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Abstract

With the nation's need for electricity and want for a cleaner environment increasing, nuclear energy seems to be an effective resource for meeting both those needs. MIT has recently released a paper entitled "The Future of Nuclear Energy" in which they propose the feasibility a large growth of the nuclear industry. However, their growth scenario fails to take into account several regulatory and liability issues that would arise with a large growth in the nuclear industry. Those issues must be understood before the nuclear industry can begin to grow. In this report, we attempt to clarify those issues.

Introduction

Currently there is an attempt underway to increase the nuclear capacity of the United States to meet the nation's ever-growing need for electricity. This movement finds its basis in the fact that nuclear power is an environmentally cleaner alternative to current coal-based and natural gas-based energy since it does not release any additional carbon dioxide into the atmosphere, thus reducing the greenhouse gas effect. Expansion of the nuclear industry would also ease the strain on the dwindling supply of fossil fuel and would help to ease the United States off of foreign oil dependence though the possibility to produce hydrogen for proposed hydrogen-fuel cell cars of the future.

The United States has 103 operational nuclear power plants, which supply approximately 20% of the nation's total electricity. Current legislation has been adequate up to now for dealing with any problems that have arisen since the birth of the nuclear industry in this country. However, with the nuclear industry poised to begin growing in the future, the question arises of whether or not the legislation currently in use will be enough to safely regulate the industry if it were to grow beyond its current capacity.

This is a question that must be answered before the nuclear industry is allowed to grow by any significant margin. Nuclear power is of a dual nature; properly regulated, it is a clean and effective form of energy. However, if proper legislation is not present, it proposes a significant risk to the entire nation.

The MIT Growth Scenario

One recent publication that makes an attempt at answering the question of the ability of the US to sustain a large growth of the nuclear industry is the MIT report *The Future of Nuclear Power*. In order to explore the possibilities and pitfalls of a large expansion of the nuclear industry, the MIT report considers a growth scenario that would see the world have 1000 1gigawatt-electric nuclear reactors by 2050. Of these 1000 reactors, 300 of them would be in the US. Of the remaining reactors, 210 would be shared between Europe and Canada, 115 would be in developed East Asia, and 50 would be built in the developing world. For these reactors, the report assumes that a "once-through" fuel cycle will be utilized, rather than reprocessing of spent fuel. Although the report isn't completely in favor of it, it assumes that the geologic disposal of spent fuel would continue unless through future research a better solution is found. [1]

Global Growth Scenario

REGION	PROJECTED 2050 GWe CAPACITY	NUCLEAR ELECTRICITY MARKET SHARE 2000	NUCLEAR ELECTRICITY MARKET SHARE 2050
Total World	**1,000**	**17%**	**19%**
Developed world	625	23%	29%
U.S.	300		
Europe & Canada	210		
Developed East Asia	115		
FSU	50	16%	23%
Developing world	325	2%	11%
China, India, Pakistan	200		
Indonesia, Brazil, Mexico	75		
Other developing countries	50		

Projected capacity comes from the global electricity demand scenario in Appendix 2, which entails growth in global electricity consumption from 13.6 to 38.7 trillion kWhrs from 2000 to 2050 (2.1% annual growth). The market share in 2050 is predicated on 85% capacity factor for nuclear power reactors. Note that China, India, and Pakistan are nuclear weapons capable states. Other developing countries includes as leading contributors Iran, South Africa, Egypt, Thailand, Philippines, and Vietnam.

Figure 1 From MIT's "The Future of Nuclear Power" page 3 [1]

Current Legislation

There are two major pieces of US legislation that would be tested by a growth of the nuclear industry from its current level of 103 reactors; those same two pieces of legislation, if they fail, would mean that the nuclear industry as a whole would be placed in danger.

First among these is the Price-Anderson Act, which addresses the liability that nuclear power plants face in case of accidents. The Price-Anderson Act requires nuclear plants to carry the maximum liability coverage available to them from private insurers (currently $300 million) and creates a joint insurance pool from among the nuclear plants themselves, with each having to pay up to $100.6 million. These mandates create a total liability limit of $10 billion, past which state and federal governments are left to cover any excess costs. [2]

Next is the Nuclear Waste Policy Act of 1982. This Act, through its amendments, is what has established the federal government's focus on Yucca Mountain as a site for the geologic disposal of nuclear waste. It also establishes the Nuclear Waste Fund, which is the source of funding for any waste-related activities, including the construction of disposal sites and possibly to pay for any waste-transportation accidents. [3]

The MIT report makes mention of these two major pieces of legislation; however, it fails to adequately examine the effectiveness of these two pieces of legislation to sustain a large growth of the nuclear industry. If they were to fail under a large growth, the possibility opens up for the nuclear industry to be left without adequate liability coverage for accidents and without enough funding to create adequate waste disposal sites—two legislative concerns that are possibly the biggest that the industry as a whole faces.

The Price-Anderson Act

A total of $202 million dollars has been paid out of the insurance pool created by the Price-Anderson. Of that, $70.8 million is due to the 1979 accident at Three Mile Island. [4] With the total payment being only about 2.1% of the total liability coverage currently available to, not even half of that coming from the largest nuclear accident in US history, it seems that the liability limits set by the Price-Anderson act would be enough to support the MIT growth scenario.

However, rather than providing too little insurance, the MIT growth scenario shows that it may be providing too much. Supposing that each of the 300 proposed plants would pay the current-day requirements towards the insurance pool the availability of liability coverage from the pool in 2050 becomes:

300 reactors x $100.6 million per reactor = $30.2 billion dollars

This excludes even the liability coverage that nuclear plants must carry with private insurance companies. This means that the insurance pool alone could cover a Three Mile Island sized accident 426 times over. It would seem that the liability limits could easily be reduced and still provide adequate coverage, with the reduced limit corresponding to reduced cost per kilowatt-hour to the customer.

This analysis shows a flaw in assuming such a large growth scenario proposed by the MIT report. The growth scenario requires 4 reactors a year be built without any of the current 103 operational reactors being decommissioned. In fact, all of them will face the choice to decommission within the next 40 years. [5] This means that the growth scenario would require anywhere between 4 and 7 reactors be built every year on average in order to achieve the goal of 300 reactors by 2050. Even with the current legislation being streamlined for the approval to build new nuclear plants, this rate of construction seems very unrealistic. A more conservative estimate for construction of new nuclear plants would change the conclusion that the Price-Anderson Act provides an overabundance of liability coverage for nuclear accidents.

If the growth scenario proposed by MIT is cut in half to 150 commercial reactors by mid-century, the growth rate becomes a more realistic, although still optimistic, 1 to 3 new reactors per year, which more closely matches the nation's average of 2 per year since the first commercial nuclear reactor began construction in 1954. [6] Using current-day liability standards, it also cuts down the available insurance pool available for nuclear accidents to:

150 reactors x $100.6 million per reactor = $15.1 billion

This more conservative estimate decreases the overabundance of liability. When it is considered that this would be a peak for the insurance pool, and that possible accidents would have to be paid for along the way, it becomes apparent that it will be a long time before the Price-Anderson limits could be cut while still providing the same level of protection as is provided today.

However, because of the wording of the Price-Anderson Act, it is possible that the insurance pools and other reactor liability coverage will be the financial source for paying any damages that may occur due to future waste transport accidents. If America continues its push for a geologic depository at Yucca Mountain, Nevada for spent nuclear fuel, it means that spent fuel will have to be transported from the various current waste-holding facilities to Yucca Mountain. This creates an entirely new liability concern for the nuclear industry, as it will be their responsibility to pay the costs of such an accident.

If it is the case that the coverage created by the Price-Anderson insurance mechanisms will be applied towards waste transport accidents then the insurance limits should be increased. The possible $30 billion dollars from 300 reactors by the MIT Growth scenario may not even be enough coverage to pay back the costs of even a small number of waste accidents.

The Nuclear Waste Policy Act

The Nuclear Waste Policy At of 1982 mandates that each reactor pay into the Nuclear Waste Fund at the rate of one-tenth of a cent per kilowatt-hour of electricity produced. [3] At that rate, assuming a reactor running at an average of 90% of its total capacity, the total funding from each reactor

1000 MW x .9 capacity x 365.25 Days/Year x 24 hours/Day x 1000 kW/MW x .001$/KW-h = $7 889 400 per Reactor per year

Taking into account the number of reactors today, under the MIT Growth Scenario, and under the more conservative estimate, that makes the current annual budget of the Nuclear Waste Fund:

7889400 $/reactor x 103 reactors = $812 608 200 today

7889400 $/reactor x 300 reactors = $2 366 820 000 in 2050 under the MIT scenario

7889400 $/reactor x 150 reactors = $1 183 410 000 in 2050 under the conservative scenario

This funding is intended to be used to pay for the development, licensing, construction, and maintenance of a permanent waste storage facility, and for any costs involved with transporting waste to such a site. Currently, the United States plans on utilizing geologic disposal of spent nuclear fuel. The Office of Civilian Radioactive Waste Management estimates the total cost of Yucca Mountain to be $36.6 billion dollars over its lifetime of an estimated 117 years, meaning an average yearly cost of about $313 million. It is clear that the current funding level of the Nuclear Waste Fund can support a single Yucca Mountain site. However, the question is if this funding is enough to pay for the construction and maintenance of geologic disposal sites as they are needed.

There are several different volumes of spent fuel that could be held at Yucca Mountain. It will initially be cleared to hold 63 000 metric tons of commercial spent nuclear fuel. Over time, it may be cleared to hold up to 97 000 metric tons or even a maximum load of 119 000 metric tons. [7] The average 1 gigawatt nuclear plant produces 20 metric tons of spent fuel per year. Under the MIT growth scenario, this means that at maximum capacity the nuclear industry will produce the need for a new Yucca Mountain-sized depository every:

63 000 metric tons/Depository / (20 MTHM/Reactor/year x 300 Reactors) = 10.5 Years

If the total capacity of Yucca Mountain is increased from its starting capacity of 63 000 metric tons to its maximum possible capacity of 119 000 metric tons, the need for a new depository would become one ever 20 years, each of them potentially costing the same estimated $36.6 billion over their lifetime. Under the more conservative scenario, the need for new depositories decreases to one every 21 years in 2050 assuming the 63 000 metric ton capacity.

It would seem that under either scenario, the Nuclear Waste Fund would possibly be able to afford the continued construction and maintenance of new geologic disposal sites. However, this fails to take into account the added possibility that the Nuclear Waste Fund would have to cover liability costs of waste transport related accidents. The wording of the Nuclear Waste Policy Act of 1982 makes this a possibility. If this is to be the case, the Nuclear Waste Fund would have to set aside a large portion of its annul budget to cover liability costs, and depending on what percentage that is, there may not be enough money left aside to afford the costs of constructing the waste disposal sites that would be needed in the future.

Conclusion

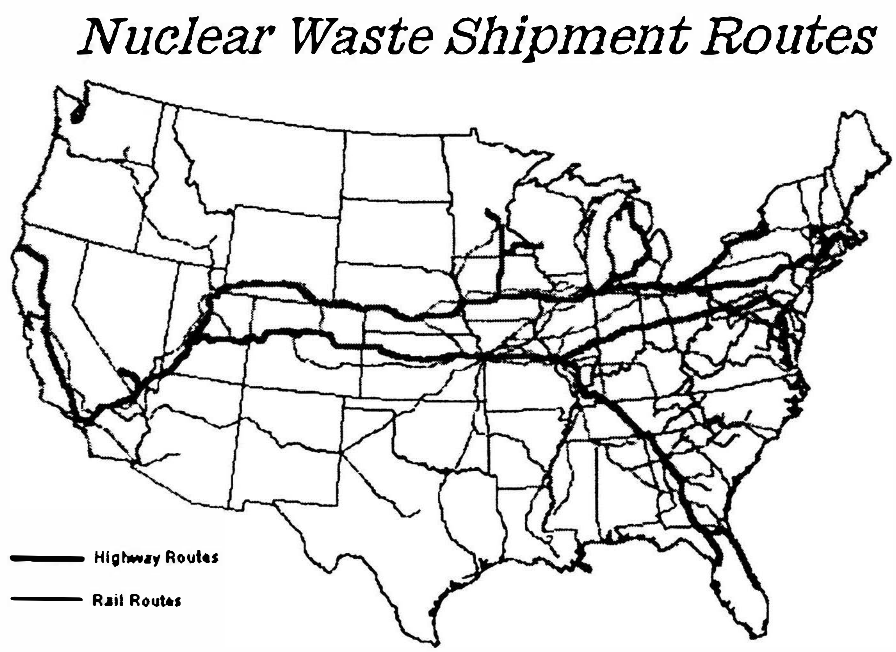

Figure 2 From Nevada state's website [8]

Many of the proposed routes for nuclear waste shipment to Yucca Mountain run near or through very populated areas. If an accident should at such a point, the cost of repairing possible damages and decontaminating those exposed areas would be very high. It seems self-evident that a large amount of funding should be set aside to pay for any such accidents. If the nuclear industry is to grow in the future, current legislation must be clarified to do so. Both the Price-Anderson Act and the Nuclear Waste Policy Act have mechanisms in them that can allow for the coverage of liability due to waste transport accidents. When looking a conservative growth scenario each of the two appears to be inadequate in order to pay for the costs it is intended to cover and to pay for the waste transport liability that they could potentially be required to sustain. Either one of those pieces of legislation, if they must cover waste transport liability on top of their own burden, will have to have their financial limits increased, most probably by a very significant amount. However, it is not necessary that each have the fees they charge to reactors be increased. Instead, current legislation should be modified so that it is clear which of them is to cover waste transport liability, or an entirely new piece of legislation should be passed that would create an independent liability fund for waste transport accidents.

Without taking action to resolve this conflict between the Price-Anderson Act and the Nuclear Waste Policy Act of 1982, a large growth of the nuclear industry presents the distinct threat of a major waste transport accident without any funding to aid in the clean-up of the accident, or of reimbursement for damaged property. Without such liability funding, the threat of waste transport accidents should be more than enough to keep from allowing the nuclear industry to grow.

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Reflection on the Learning Experience

1. I found that research of the nature that I have tried, dealing mostly with technical reports and federal legislation, is done online. This is because of the size of many of the documents that must be read. Few are under a hundred pages. It would be a waste of time and resources to print out each paper that needed to be read. Because of the complexity of the issues, having to take into account public acceptance, possible risk analysis, and logistics, many of the projections I came across were purely hypothetical.
2. I have very much expanded my understanding of the information available regarding nuclear power. Since most all of the information and reports are online, it is very easy to get a hold of information, to the extent that one is overwhelmed by the information available. It seems that because of the volume of information available, it is most efficient to look for very specific information, rather than to look for information regarding general concepts, so that the extraneous can be avoided.
3. Rather than the fundamentals of tangible experimental design, my research was focused towards examining hypothetical situations, and, to that extent, I've gained a large amount of knowledge. Through my research, I came across several hypothetical situations for waste transport accidents and for growth scenario problems, and had to analyze the probability of each occurring. I gained the knowledge of being able to recognize which of these scenarios presents a serious problem and should be examined, and which are, for all intents and purposes, impossible.
4. I have learned to interpret what is a distinct problem and what is not. Several issues came forth when I had to examine a large growth of the nuclear industry, and I needed to interpret which of these was a serious problem, and which were minor. After doing so, I had to determine what the magnitude of the problem presented, and what an effective method would be to resolve the problem.