embarrassed Westinghouse and furious utility companies. An outside consultant blasted the shamed company stating, "This was the most stupid performance in the history of American commercial life." 4

The problem of limited supplies of nuclear fuel (uranium) was supposedly solved by Milton Shaw, a director of the AEC in 1964, who had the "foresight" to see that the breeder reactor could stretch fuel supplies indefinitely. He then focused the energies of the AEC on the development of this type of reactor and neglected the light water technology totally; this at a time when the light water reactors were being scaled up by factors of ten and twenty times. When the first breeder reactor came on line in October, 1966, it suffered a small melting incident in its uranium core. Although this was not close to a meltdown, it was in excess of the industry's postulated "worst-case accident." Four years later, the power plant was about to go into operation again, and it had an explosion in a reactor pipe. The AEC lifted the license of the operator, and to this day there are no breeder reactors operating in the United
To get back to the light water reactors that had been scaled up during this period in response to the demand for nuclear power; there had not been attendant safety studies made to assure that the level of scale up was truly safe. Such studies as the Atomic Energy Commission did do were done by computer models, but not by running a reactor to destruction to see what really would happen. This type of testing would be extremely expensive but would remove doubt as to what the worst-case consequences of a nuclear accident would be.

In destructive, full-scale testing to investigate the explosion and radioactivity release potentials of the worst possible accidents (WPA), the reactor vessel is likely to be destroyed, which would drive up the cost of each test from, say, $20 million per test (core costs) to, say, $300 million to replace the reactor system and for radioactivity cleanup, if cleaning is feasible. This, plus the fact that there are many substantially different WPAs requiring tests, makes any meaningful experimental program economically impossible. Note that this was taken from a 1976 text.

The 1970s saw continued expansion of the rapidly developing technology amid rising doubts as to its safety. Powerful economic forces began to affect the nuclear industry in the late 1970s as declining usage of electricity,
runaway inflation and sharply rising interest rates began to erode the glamour of nuclear power. (A reactor came to cost over $1 billion.) Then, too, changing safety standards and court interventions caused lengthy delays in construction time (that already exceeded ten years) with corresponding cost overruns.

By this time, it was becoming obvious that the problem of waste disposal had not been given the attention that it deserved. Waste has been accumulating at nuclear plant sites since there is no federal repository for high level waste.

In 1975, the Browns Ferry Nuclear Power Station, near Decatur, Alabama, suffered a fire caused by a careless technician that crippled the emergency core cooling systems; a last minute jury rigged pump prevented a meltdown of the core. Four years later, on March 28, 1979, a $0.15 part malfunctioned and triggered the most severe accident in the history of commercial nuclear power. The Three Mile Island reactor began to heat up and steam pressure in the pipes began to rise. The pressure valve, as it was supposed to do, blew open, but as it was not supposed to do, it failed to close. This resulted in several hundred thousand gallons of cooling water leaking out and left the core exposed for more than an hour. The resultant heat caused uranium gasses to be vented into the surrounding atmosphere. The control room operators were inexperienced
and did not know how to cope with an accident of this type. Since then, better emergency planning, fire safety codes and more rigorous inspection procedures reduce the chances for another such accident. (Three Mile Island has still not reopened.)
Appendix Notes


2 Ibid.

3 Ibid.

4 Mark Hertzgaard, Nuclear Inc. The Men and Money Behind Nuclear Energy (1982), p. 84.

5 Kaku and Trainer, p. 21.

6 Ibid.

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