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NUCLEAR ENERGY: SOCIETY'S SALVATION OR DOOM?

Introduction

Predictors of America's energy future are all painting a dismal picture. The worst possible scenario calls for severe shortages by 1985, and even the best possible scenario calls for extreme measures to avert widespread hardships. In the midst of this impending crisis, an angry debate is raging over what appears, on the surface at least, to be one of our most promising long-run energy solutions: the Liquid Metal Fast Breeder Reactor (LMFBR). Opponents of the breeder claim that it represents a threat to our very civilization while its proponents claim that it holds the key to civilization's salvation. On both sides, rhetoric and emotion have tended to replace fact in the presentation of arguments. The result has been the growth of widespread misconceptions as to nuclear power in general and the LMFBR in particular.

While there are legitimate bases for the disparity of opinions existing with regard to the development of nuclear power, no useful purpose is served by the current emotional nature of the debate. With our nation facing at a minimum severe energy deficits over the next several decades, it is more important than ever that each energy option be considered solely on its merits and weighed rationally against other alternatives. It is our purpose here to provide some of the basic data for such a comparison regarding the LMFBR.

Nuclear Energy vs. Nuclear Weapons

The question of development of the LMFBR is really only the tip of the iceberg in the nuclear debate. What is really at issue is nuclear power itself. While there has been limited activity in opposition to nuclear development from the late 1940s, it is only in the past few years that nuclear energy has become highly controversial. In a large degree, this increased controversy may be attributed to two factors. First, increased concern over the environment has led to a higher level of consciousness in reference to potential hazards of energy sources; and secondly, the growth of the number of nuclear power facilities in use across the nation has focused more people's attention on the nuclear power question.

One problem inherent in the environmentalists' fears regarding nuclear power generation is the tendency to equate nuclear power with nuclear weapons. Dr. Petr Beckman, a graduate engineer and expert in the area of nuclear energy, has stated succinctly the basic fallacy underlying this fear: "Equating nuclear with bomb is the same as equating electric with chair."

In spite of all evidence to the contrary, opponents of nuclear energy seem intent in raising the spectre of a nuclear plant exploding. For example, Ralph Nader, in a question posed to AEC Commissioner Doub at Nader's 1974 "Critical Mass" meeting, asked "How many atomic explosions in our cities would you accept before deciding that nuclear power is not safe -- no complexities, just a number."

The simple fact is, rhetoric notwithstanding, it is impossible for the fuel used in most conventional Light Water Reactors (the only kind currently in use in the United States) to explode. This is because the fuel lacks sufficient enriched uranium or other fissionable material. To understand why this is so, one must understand that a reactor produces energy through a sustained, controlled chain reaction. This is done through use of fuels which contain diluted fissile material (U235 or U233) which will convert into heat when its nuclei are split. The amount of fissile material is dependent on the type of fuel used; enriched uranium usually runs 2-4%, and U233 usually runs something under 15% of the total mass. What is important here is that neither concentration is adequate to provide bomb-grade material -- until such time as the laws of physics are changed.

Plutonium

Plutonium, the fuel which would be used in the Liquid Metal Fast Breeder Reactor, does present a greater hazard. Unlike enriched uranium fuels or U233-based fuels, it is used in concentrations which can explode but not in the fashion envisioned by nuclear opponents. Plutonium used in the manufacture of nuclear weapons is precompressed. The reason for this is that in order to obtain the maximum reaction, density of the fissionable material should be as great as possible so that a maximum number of nuclei will be split in the shortest amount of time. The relatively lower density of the plutonium used in a reactor would result in a far less efficient conversion of the material. The effect of this decreased efficiency would be that instead of an explosion in the kiloton or megaton range, it would more likely be the equivalent of something less than a ton of TNT. This magnitude of explosion, it should be noted, is well within the limits of tolerance of reactor containment vessels; and, as a result, there would be relatively little effect in terms of potential damage from the explosion in and of itself. At a minimum, it should at least not breach the reactor's containment vessel.

Nuclear Terrorism

There remains, of course, the question of whether a determined band of terrorists could steal enough plutonium or enriched uranium to construct a nuclear device. While there is an outside chance of such an occurance, there are no small number of difficulties involved in executing this sort of act. First, there is the problem of obtaining the personnel necessary to construct a nuclear device. This problem should not be minimized. While individuals with a background in nuclear physics know the fundamentals of making a nuclear weapon, this is quite different from having experience in the actual construction of such a device. Secondly, it is necessary to have a very pure form of plutonium with which to work. This problem is compounded by the fact that reactor-grade plutonium is usually replete with plutonium 240, the presence of which would substantially impair the potential for explosion. A third prolem is that there would be considerable amount of skilled labor involved in the construction. In addition to skilled mechanics, over a ton of high explosives would have to surround the subcritical masses -- explosives which would have to be simultaneously detonated if the proper implosion of the subcritical masses necessary to cause the mass to go supercritical and explode were to occur. While these problems could possibly be solved, they demonstrate that the construction of a nuclear device from stolen materials by a terrorist group is not something which could be easily accomplished. Further, most of the problems inherent in the construction of a plutoium-based device also hold true for one using enriched uranium.

On balance, while there is some danger that there could be an instance in which a determined band of terrorists, possibly with tacit assistance from a friendly foreign government, could successfully steal enough fissionable material and construct a nuclear device, the chances of this happening at present are extremely slim. This slim chance can be even further reduced by the advent of increased security in the transportation of nuclear fuels and nuclear storage facilities.

Coal vs. Nuclear: Which is Safer?

In examining the alternative energy paths our nation may take in order to cope with the current crisis, most policy makers are determined to insure that the environmental impacts of whatever solution or solutions are finally agreed upon, are fully considered. Toward this end, much has been made of the potential health hazards of nuclear energy. There is, however, considerable controversy as to just what those hazards are. Much of the disagreement has stemmed from WASH-1400, better known as the Rasmussen Report. This report, originally a study initiated by the Atomic Energy Commission, was an attempt to assess the safety and health aspects of nuclear power. It used sophisticated mathematical techniques to stimulate various possible accidents and their consequences, and the hazards accompanying normal operations. Various groups including the Union of Concerned Scientists, have criticized cerain areas of the report's methodology. The major criticism is that the report presents an overly optimistic picture of what would happen in the event of a nuclear disaster and of the chances of such an event occurring. Other studies, however, while reiterating some of the criticisms of the report still find that it is a useful tool for discussion. For instance, the recent Ford Foundation-funded study by the Mitre Corporation simply made more pessimistic assumptions for the WASH-1400 scenarios. It is interesting to note that even with the extremely pessimistic assumptions used by the Ford Foundation study, nuclear energy still had a clear advantage over coal as an energy source. According to the most reliable estimates, the health impact of nuclear energy will amount to approximately one death per 1,000 MWe plant per year as opposed to 2 to 25 deaths per similar sized coal-fired plant. It should be noted that the question of CO_2 emissions from coal-fired plants is thought by some to present an even greater hazard to the long-run environmental well-being of the earth than any of the hazards associated with nuclear power.

More importantly, what is usually overlooked in the criticisms of nuclear energy's safety is the relatively accident-free record the industry has enjoyed to date. According to the recent Ford Foundation study, in the 200-odd reactor years of operation, commercial Light Water Reactors have demonstrated no adverse health effects. The same may not be said of other forms of power generation. While it is true that an increase in the use of nuclear plants will increase the possibilities of adverse health effects, the same increase in any power source would have a similar impact. In short, based on previous experience nuclear energy carries no higher risk than other means of energy conversion during normal operations.

LOCA and Core Melt Down

Opponents point out that there is a special hazard regarding nuclear energy: The chance of a nuclear disaster. This possibility may not be lightly dismissed; however, it should also be viewed in proper perspective. As has been previously stated, a nuclear plant of conventional design cannot explode, and even a breeder reactor would not likely generate an explosion of sufficient force to rupture the reactor's containment vessel. What is possible, however, is that through a long chain of accidents and coincidences, the reactor could loose its coolant, resulting in what is termed a LOCA (Loss of Coolant Accident). The result of a LOCA could be what is termed a "Melt Down." In this type of accident, the reactor fuel, having lost its coolant, literally melts. Accompanying such an accident would probably be a cloud of highly radioactive steam and fallout which could cause severe radiation burns in the immediate area and long-term radiation-related illnesses. While there are deep-seated differences of opinion as to the magnitude of the loss of property and personal injuries resulting from such an accident, most reliable estimates place its consequences on par with those of other natural disasters society has successfully coped with.

The most important consideration with regard to the possibility of such an accident is the chance that it would occur. We have no firm data on its actual effects as there has never been a melt down, even on an experimental basis. There have been computer simulations of the possible consequences of a melt down; however, they cannot be considered infallible. Therefore, since the consequences are uncertain, the chance of such an accident becomes of prime importance. The best available estimates, assuming that the Rasmussen Report erred by a factor of 500 though the opposite may be true, still place the probability of the most serious accident at one chance in 400,000 reactor years. This, to even the most biased observer, is a relatively low probability. Further, the probability of a LOCA and melt down is one in 20,000 reactor years.

The Economics of Nuclear Energy

In considering nuclear energy as a possible alternative, the key factor to be considered is whether or not it is economically feasible. Here again there is much controversy. On the one hand, early nuclear plants suffered from a fairly low reliability and as a result have been frequently cited by nuclear critics as evidence that nuclear energy is not a viable alternative. In so doing, these opponents of nuclear energy are largely ignoring the normal process of technological development. It is highly unusual for any new technology to work smoothly in its early stages. There are inevitable wide disparities between theory and practice which must be worked out through experience. In recent years, many of these problems have been solved, and the reliability of newer nuclear installations has been far higher than that of prototypes.

A major argument of nuclear opponents has been the increase in the cost of nuclear fuel over the past several years. They argue that as the cost of fuel continues to increase as a result of greater dependence on nuclear energy for power generation, a point will be reached where such facilities are no longer cost-effective. This argument is essentially specious, as fuel comprises a small portion of the overall costs of power generation by a nuclear plant. The most significant factors contributing to the cost of nuclear power are capital costs. It has been estimated that the cost of uranium could increase sixfold before it had a significant effect on the cost of nuclear-generated electricity.

It should also be noted that among the greatest contributors to the increased capital costs associated with the construction of nuclear plants have been the additional interest costs resulting from delays caused by increased paperwork and litigation initiated to assuage environmentalist's concerns. In fact, the amount of capital expenditures accounted for by interest charges have risen from 12% of the total costs of construction to 20% in recent years with even greater increases projected if current trends continue.

In spite of delays and increased construction costs, nuclear power is playing a significant role in today's power outlook. In 1976, 9.4% of all electricity generated in the United States was accounted for by nuclear facilities. Arguments as to its relatively low efficiency to the contrary, the Connecticut Public Service Commission actually ordered a rate reduction based on savings realized through that state's heavy dependence on nuclear generating facilities. The 191 billion kwh generated by nuclear facilities in 1976 represented the energy equivalent of 325 million barrels of oil, or of 90 million tons of coal, or of 2 trillion cubic feet of natural gas. Further, the use of nuclear energy represents a savings of over $1.4 billion over the cost of comparable power generated by oil or gas. To date, studies of the cost-effectiveness of nuclear power generation indicate that it compares quite favorably with more conventional power facilities. According to the Atomic Industrial Forum, the cost of generating one kilowatt of electricity with nuclear power is 18% less than generating a kilowatt of power with coal and 38% less than generating it with oil. A study by the Edison Electric Institute comparing the relative costs of nuclear power and fossil fuel plants indicated that in every region of the country nuclear power enjoyed a decided advantage ranging from 12¢ per ten kwh to 18¢ per ten kwh.

While there is much speculation as to the possibility that nuclear energy may not be an economically feasible power source in the future on the part of its opponents, current data does not bear their fears out. In 1975, the relative costs of all aspects of power generation demonstrated that nuclear power continued to enjoy a relative advantage. When all costs are included--<u>i.e.</u>, operating costs, fuel costs, capital costs, and maintenance costs--nuclear power came out clearly ahead at 1.2¢ per kilowatt hour. Coal-fired plant costs were 1.7¢ per kilowatt hour, and the costs of oil-fired plants were 3.3¢ per kilowatt hour. The costs of coal-fired plants are likely to increase significantly in the near future. This is due to the Carter Administration's stated policy of requiring scrubbers on all new facilities. These devices add a tremendous amount to the capital required for construction and thereby raise the overall cost to the consumer. Also, as the cost of oil increases, there can be little doubt that the relative advantage of nuclear power over oil will at least be maintained and possibly increased.

An example of what can occur in relation to escalating costs is found in the Peach Bottom plant of the Philadelphia Electric Company. When proposed in 1965, it was estimated that the nuclear facility would enjoy a .7 mill advantage per kilowatt hour over a similarly sized coal-fired facility. However, by 1975 that relative advantage had increased to 4 mills per kilowatt hour. Projections which include scrubbers for future coal-fired plants further increase the relative advantage of nuclear energy. Since one ton of U235 can generate enough electricity to power a city of one-half million persons for a period of one year, there can be no doubt that nuclear energy holds tremendous promise for alleviating the nation's energy quandry. Given the fact that at present there appears to be a clear cost advantage, it seems foolish to dismiss this valuable energy source as a potential avenue of development. With the addition of breeder reactors, this already abundant source could be even further increased, thereby reducing our dependence on unreliable foreign sources of supply to meet our energy needs.

Nuclear Proliferation

A major foreign policy goal of the Carter Administration is to attempt to control the spread of nuclear weapons. This concern on the part of the Administration has recently evidenced itself in President Carter's decision to halt construction of the Clinch River Demonstration Project. Proponents of this policy claim that a gesture on the part of the United States is necessary in order to demonstrate our sincerity with regard to halting the proliferation of nuclear armaments. Opponents of the Carter policy feel that the halting of our development of the Liquid Metal Fast Breeder Reactor and of uranium enrichment facilities will have the opposite of the desired effect.

To date, some 45 nations have chosen to exercise the nuclear option. Most notable among these are France, Great Britain, Canada, Japan, and West Germany. In addition to these countries, several multi-national organizations have embarked on plans to develop nuclear facilities. The extent of nuclear facilities outside the United States is impressive. There are at least 112 reactors operating outside of the United States, and there are another 117 under construction. Sixty additional reactors are on order and 180 are in the planning stages. In fact, some six nations have a larger percentage of their electrical capacity supplied by nuclear power than the United States.

The development of foreign reactor technology has led to a decline in United States exports. At least five other nations are currently supplying reactors. These include West Germany, France, Japan, Canada, and Sweden. To the extent that such nations continue to develop their domestic capabilities, the ability of the United States to influence nuclear proliferation will be diminished. To a degree that ability has already been diminished is evidenced by the decline in orders for reactors from U.S. firms. In the three years between 1972 and 1975, the United States' share of the world market for nuclear technology dropped from 85% to 42%. Further, with the French development of the Breeder Reactor, this may well mark the beginning of foreign dominance of the field.

It is interesting to note that while we are debating the establishment of an experimental Breeder Reactor facility at Clinch River, the French have had such a plant on line and providing power since 1974. This is the Phenix reactor. The French have enjoyed such success with their Breeder that they plan to build yet another larger Super Phenix in the near future.. Other nations also have the capacity for commercial-scale nuclear enrichment facilities. These include Great Britain, France, The Union of Soviet Socialist Republic, and the People's Republic of China. Since two of the nations with commercial enrichment capacity are members of the communist block, there are serious foreign policy implications for U.S. initiatives to halt the construction of such facilities.

There is also the question of the loss of potential foreign markets resulting from the failure of the United States to fully develop its nuclear technology. It has been estimated that the nuclear export market holds the potential for the creation of a significant number of new jobs. Export revenues from the sale of nuclear technology, i.e., nuclear power plant equipment and uranium enrichment, were estimated at $1.5 billion for calendar year 1974. Projections indicate that the potential revenues in constant 1974 dollars by the year 1985 could be as much as $3 to $4 billion dollars; and through the end of the century, total revenues from the export of nuclear technology could run as high as $120 to $140 billion. In light of these figures, the export of nuclear technology is something which cannot be readily ignored. This is further enhanced by the fact that as other nations garner a larger share of the world market for nuclear technology, their impact on the question of proliferation will tend to overshadow that of the United States. It is very difficult to argue against something in which your nation has no stake.

The degree to which the other nations of the world are staking their energy future in the atom is evidenced by the extent of orders or plans for reactors. The table on page 12 is based on a survey done by the Atomic Industrial Forum of Nuclear Power Reactors outside the United States.

On balance, it would appear that if the United States truly wished to have a major voice in the limitation of the proliferation of nuclear technology and its confinement to peaceful uses, the wisest policy would be to continue domestic development. It is clear that the world is moving rapidly towards a dependence on the atom as a source of electric power. To the degree which the United States participates in the development of this new power source, it will have a voice in the decisions regarding the purposes to which it is applied.

Of particular value in the attempt to insure the peaceful uses of nuclear energy is the development of uranium enrichment facilities. It is clear that for many nations such facilities are not economically justifiable on a commercial basis. By being the supplier of enriched uranium the United States could be in a position to determine the uses to which it is put. Further, as a major supplier, it could insure that the material is properly safeguarded so as to minimize the possibilities of theft by terrorists. If, however, enrichment facilities are not constructed, it virtually assures that this nation will have no input as to safeguards.

Conclusion

It is clear that some sort of decisive action must be taken in the immediate future to stand off the potential economic dislocations which will result from the advent of a major energy shortage. Projections of current supplies and demand indicate that unless alternatives to oil and natural gas are developed by 1985, there could be a deficit in net power generation of as much as 20%. Such figures, while highly speculative, still serve to underscore the seriousness of the current situation. We must develop some sort of alternatives; and we must do it soon. No matter what alternatives are decided on, it should be noted that almost any sort of power generation facility is going to require a long lead time for construction. In the case of a nuclear facility, the normal lead time is a minimum of from 6 to 7 years. If environmental litigation takes place, it is not uncommon for the process to take as long as 10 years.

Nuclear energy has a number of advantages over coal, with regard to both health and economics. We know that in normal operations the health hazards associated with coal conversion on a massive scale would be at least twice as serious as those associated with nuclear energy. Further, even considering the possibility of a full-scale nuclear disaster, the health hazards of nuclear facilities still compare favorably with those of coal.

In terms of economics, there are two technological factors which will have an immediate impact on the relative economics of nuclear power and of coal. The first is the intent of the President to require that all coal-fired facilities install scrubbers. This will greatly increase the costs associated with the generation of power using this fuel. Secondly, there is the advent of advanced technologies, including laser beam enrichment which make the availability of fuel for conventional reactors far greater and far less costly than has previously been the case. The combination of these two factors may further widen the gap between coal and nuclear energy in terms of economics.

A third factor which will impact nuclear development is the advent of the breeder reactor. The Soviet Union currently has one on line and one planned. The French have their Phenix on line and will soon have their Super Phenix. The West Germans, the British, and the Swedes are all examining this technology. If we are to play a meaningful role in the world's nuclear future, then we, too, must examine this resource. This is particularly true as our nation happens to possess a large portion of the free world's uranium reserves and already possess large stockpiles of plutonium. It is foolish, on the surface at least, for us to ignore such a major potential energy resource.

There are questions remaining regarding nuclear energy. Greater precautions must be taken to insure the security of both reactors and of nuclear materials. More research should be undertaken as to uses beyond the generation of electricity. Steps need to be taken to prepare for the disposal of wastes. All of these questions, however, have technological answers which are within the grasp of current levels of knowledge. Most recent studies have agreed that the disposal wastes can be safely accomplished through burial in stable geological formation. A further safeguard against the emission of such substances into the environment lies in the vitrification (encasement in glass, essentially) of high-level wastes. The point is that the problems of nuclear development are soluable, and soluable in the near future. Their solution, however, can only be accomplished if the nation is committed to nuclear development. Only time will tell if this is the case.

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AIF SURVEY OF NUCLEAR POWER REACTORS

COUNTRY	OPERATING	UNDER CONSTRUCTION	ORDERED	PLANNED	TOTAL
ARGENTINA	1	1	3		5
AUSTRIA		1		1	2
BELGIUM	3	2	2		7
BRAZIL		3		6	9
BULGARIA	2	1	1	4	8
CANADA	7	10	4	5	26
CHINA (TAIWAN)		4	2		6
CZECHOSLOVAKIA	1	4		16	21
DENMARK				6	6
EGYPT				5	5
FINLAND		4			4
FRANCE	10	17	12	8	47
GERMAN DEMOCRATIC REP.	3		2		5
GERMAN FEDERAL REP.	7	12	8	4	31
HONG KONG				1	1
HUNGARY		1	1		2
INDIA	3	5			8
INDONESIA				3	3
IRAN			4	1	5
IRELAND				1	1
ISRAEL				1	1
ITALY	3	2	4	16	25
JAPAN	10	14		5	29
KOREA (SOUTH)		1	1	8	10
LUXEMBOURG			1		1
MEXICO		2		7	9
NETHERLANDS	2			3	5
PAKISTAN	1			1	2
PHILLIPINES			2	8	10
POLAND				2	2
PORTUGAL				4	4
RUMANIA			1	2	3
SOUTH AFRICA			2		2
SPAIN	3	7	7	21	38
SWEDEN	5	6		3	14
SWITZERLAND	3	1	3	2	9
THAILAND				3	3
TURKEY				1	1
USSR	19	8		10	37
UNITED KINGDOM	29	10		7	46
YUGOSLAVIA		1		1	2
* CUBA				8	8
* KUWAIT				2	2
* LIBYA				2	2
* NEW CALEDONIA				2	2
45 Countries	112	117	60	180	469

*No details are available on the implementation of the planned nuclear power programs for these countries.