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INHERENTLY SAFE NUCLEAR POWER AND THE POLITICS THAT EFFECT IT

An Interactive Qualifying Report

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by

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Introduction

Current State of Energy Production

As the population of the world grows there is a parallel increase in the need for energy. This need is apparent in the United States. Today more people have computers, air conditioners, dishwashers and other major home appliances that require large amounts of electricity. This increasing demand for electricity must be met with a means of supply.

Currently, the United States relies heavily on fossil fuels to generate electricity, but the known sources of these fuels are being diminished far more quickly than they can be replaced. According to Livingston, known world oil reserves will last for perhaps 40 years and gas reserves for about 150 years, but with consumption increasing by 6 to 7 percent each year, even the gas reserves would be consumed in less than 40 years (Livingston, 1988, p. 15). While these estimates have been lengthened a bit in recent years due to discoveries of new reserves and an increase in the efficiency of automobiles, it is obvious that an alternative to fossil fuels must be found and implemented soon, because the United States relies so heavily on electricity (Livingston, 1988, p. 20).

The knowledge that fossil fuels will eventually run out forces an investigation for another energy source to replace fossil fuels. "For an energy source to be viable, it must meet four criteria:

- Maintain a relationship with the rest of the world that improves its well-being, contributes to international stability, and leaves the United States free to follow relatively independent policies;
- Provide for future U.S. energy needs so that economic aspirations can be fulfilled and lifestyles can remain a matter of choice;

- Maintain and evolve institutions that allow citizen participation in decision making; and
- Ensure the benefits and costs are distributed fairly in U.S. society" (Livingston, 1988, 30).

Possible replacements for fossil fuels in generating electricity are hydroelectric, solar, wind and nuclear power. There are no emissions from hydroelectric power and it is economical, but the potential from this source of energy is limited (D'Arruda, Harrington, and Waterhouse, 1991, p. 50). "The capacity from hydroelectric power could never be as high as the capacity from fossil fuels or nuclear power because there are only a few suitable environmentally acceptable sites left that could accommodate hydro's requirements"(D'Arruda, Harrington, and Waterhouse, 1991, p. 50). A major drawback for solar power is that scientists have not yet learned to maximize the total potential of the sun's power (D'Arruda, Harrington, and Waterhouse, 1991, p. 50). This lack of efficiency puts solar power at an enormous financial disadvantage. Solar power costs were about $0.12 per kilowatt hour, which is far more costly than the $0.05 to $0.07, which is the cost range for fossil fuels in 1989 (DOE, 1989). Another disadvantage of solar power is that it requires "vast open space due to the large heliostats that must be installed" (D'Arruda, Harrington, and Waterhouse, 1991, p. 50). According to the chairman of Scientists and Engineers for Secure Energy, "To meet our electrical needs, we'd have to build enough collector plates to cover the state of Delaware." Some of the drawbacks surrounding wind power are "electromagnetic signals, noise generation, aesthetics, soil erosion, dangers to migrating birds, and land requirements" (Nuclear Information and Resource Service, 1989).

The only other existing source of energy today is nuclear power. Energy is created by nuclear fission of a radioactive substance such as uranium or plutonium. Fission involves striking the radioactive material with neutrons such that it breaks down into two lighter atoms and two neutrons. The reaction, more importantly, gives off considerable amounts of energy in the form of heat. This heat is used to create steam that will pass through turbines to generate electricity. The neutrons that are released will collide with other uranium/plutonium nuclei and cause the same reaction to occur. With the use of neutron absorbing rods there is a controlled, self-sustaining reaction whose energy can be used to generate electricity. Nuclear power produces no air pollution, but the spent fuel is radioactive with half-lives ranging from tens of thousands of years to billions of years. Another problem with nuclear power is the release of low level radiation. The effects of low dosages of radiation are not precisely known at this time, but there are studies currently being done to determine whether or not low levels of radiation actually have positive effects on the health of humans. "A vital U.S. energy source has become enshrouded in a fog of misinformation and fear" (Bennett, 1981). The misconceptions about nuclear power hinder the continued development of an energy source that is inexpensive, reliable, efficient, and safe for the environment and the people in it (D'Arruda, Harrington, and Waterhouse, 1991, p. 50)

Introduction to the Nuclear Subgovernment

A subgovernment is a small group of players who control a certain issue, in this case nuclear power (Berry, 1984, p. 12). The group of "players" consists of people who benefit from influencing the issue. “In many respects, the atomic energy program in the twenty years following World War II was the archetypical subgovernment. A small, cohesive, and stable group of actors exercised considerable autonomy in policy making" (Duffy, 1997, p. 20). In the beginning, nuclear power policy was written by those who had a stake in its success. The actors in this monopoly were united by a conviction that the development of atomic energy as a means of generating electricity was both necessary and desirable for the nation's welfare (Duffy, 1997, p. 21). This consensus meant that decision making would be extremely accommodative and that policy would be quite stable (Duffy, 1997, p. 21). The important decisions concerning the atomic program were made with little public debate by this small set of participants. Those who were not directly involved with the subsystem were not interested in atomic energy (Duffy, 1997, p. 21).

The atomic subgovernment's control was enhanced by the widespread perception, nurtured by them, that atomic energy was primarily a national security issue, which meant that few actors would have a detailed knowledge of the program (Duffy, 1997, p. 21). "For all intents and purposes, only supporters of nuclear power were mobilized for action" (Duffy, 1997, p. 21). This one-sided participation ensured that generous subsidies and the absence of political conflict characterized government policy during the period from 1945-1965.

"In 1965 the politics of nuclear power was of little concern to anyone not having a direct stake in the program's success, but by the middle of the next decade the policy-making arena was crowed and complex" (Duffy, 1997, p. 49). People previously uninvolved in nuclear power would be drawn into the conflict over issues concerning the environment, the release of radiation from plants, and overall safety of the plants. The credibility of the Atomic Energy Commission (AEC) and the Joint Committee on Atomic Energy (JCAE) began to suffer when their experts began to disagree in public (Duffy, 1997, p. 63). "The AEC was the primary actor in formulating the nation's atomic energy policy. Its principle duties…were the production of atomic weapons and the fissionable materials required for their manufacture" (Duffy, 1997, p. 23). Congress tried to create an expert agency that would be insulated from the political pressures that could conceivably distort its decision-making processes (Duffy, 1997, p. 23). The JCAE was created to oversee the operations of the AEC. Also, the committee had exclusive jurisdiction over all bills pertaining to atomic energy (Duffy, 1997, p. 23). Once the credibility of the AEC and Joint JCAE came into question, the entire atomic subgovernment began to fall apart.

Beginning with the passage of NEPA in 1969, new laws chipped away at the AEC's monopoly, granting other federal agencies some jurisdiction over commercial nuclear power (Duffy, 1997, p. 103). The rise of energy issues a few years later led to an effort to overhaul the federal government's energy apparatus and quickly led to the abolition of the AEC (Duffy, 1997, p. 103). The Nuclear Regulatory Commission (NRC) would replace the AEC, but could not be counted on to be quite as supportive as the AEC.

The NRC was established in 1974 by the Energy Reorganization Act, but there were many acts passed from 1969-1977 that had detrimental effects on nuclear power by affecting AEC jurisdiction (Duffy, 1997, pp. 104-112). The Water Quality Improvement Act of 1970 transferred to the EPA the responsibility for regulating thermal discharges from nuclear plants and gave the EPA the leading role in determining the type of cooling system to be used at power plants (Duffy, 1997, p. 104). Other laws that affected the AEC were the Coastal Zone Management Act, the Federal Water Pollution Act, the Endangered Species Act, the Toxic Substances Control Act, and the Clean Air Act (Duffy, 1997, pp. 104-105).

E.E. Schattschneider (1960, pp. 47-48) wrote that "in politics as in everything else it makes a difference whose game we play. The rules of the game determine the requirements for success. Resources sufficient in one game may be wholly inadequate in another." If that is the case, then those interests who can correctly identify which game is being played stand a better chance of winning (Duffy, 1997, p. 151). The demise of the AEC and the dismantling of the JCAE created a new game, and, as a result, the requirements for success changed (Duffy, 1997, p. 151).

By the 1980s, the politics of nuclear power bore few of the signs of subgovernment dominance (Duffy, 1997, pp. 152-180). The one-sided mobilization of interests that characterized atomic energy's first twenty years had been replaced by two stable, well-defined coalitions organized for action, each seeking different policy outcomes (Duffy, 1997, p. 179). The politics of nuclear power was now a center of conflict (Duffy, 1997, p.179).

Throughout their tenures, Reagan and Bush tried with mixed results to resolve the nuclear industry's most pressing problems (Duffy, 1997, pp.182-187). White House actions during their presidencies were as follows: legislative proposals designed to resolve the high-level nuclear waste issue, use of appointment power and executive orders to create a more favorable regulatory environment, facilitation of reform of reactor licensing procedures and support of progress toward NRC certification program on advanced reactors (Duffy, 1997, p.183). Although the combination of statutory reform and executive action by Reagan and Bush failed to immediately revive the nuclear industry, significant progress was made toward overcoming some of its biggest obstacles (Duffy, 1997, pp.182-183). "By any standard, nuclear power's prospects were considerably brighter in 1992 than in 1980" (Duffy, 1997, p.185).

Current State of Nuclear Power

"There are currently 110 nuclear reactors operating in the United States, producing 21.1 percent of the nations total utility generated electricity" (Duffy, 1997, p.213). There are some key issues confronting nuclear power today. Among them are trends in electricity usage, nuclear waste disposal, and a recent shift to a deregulated and intensely competitive electric power market (Duffy, 1997, p.214).

To quell concerns about nuclear power safety, designs for nuclear reactors have been developed that have inherently safe features. The inherently safe nuclear reactors incorporate features that allow the laws of physics to stop a run-away reaction and prevent core meltdown without the need for the intervention of operators or active safety mechanisms. The replacement of operator intervention with passive safety systems nearly guarantees that the core cannot meltdown.

Policymakers continue to be ambivalent about commercial nuclear power (Duffy, 1997, p.214). "Reflecting their ambivalence, nuclear policy making has been marked by incrementalism, with policymakers unwilling, or unable, to stray far from the status quo" (Duffy, 1997, p.216). Barring another energy crisis, it is unlikely that American utilities will soon begin building any additional nuclear plants and in the absence of a severe accident, policymakers are equally unlikely to require the shutdown of existing reactors or rule out the possibility of future contributions from nuclear power (Duffy, 1997, p.216). This is where we stand today, seemingly going nowhere because there is no reason to go.

Report Outline

The first section of our paper following the introduction is the goal statement. The goal statement describes what we are trying to accomplish with this paper.

Next, we describe our methodology. Our methodology can be broken down into five parts: background information on subgovernments, discussion of literature review, interview in formation, personal interview information, and developing a questionnaire. The methodology contains background information on our topic as well as an outline of how we undertook the project.

The methodology is followed by our literature review on nuclear power. We thought it important to first describe the current technology and issues. We also include descriptions of how reactors work, a brief background of inherently safe nuclear power, and descriptions of inherently safe reactor designs.

Because our project concerns political aspects of nuclear power, we included a section on the history of nuclear power politics in the literature review. The political history addresses nuclear power from its first days. It chronicles the rise of the atomic subgovernment and atomic power in America and traces its history through the late 1980's.

Following the political history is the economic impact on the nuclear industry. We thought that the politics of the issue were not the only driving forces explaining why nuclear reactors are not being built. This section is included in our literature review to explain some of the financial aspects of nuclear power. There is also a brief chronological description of building practices of nuclear reactors.

After the literature review there are our interviews and conclusions. This follows our methodology in that we researched our topic and then questioned some experts on what we found. We have included a write-up of each of the interviews we conducted. Finally our conclusions are presented; backed by information gained through the literature review and the interviewing process.

Goal Statement

The question we will try to answer in this report is: given the political history of nuclear power and the current state of politics in America, will inherently safe technology have enough of an impact on the politics of nuclear power to allow nuclear power to grow in America?

Methodology

Background Information on Subgovernments

A policy subgovernment once controlled legislation surrounding nuclear power. A policy subgovernment is a small group of actors who control the policy of a given issue, such as nuclear power. (Duffy, 1997, p.3) The atomic subgovernment dominated nuclear power policy making for the first twenty years of the nuclear power program (Duffy, 1997, p.20). The atomic subgovernment has since been replaced by the rise of issue networks. Issue networks are similar to policy subgovernments in that they both contain members that have a common technical expertise (Duffy, 1997, p.14). Issue networks, though, are more accessible to new members than the policy subgovernments (Duffy, 1997, p.15).

The change from policy subgovernments to issue networks is where we begin our project. We want to examine how the political system in America deals with issues of controversy such as nuclear power. By understanding policy subgovernments and the environment in which they exist we can trace the political history of nuclear power to discover the changes that took place that slowed the progress of the nuclear power program in America. By finding reasons for the problems encountered, we will be able to determine whether or not nuclear power can survive in the existing political system and what effects, if any, inherently safe nuclear reactor technology will have on its survival.

Discussion of Literature Review

Our research methodology consists of an extensive literature review and interviews. The purpose of the literature review is to gain a firm understanding of the history of nuclear power politics. It is important to understand how the program was started and to examine the environment that fostered its development so that we can compare it to the existing political situation. Comparing the political situation under which nuclear power was fostered in with today's political situation is important because we want to draw a conclusion as to the future of nuclear power in the current political system. The literature review will also contain information about developments with inherently safe nuclear reactor designs. Because we are trying to determine whether or not inherently safe technology will have an impact on the ability of nuclear power to survive given the current state of politics in America, we feel that information about inherently safe nuclear power should be included. The literature review will also contain information about current nuclear reactors for the purpose of background information.

Interview Information

Because people control politics, we feel that the best way to understand what is going on with the politics of nuclear power is to interview the people involved. The people that we chose to interview represent interest groups that both favor and oppose nuclear power, federal politicians that are on committees involved in nuclear policy, state politicians whose district contains a nuclear reactor, industry representatives, and utility representatives. Our first step in deciding who to interview was to get in touch with the Nuclear Regulatory Commission. They gave us the names of the interest groups in Washington, D.C. that do the most lobbying on nuclear power issues. Upon interviewing those people, we asked for the names of other people who would be willing to speak with us. This is an example of reference sampling.

The method of interviewing was that of an in depth qualitative interview. This method has been chosen because it allows the interviewer to adjust later questions based on previous responses. It is important for us to find out how the people involved interpret what is going on with nuclear power and we feel that the in depth qualitative interview will be most effective.

The number of people we interview will depend on how far the reference sampling takes us. By definition, we will stop interviewing a sequence of people when the answers become redundant or the interviewees begin giving us the names of people we have already interviewed. We also developed a list of questions to ask based on whom we are going to interview. For example, we did not ask an interest group all of the same questions that we will ask an industry representative. The interviews themselves took about 30 minutes and we intend to record each interview. Interviews were conducted over the phone.

The ultimate success of the IQP will be determined by the interviews. The people we will be interviewing are in the middle of the battle over nuclear power. They have influence on every aspect of the policy making surrounding nuclear power. In interviewing these people we hope to be able to draw a conclusion as to the future of nuclear power in America in light of recent developments with inherently safe nuclear technology.

Personal Interview Information

"The personal interview is a face-to-face, interpersonal situation in which an interviewer asks respondents questions designed to elicit answers pertinent to the research hypothesis (Nachmais, 1996, p.232)." (The personal interview is one of the ways that we intend to gather information for our IQP. There are three different ways in which personal interviews can be structured. There is the schedule-structured, the focused structured, and the non-directive interview (Nachmais, 1996, pp.233-234). We have chosen the focused interview as the structure in which our personal interviews will be conducted.

"The focused interview has four characteristics:

1. It takes place with respondents known to have been involved in a particular experience.
2. It refers to situations that have been analyzed prior to the interview.
3. It proceeds on the basis of an interview guide specifying topics related to the research hypothesis.
4. It is focused on the subjects' experiences regarding the situation under study". (Nachmais, 1996, p.234).

The encounter between the interviewer and respondents is structured and the major aspects of the study are explained, but the respondent is given considerable liberty in expressing their definition of a situation that is presented to them (Nachmais, 1996, p.234). We feel this method best suits our interests because of the latitude given to the respondents. Each respondent can interpret the questions based on their opinions and knowledge of nuclear power. It is structured enough, though, that we can ask all of the respondents the same applicable questions. By applicable questions we mean that we can ask all of the interest groups the same questions and all of the politicians the same questions and all of the industry representatives the same questions.

"The focused interview permits the researcher to obtain details of personal reactions, specific emotions, and the like" (Nachmais, 1996, p.235). Politics involves people and people all have their own opinions that are going to shape their political views. We are attempting to determine what affect, if any, inherently safe nuclear reactor technology will have on the politics of nuclear power. So, in effect, we are attempting to find out the opinion of the people who are involved in nuclear power policy and whether or not their opinion will be altered by the development of inherently safe nuclear reactor technology. In an attempt to gather their opinions, we feel the focused interview will present the greatest chances of success.

There are some advantages as well as disadvantages to conducting personal interviews. We will first discuss the advantages. The first advantage is flexibility. The personal interview allows great flexibility in the questioning process (Nachmais, 1996, p.237). With flexibility comes the opportunity to probe for additional information and detail (Nachmais, 1996, p.237). Another advantage is that the researcher is given control over the interviewing situation. The interviewer can ensure that the respondents answer the questions in the appropriate order or that they answer certain questions before they are asked subsequent questions (Nachmais, 1996, p.238). The interviewer can also control the environment in which the interview is conducted to ensure that the interview is conducted in private and thus the respondents do not have the opportunity to consult one another before giving their answers. A third advantage is a high response rate. This is an advantage over mail questionnaires because respondents that ordinarily would not respond to a mail questionnaires will often respond to a request for a personal interview (Nachmais, 1996, p.238). The final advantage is that interviewers can collect supplementary information about respondents (Nachmais, 1996, p.238). This information can often come in the form of a spontaneous reaction to a question that the interviewer can record and that might be useful in the data analysis stage (Nachmais, 1996, p.238).

The greatest disadvantage for our research is interviewer bias. The lack of standardization in the data collection process makes interviewing highly vulnerable to interviewer bias (Nachmais, 1996, p.238). This bias can occur in both directions, though. “Sometimes even the interviewer’s race or gender can influence respondents who may give socially admirable but potentially misleading answers because they are trying to please the interviewer" (Nachmais, 1996, p.238).

There are certain principles of interviewing that should be followed as closely as possible to enhance the advantages and downplay the disadvantages of personal interviewing. "The first step in the interviewing process is getting the respondent to cooperate and to provide the desired information" (Nachmais, 1996, p.239). "Three factors help in motivating the respondent to cooperate:

1. The respondent must feel that their interaction with the interviewer will be pleasant and satisfying.
2. The respondents need to see the study as being worthwhile.
3. Barriers to the interview in the respondents' minds need to be overcome" (Nachmais, 1996, p.240).

Before the interview can take place, the respondent must agree to give an interview. "The Survey Research Center of the University of Michigan's Institute for Social Research provides some useful pointers on how interviewers should introduce themselves to respondents:

1. Tell the respondent who you are and who you represent.
2. Tell the respondent what you are doing in a way that will stimulate his or her interest.
3. Tell the respondent how he or she was chosen.
4. Adapt your approach to the situation.
5. Try to create a relationship of confidence and understanding between yourself and the respondent" (Nachmais, 1996, p.240).

Once the respondent has agreed to an interview, the interviewer is ready to begin the interview. "There are specific techniques that the interviewer can use in this process:

1. The questionnaire should be followed, but it can be used informally.
2. The interview should be conducted in an informal and relaxed atmosphere and the interviewer should avoid creating the impression that what is occurring is a cross-examination or a quiz.
3. The questions should be asked exactly as worded on the questionnaire.

4. Read each question slowly.
5. Questions should be presented in the same order as in the questionnaire.
6. Ask every question specified in the questionnaire.
7. Questions that are misinterpreted or misunderstood should be repeated and clarified" (Nachmais, 1996, p.240).

Following the instructions above should give us the ability to gather valuable information. Now that the format has been laid out, the important part of the information gathering process will be the questionnaire. We may develop a good game plan for conducting the interviews, but if the questions do not evoke valuable responses then the properly conducted format is pointless.

Forming a Questionnaire

"Because the findings of surveys often influence policy decisions that have an impact on people's lives and may be the only source of information on an issue available to the public, survey questions must be carefully constructed and ordered to elicit accurate data" (Nachmais, 1996, p.250). While the findings of our survey will only affect our lives, we do find it of the utmost importance that the data we do collect is accurate and pertinent to our research. We will start out by examining the question itself.

Properly constructed questions will provide data for hypothesis testing (Nachmais, 1996, p.250). "The question must also motivate the respondent to provide the information being sought" (Nachmais, 1996, p.250). The major considerations involved in formulating questions are their content, structure, format, and sequence (Nachmais, 1996, p.250).

Most questions can be classified into two separate categories: factual questions and questions about subjective experiences (Nachmais, 1996, p.251). We will be focusing on the questions about subjective experiences because we have already gathered facts about inherently safe nuclear technology, now we want to find out what impact it will have on the people who are involved in nuclear power policy. "Subjective experience involves the respondents' beliefs, attitudes, feelings, and opinions" (Nachmais, 1996, p.252). Attitudes are general orientations that can incline a person to act or react in a certain manner when confronted with certain stimuli (Nachmais, 1996, p.252). Individuals express their attitudes through speech or behavior only when they perceive the object of the attitude; thus a person may have strong attitudes towards nuclear power, but these are aroused and conveyed only when that person is confronted with a stimulus such as a question in an interview (Nachmais, 1996, p.252).

Attitudes are described by their content, direction, and their intensity (Nachmais, 1996, p.252). That is to say that a respondent's will be about some attitude, will contain positive, neutral, or negative feelings towards this attitude, and will be held with greater or lesser vehemence (Nachmais, 1996, p.252). We are interested in measuring attitudes because they account for the respondent's general inclination (Nachmais, 1996, p.252).

In order to measure a respondent's attitude, we must use questions that evoke this attitude. There are three types of questions: closed-ended question, open-ended questions, and contingency questions (Nachmais, 1996, pp.253-254). We will focus on the open-ended question type because that is the one that suits our research. "Open-ended questions are not followed by any kind of specified choice, and the respondents' answers are recorded in full" (Nachmais, 1996, p.254). The best feature of an open-ended question is that it does not force the respondent to use any preconceived answers (Nachmais, 1996, p.254). Open-ended questions also allow the interviewer to clear up any misunderstandings, and they encourage a certain comfort level between interviewer and respondent (Nachmais, 1996, pp.254-255). A draw back to open-ended questions is that "open-ended questions are difficult to answer and still more difficult to analyze" (Nachmais, 1996, p.255).

We have identified the type of survey that we will conduct, the type of responses that we are looking for, and the type of questions that we want to ask in order to get the responses we desire. Now we need to determine the most proper order for asking those questions. Two types of questioning sequence are the funnel sequence and the inverted funnel sequence (Nachmais, 1996, pp.260-261). The funnel sequence involves each successive question relating to the previous question, with the scope of the questioning becoming more and more narrow (Nachmais, 1996, p.261). The inverted funnel sequence is the opposite of the funnel sequence. The inverted funnel sequence starts with the specific questions and moves on to broader questions towards the end of the questionnaire (Nachmais, 1996, pp.261-262). We will use the funnel sequence method. It seems to suit our needs because we will be discussing an issue that the respondents feel very strongly about and asking them a narrow question at the beginning of the interview could quickly put them on the defensive and ruin the rest of the interview.

To apply the inverted funnel technique we started our interview asking questions to obtain general information. Such questions elicited background information about the particular group the interviewee represents. Initial questions sought information about how the interviewee became acquainted with the group they represent. For example, the questions we asked everyone may have included the following:

1. How did you become involved in (whatever group they are)?
2. What is the stance you take towards nuclear power?
3. What is the opinion of the group you represent?

These questions were non-confrontational. They allowed the interviewees to do what people

like to do best, talk about themselves. As the interviewee becomes comfortable we began to ask more difficult questions.

The questioning then proceeded to asking questions about their knowledge of nuclear power and inherently safe nuclear reactor designs. These questions were also non-confrontational. They allowed us insight into the interviewee's opinion of inherently safe nuclear power by paying close attention to the tone of their voice. They may also have said that they do not buy into the inherently safe design even though we did not ask them. Questions for this part of the interview may have been the following:

1. What are some of the benefits or drawbacks of current nuclear reactor designs?
2. Are you familiar with inherently safe nuclear reactor designs?
3. Do the safety features of inherently safe nuclear reactors seem better, worse, or the same as the current defense-in-depth systems?

To the interviewee, these questions also seemed to only seek information. In the first set of questions we established the interviewee's opinion of nuclear power. With these second set of questions we began to elicit information about their views of inherently safe nuclear power.

At this point in the interview we had a relatively good idea about the interviewee's stance on both nuclear power and inherently safe nuclear power. The questions we have asked are open-ended questions that mainly seek to measure the background knowledge of the interviewee. The questions now depended on their previous responses. For those interviewees who seemed anti-nuclear the questions may have included the following:

1. Would you support nuclear reactors that contain safety measures that eliminate the chance of a core meltdown?
2. Do you think the development of safe reactors lead to legislation supporting the construction/operation of nuclear reactors?

3. If inherently safe nuclear reactors were the standard, would you support reactor construction/operation licensing reform?

Other questions that might have been asked of anti nuclear interviewees in order to find out where the weak points of nuclear power lie would be the following:

1. What are the most difficult problems for nuclear power to overcome?
2. Could inherently safe reactors in combination with legislation reform overcome these barriers?

Asking questions such as the first question directly above gave us some insight as to how the opposition is going to attack inherently safe nuclear power.

Background Information on Nuclear Power

Introduction

There is currently a need for electricity, since it runs everything from computers, to lights, and, perhaps, soon cars. Since we have such a great need for electricity, which source should we choose? There are four major possibilities: coal, nuclear, oil, and natural gas. If we are to decide which we should use, we must look at the entire positive and negative aspects of each one, and decide which is the best, at this time.

First, we shall compare the four economically. Figure 1, page 22, shows a graph, which calculates the cost of each of the four energy sources, and compares the four. The figure takes into account only operation costs, maintenance costs, and fuel costs. Looking at Figure 1, we can see that nuclear would be a very competitive source. That graph does not even consider the capital costs.

Comparing the capital costs of a coal, natural gas, oil, and nuclear power plants, we can further demonstrate that nuclear is not economically competitive. Coal-fired plants cost between \$1200-1700/kW for construction and take about 6-8 years to come online. Natural gas and oil plants cost between \$800-900/kW to build and about four years to become operational. The construction costs for nuclear power plants are between \$1500-2500/kW and the time for construction is at least twelve years. It is these costs that make nuclear power not competitive (www.greentie.org/class/ixc01.htm, 1999). Such an immense initial capital investment cripples nuclear power before it can get started. However, nuclear power cannot be reviewed in isolation. We must take into account other factors, besides initial cost.

Coal, as a source of electricity, is not a very viable option. It gives off many gases, which is detrimental to public health. It also spews carbon into the atmosphere, which would contribute to the greenhouse effect.

Oil is a source of power for many countries in the world. Oil is relatively cheap right now, which is good for the consumer. The drawback of oil power is that oil gives off gases that cause global warming. The other drawback to oil is the limited resource. Production may become limited in the future, and it is currently essential for transportation.

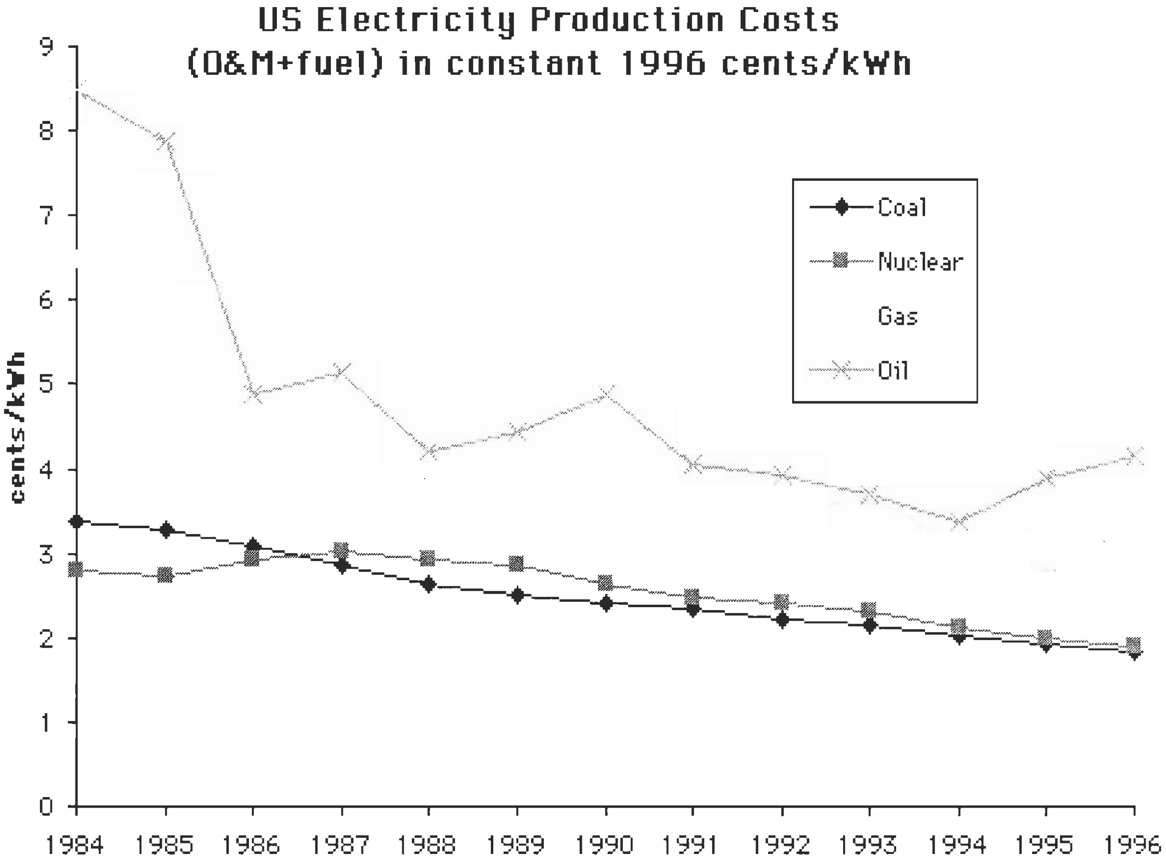

Figure 1. Electricity production costs in the United States. (Uranium Information Center, 1998)

Natural gas is an excellent source of energy right now, as it gives off the least amount of negative gases of all the fossil fuels. Also, with the advances in efficiency, natural gas is definitely a viable source for the near future. Natural gas' limitation is the same as oil's. There is not enough to last us indefinitely. At some point, both oil and natural gas are going to run out. We must be able to look into the future, and prepare for that day. One option that we should investigate is nuclear power.

Nuclear power is a virtually untapped source of electricity. It does not give off any global warming gases, and the radiation leakage from plants is only a slight percentage of the background radiation. Recently, scientists have challenged the linear no-threshold hypothesis for the health effects of low level radiation (The President's Committee of Advisors on Science and Technology, 1997). There are only two major negative attributes for nuclear power. One is the economic burden, and the other is the nuclear waste problem. Now, we will discuss basic nuclear power.

Current Nuclear Power

Current operating reactors in the United States are fission reactors. Standard fission reactors fall into three categories: the breeder reactor, the boiling water reactor (BWR) and the pressurized water reactor (PWR).

The breeder reactor uses a different type of fission reaction than does the BWR and the PWR. The fuel in the breeder reactor is a combination of Plutonium-239 and Uranium-238. A neutron striking the Plutonium initiates the reaction. The result is two smaller atoms, two or three neutrons and energy in the form of heat. The heat is used to create steam that will be passed through turbines in order to generate electricity. The neutrons that are released will do one of two things. They can collide with other

Plutonium nuclei causing the reaction described above or they can be absorbed by the Uranium-238 and become Plutonium-239. Because Plutonium-239 does not occur naturally, it is convenient that it is can be made inside the reactor for which it is the fuel. The breeder reactor actually creates more Plutonium than it consumes. The amount of energy that is currently obtained from a given amount of Uranium in a breeder reactor is sixty times greater than the amount given from the same amount of Uranium in other types of standard fission reactor. The cooling system for the breeder reactor is much the same as the PWR, but the breeder uses liquid sodium to cool the core rather than water.

The BWR and PWR function in much the same manner, the difference coming in how they use the heat from the core to create the steam to run the turbines. In their cores there is a quantity of Uranium-235. The Uranium is a highly radioactive material and is the fuel for the reactor used to generate energy in the form of heat. Neutrons are introduced to the core to initiate the nuclear reaction. The neutrons collide with the Uranium-235 nuclei causing them to break down into two smaller atoms, two neutrons and give off energy in the form of heat. The smaller atoms are generally Krypton and Barium or Xenon and Strontium. The neutrons that are released collide with other Uranium-235 nuclei causing the same reaction as described above. The energy released as heat is used to convert water to steam, which is used to run turbines capable of generating electricity. The BWR controls the pressure inside the reactor vessel so that the cooling water boils as it is passing through. The reactor generates steam directly from the heat of the core. The PWR maintains high enough pressure to prevent the water from boiling even at extreme temperatures. The heated water from the core is pumped into a steam generator where the heat from the water is used to generate steam, but is never actually converted to steam itself.

During the fission reaction, the amount of neutrons in the core controls the speed of the reaction. When the reaction begins to proceed too fast, control rods are inserted into the core. These control rods are made of materials such as cadmium that absorb neutrons very efficiently (Serway, Moses & Moyer, 1997, 577). If the reaction slows too much, the rods are removed slightly, and if the reaction goes to fast, they are inserted slightly.

In a perfect world, this would be fine for controlling nuclear reactions and there would be no reason to worry about a nuclear disaster. Unfortunately, we live in a world where systems malfunction and parts break. If the system that maintained the control rods were to fail, the core could heat up out of control, resulting in an explosion or a core meltdown. For this reason, there are emergency back-up systems. Such systems flood the core in order to cool it down enough to cause the reaction to slow or stop. This presents the situation of defense in depth. If the control rods fail and the cooling system fails, what happens next? The water that is inside the reactor will begin to heat up. As the reaction continues, more and more neutrons will react with the uranium, which will give off more heat. This action, if left uncontrolled, would heat up to the point where the uranium would melt through the concrete floor of the plant, or "melt down". This is why the control systems are so essential. If one fails, there must be another that will take over. There could be five back-up systems for an emergency, but what if they all fail?

Inherently Safe Nuclear Power

There are reactor designs that make use of inherently safe concepts. They rely on passive systems, which work with the use of natural and dependable protection forces such as gravity, natural circulation, convection, evaporation and condensation. Some are described as "passively safe" or "inherently safe", meaning that they may not need active controls or operator intervention in case of an emergency (www.nuc.berkeley.edu, 1997). For example, some reactor designs control the flow of cooling water by use of gravity instead of pumps (www.nuc.berkeley.edu, 1997). Inherently safe nuclear reactors are more efficient than their defense in depth counterparts because they do not rely on active systems, such as pumps, motors or mechanical devices, to control a problem in the core.

An important question to ask concerning safety is, in the event of a total loss of the cooling system and/or a control failure, how much time do nuclear plant operators have to intervene or emergency systems to start up before the fuel core overheats and leaks dangerous amounts of radioactivity (www.nuc.berkeley.edu, 1997)? The time frames can range from 20 minutes to unlimited, depending on the reactor design (www.nuc.berkeley.edu, 1997).

Two Advanced Light Water Reactor designs that exist today are the AP600 introduced by Westinghouse and the Advanced Boiling Water Reactor by General Electric (D'Arruda, Harrington & Waterhouse, 1991). Both plants replace mechanical components such as pumps and valves with "passive" safety features like gravity and natural convection which rely on pressure, temperature, density, etc (Livingston, 1988, 152).

First, we shall discuss the Westinghouse AP600, and then the GE Advanced Boiling water reactor (Figure 2, pg. 27). These are two of the more accepted reactor designs. Then, we shall discuss one of the designs for the High Temperature Gas Cooled Reactor.

BWR CONCRETE CONTAINMENT

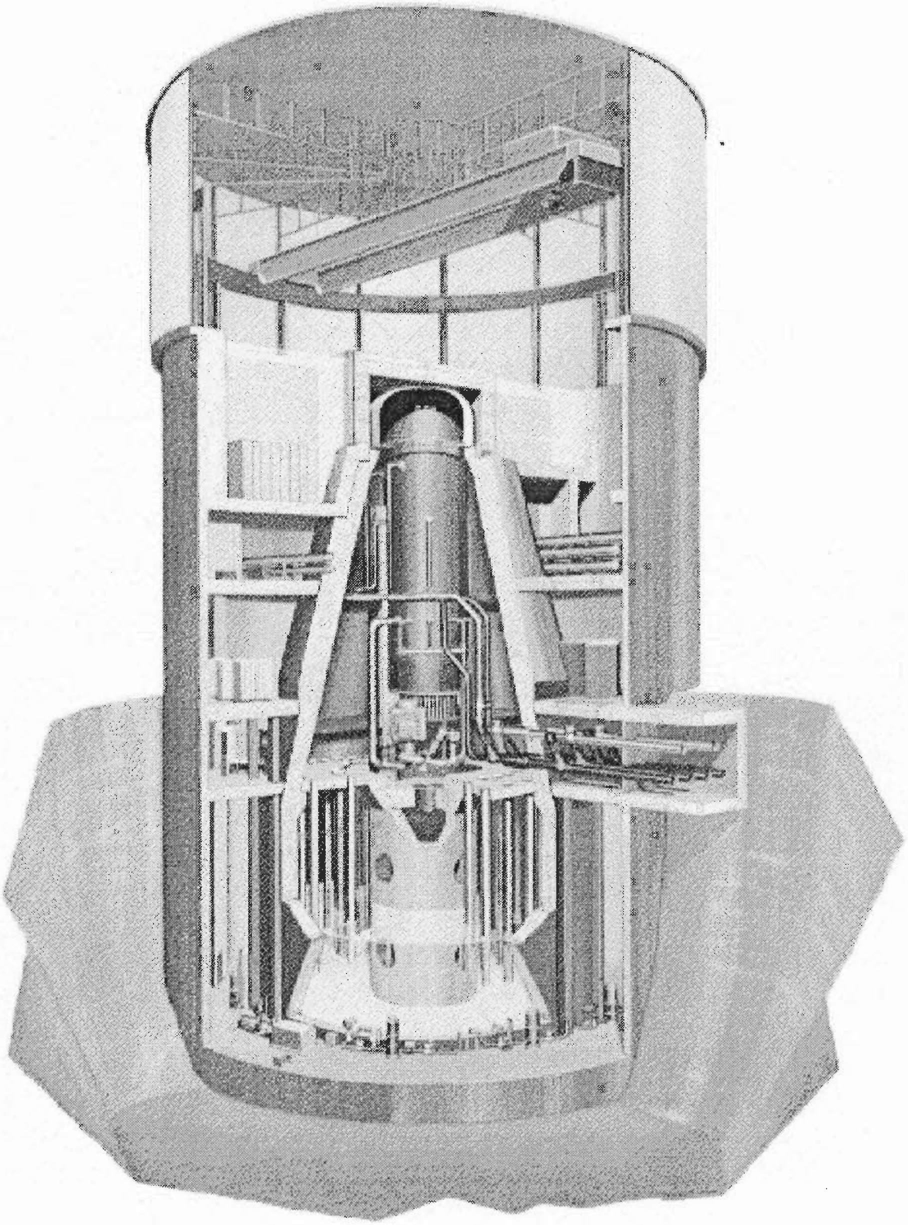

Figure 2.

Westinghouse AP600

The first reactor that we will investigate is the Westinghouse AP600 Advanced Pressurized Water Reactor (APR). The operation of a Pressurized Water Reactor (PWR) is rather straightforward. The core of the reactor contains Uranium pellets coated in zirconium alloy cans, which undergo fission (Jones, 1993, 45). Water is then pumped through the core of the reactor at an extremely high pressure. The pressure is kept so high so that the water may be heated to 600° F without boiling (`http://axil.whatswhat.com`, 1998). It then goes to the external heat exchanger. The water inside the heat exchanger is boiled, and the steam is fed into a generator system, where the actual electricity is generated.

The original safety system was the defense in depth system, which would have emergency coolant systems, and backups to those systems, and backups to the backups, and so on. This was very expensive, in maintenance and construction. "Westinghouse decided to use passive safety systems to enhance the overall safety of the AP600" (`http://www.ne.orst.edu`, 1996). The passive safety systems utilize gravity and convection to transfer coolant to the core during emergency conditions. The advanced safety system has many positive attributes over the defense in depth counterparts.

- 35% fewer pumps than a regular power plant.
- 50% fewer valves than a regular power plant.
- 70% less cabling than a regular power plant.
- 45% less seismic volume than a regular power plant.
- 80% less duct work than a regular power plant.
- 80% less piping than a regular power plant. (`http://www.ne.orst.edu`, 1996)

This makes the AP600 much easier to operate, fix, and maintain.

The advanced safety system of the AP600 can be broken down as follows.

- CMT's (Core Makeup Tanks)
- Accumulator tanks
- IRWST injection (Incontainment Refueling Water Storage Tank)
- DVI line (Direct Vessel Injection)
- Long Term Cooling via Sump Recirculation
- Passive Containment Cooling
- PRHR Heat Exchanger (Primary Residual Heat Removal)
- ADS (Automatic Depressurization System) (`http://www.ne.orst.edu`, 1996)

Each part will be examined, and described.

The first are the core makeup tanks. These are used to inject cool boronated water into the primary system of the reactor during an accident. CMT's are kept at the same pressure as the primary cooling system, and when an accident occurs, a valve on the CMT injection line opens to allow the boronated water to be gravity fed into the reactor core. The water enters the reactor vessel through the DVI line. The main advantages to the core makeup tanks are the fact that no high-pressure injection pumps are required, and the gravity fed system requires no power (`http://www.ne.orst.edu`, 1996).

The accumulator tanks are used in many systems. A small tank of boronated water is kept at a percentage of the system operating pressure (`http://www.ne.orst.edu`, 1996). This pressure is maintained with a bubble of nitrogen at the top of the tank (`http://www.ne.orst.edu`, 1996). A check valve is located along the injection line keeping primary water from entering the accumulator. The accumulator water is injected into the DVI line where it enters the reactor vessel. The accumulator is another component, which does not require power to activate. It also requires no operator intervention to be activated (`http://www.ne.orst.edu`, 1996).

The in containment refueling water storage tank is a water storage unit used during normal operation. It contains boronated water, which is used to cover the reactor vessel during the refueling process. During an accident, the IRWST is used in two different ways, as a heat exchanger, and also as another neutron absorber. A large heat exchanger within the tank provides residual heat removal during some normal operations and during a plant accident (`http://www.ne.orst.edu`, 1996). "After an accident has progressed for several hours, the pressure of the primary system becomes low enough for water to gravity feed into the primary through two injection lines teed into the DVI line"(`http://www.ne.orst.edu`, 1996). An important distinction between the AP600 reactor and other conventionally built reactors is the inclusion of the IRWST inside the containment section of the reactor. Other advantages are a large heat sink located within the containment, a large source of water for cooling over a substantial time and no high pressure injection pumps necessary for injection (`http://www.ne.orst.edu`, 1996).

Another source of long term cooling is the Sump Tank. "The reactor uses water accumulated in the sump below the reactor vessel during long term circulation" (`http://www.ne.orst.edu`, 1996). Long term circulation occurs very late in the accident. "After the IRWST has injected the majority of its water, the water level in the containment tank will be higher than the break in the system" (`http://www.ne.orst.edu`, 1996). The water will flow from the sump into the main reactor vessel, be warmed by cooling the core, and will flow out the break. The sump tank provides a recirculation-cooling path from the core to the bulk of the containment where the passive containment can take over. It also requires no electrical power for core cooling to continue.

The passive containment cooling system uses natural convection to cool the containment shell during an accident. Steam is produced, inside the containment shell, by the flashing of hot primary water (`http://www.ne.orst.edu`, 1996). Cool outside air passes over the outside of the containment absorbing the heat from the containment shell. "A large water tank, mounted on top of the containment, sprays water over the containment shell allowing heat in the containment to be absorbed into the water as well as the air" (`http://www.ne.orst.edu`, 1996). As heat is removed, condensed steam inside runs down the inside containment wall and back into the sump. This system allows heat from the containment to be removed to the environment without breaching containment (`http://www.ne.orst.edu`, 1996). The system also requires no operator intervention to activate, and needs no power to operate.

The Primary Residual Heat Remover (PRHR) Heat Exchanger has a very important function. "When a nuclear power plant shuts down the reactor by lowering the control rods, the fuel does not reduce power output to zero. Instead the power output slowly drops from about ten percent of full power down to less than one percent over the period of several hours" (`http://www.ne.orst.edu`, 1996). During this time, the heat needs to be removed from the system. The PRHR heat exchanger is used as a heat sink for the residual heat. The heat exchanger is located in the IRWST tank, where a large source of water can absorb several thousand BTU's (`http://www.ne.orst.edu`, 1996). The system is passive, and can run for several hours before the water in the IRWST reaches saturation temperature (`http://www.ne.orst.edu`, 1996). "The heat exchanger is hooked into the Automatic Depressurization System (ADS) and returns through the primary side of the steam generators" (http://www.ne.orst.edu, 1996).

The final "inherently safe" system in the AP600 is the Automatic Depressurization system. During an accident, it is difficult to inject boronated-cooling water into the reactor because the primary pressure is so high. This particular problem occurs most often during a small break. The AP600 uses its ADS system to bring down the pressure in a controlled, expedient manner. The ADS acts like a pressure cooker. When the pressure gets too high, a small valve releases the pressure, until it is brought down to a low enough point. "This allows the IRWST and the accumulator systems to inject the water sooner than would normally be possible. The AP600 performs this task by opening four valves on two trains at specific timed intervals after an accident has started" (http://www.ne.orst.edu, 1996). The steam is sent to the IRWST and the sump, to use them as heat sinks (http://www.ne.orst.edu, 1996).

General Electric Advanced Boiling Water Reactor

The Advanced Boiling Water Reactor (ABWR) developed by General Electric is one of the reactor designs that integrates passively safe technology to make the reactor construction much simpler. The entire reactor can be broken down into the following major parts:

- Reactor Pressure Vessel
- Fine Motion Control Rod Drives
- Digital Control and Instrumentation Systems
- Multiplexing and Fiber Optics
- Control Room Design

- Plant Layout
- Simplified Active Safety Systems (`http://www.nuc.berkeley.edu`, 1997)

These will each be discussed briefly.

First, we examine the reactor pressure vessel. This is the containment vessel for the core, where the actual fission will occur. One major problem previously was the fact that there were welds that would be under extreme pressure, and have a possibility of leaking. This has been almost eliminated, since much of this vessel, including the four vessel rings from the core beltline to the bottom head (Figure 3, pg. 34), is made from a single forging (`http://www.nuc.berkeley.edu`, 1997). Another positive aspect of this design is the nozzle in the vessel. "The vessel has no nozzles greater than 2 inches in diameter anywhere below the top of the core because the external recirculation loops have been eliminated. Because of these two features, over 50 percent of the welds and all of the pipings and pipe supports in the primary system have been eliminated and, along with it, the biggest source of occupational exposure in the BWR" (`http://www.nuc.berkeley.edu`, 1997). Since there are 50 percent fewer welds in the reactor pressure vessel, there are 50 percent fewer places for the possibility of the radiation leaking out through a crack, or hole.

The Fine Motion Control Rod Drive technology is being introduced for the first time in the General Electric Advanced Boiling Water Reactor. To control the fission in the reactor, the control rods are inserted, so that they may absorb the neutrons, which will slow the reaction. If it is possible to adjust more accurately the amount that the rods are inserted into the core, the more accurately the speed of the reaction can be adjusted. Currently, with the Locking Piston Drive, the control rods would be inserted in 3-inch increments. Now, with the Fine Motion Control Rod Drives, the rods are inserted in 0.75 inch increments, hence "Fine Motion" (`http://www.nuc.berkeley.edu`, 1997). During an accident,

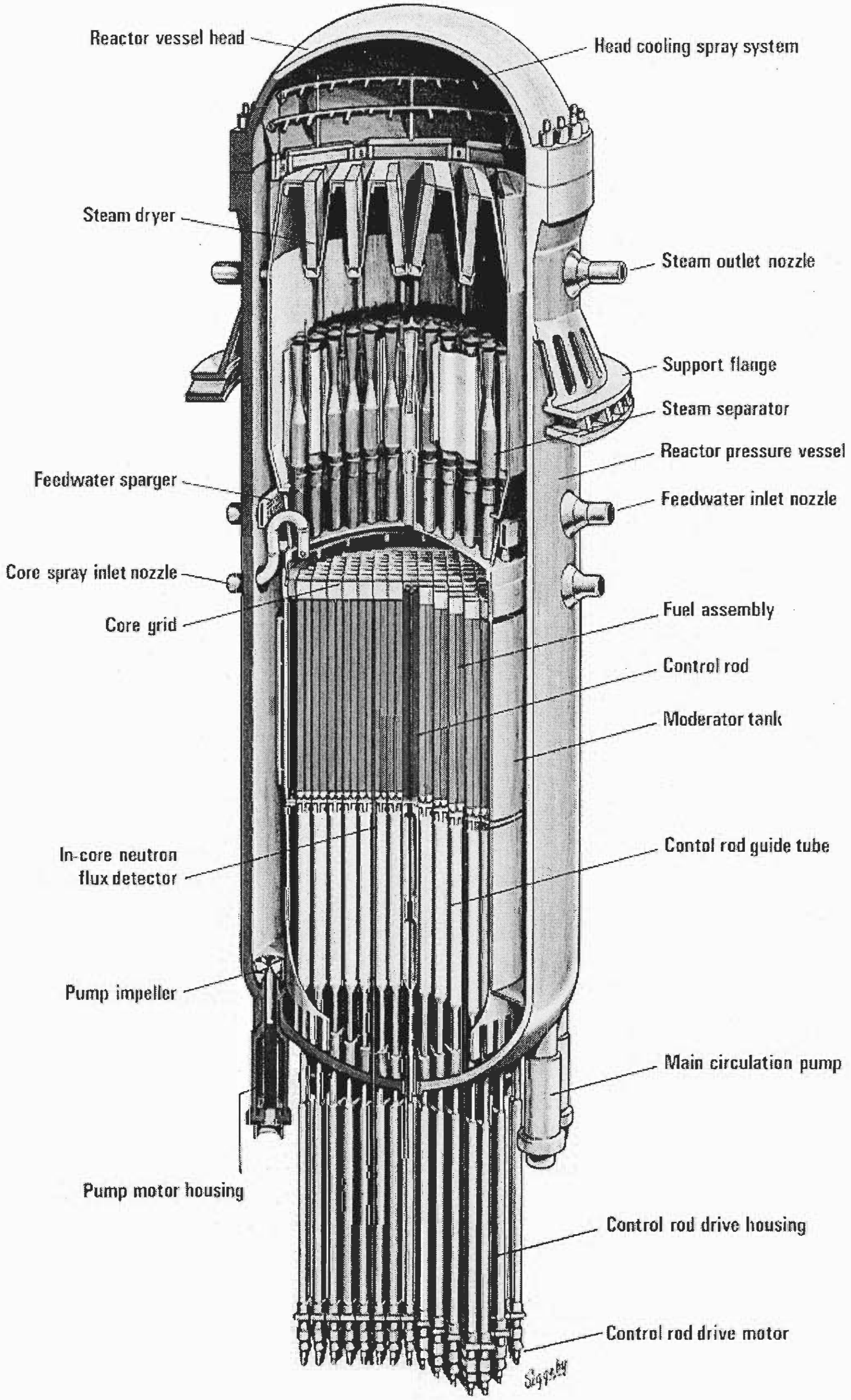
Reactor vessel head
Head cooling spray system
Steam dryer
Steam outlet nozzle
Support flange
Steam separator
Reactor pressure vessel
Feedwater sparger
Feedwater inlet nozzle
Core spray inlet nozzle
Core grid
Fuel assembly
Control rod
Moderator tank
In-core neutron flux detector
Contol rod guide tube
Pump impeller
Main circulation pump
Pump motor housing
Control rod drive housing
Control rod drive motor

Figure 3.

the control rods are "scrammed", or inserted hydraulically, completely into the core to stop the reaction, hydraulically, but can also be scrammed by an electric motor as a backup (`http://www.nuc.berkeley.edu`, 1997). The system is so reliable, that it isn't necessary to inspect all of them during the life of the plant. Therefore, only three drives will be removed for inspection during an outage, which is a huge savings of time, considering that with the Locking Piston Drives, 30 of them must be removed at every outage (`http://www.nuc.berkeley.edu`, 1997). Since the system is so much faster to inspect, the down time of the reactor is lessened, which causes a direct increase in energy production.

Another increase in reliability is caused by the changes in the control and instrumentation systems. "The ABWR has four separate divisions of safety system logic and control, including four separate, redundant multiplexing networks to provide absolute assurance of plant safety" (`http://www.nuc.berkeley.edu`, 1997). Multiplexing is the ability for 1 signal to carry two sets of information, by alternating between one and the other. This makes less wiring necessary, since each sensor need not be fed back to the control room independently, readings from 2 sensors can be sent back by 1 wire. Each system uses microprocessors to process incoming data transmissions from the sensors, and to generate outgoing control signals (`http://www.nuc.berkeley.edu`, 1997). In lay terms, the safety system and logic is separated into four different sections, completely independent of each other. Therefore, if there was a problem, and an explosion, or some other accident destroyed two of these control systems, the other two systems would be able to control all plant functions. These controllers are also "fault tolerant", meaning they continually generate simulated signals from the sensors, and compare the result with the expected outcome. If there is a problem found in one of the systems, it can be changed in minutes with a spare, without a chance of a reactor incident.

Another major advance in the General Electric ABWR is the communications between the sensors in the reactor core, and the control room. Using multiplexing, and fiber optics, the amount of cabling in the plant has been reduced dramatically. This simple change in construction will shorten the construction time by one month. In the grand scheme, it may not seem like much, but every little bit helps.

The design of the control room is very efficient, and easy to operate. The control room is broken down into three major sections. "In the center, the panels control the non-safety systems in the Nuclear Island. On the left, the panels control the safety systems, and the ones on the right control the balance of the plant" (`http://www.nuc.berkeley.edu`, 1997). Using CRT technology, the operator can call up any system or subsystem of the reactor simply by touching the screen. It is also possible to control the reactor with a system master command, which could essentially take control for short periods of time.

The ABWR is designed to meet the safety design specifications of almost all of the available nuclear sites in the world. The reactor and turbine units are "in-line", and none of the major facilities are shared with the other units (`http://www.nuc.berkeley.edu`, 1997). The containment of the reactor is a reinforced concrete containment vessel (RCCV) with a leak tight steel lining. The containment is surrounded by the reactor building, which acts as a secondary containment. A negative pressure is maintained in the reactor building, to direct any unplanned radioactive leaks to a gas treatment system (`http://www.nuc.berkeley.edu`, 1997). Construction of the plant makes use of large modules, which are fabricated in the factory, and assembled on sight. A crane lifts these modules, and places them vertically into the plant. Modular construction, along with the use of the reinforced concrete containment vessel, and other construction techniques will shorten construction times from 66 months, to 50 months. This is a very major decrease in time, which makes the plant more economical (`http://www.nuc.berkeley.edu`, 1997).

Another unique feature of the ABWR is the elimination of the external recirculation reactor cooling system. In most reactors, the water recirculation system is external from the body of the reactor. The external recirculation system has been replaced by ten internal pumps mounted to the bottom of the head of the reactor (`http://www.nuc.berkeley.edu`, 1997). For a physical description of the reactor, see figure 4. They are improved versions of pumps that have proven themselves in Europe. These pumps have been proven to be so reliable, only two of them need to be removed during an outage, which saves down time, and eventually, money (`http://www.nuc.berkeley.edu`, 1997). The motors are continually flushed with water, to keep debris from building up in them, so radiation levels around the pumps are drastically reduced (`http://www.nuc.berkeley.edu`, 1997).

The simplified active safety system of the ABWR is yet another positive aspect of plant design. There are four completely independent, completely redundant, safety systems (`http://www.nuc.berkeley.edu`, 1997). There are no cross connections between the redundant systems, which gives much more reliable results from a plant safety analysis. Each section has access to its own source of power, and its own diesel generator (`http://www.nuc.berkeley.edu`, 1997). All of the systems are completely separated, not only electronically, but also physically. A problem in one division, fire, flood, or loss of power, would have no effect on the other four divisions (`http://www.nuc.berkeley.edu`, 1997). Each system has its own high and low-pressure system, and each system has its own heat exchanger (`http://www.nuc.berkeley.edu`, 1997). This is a very dependable arrangement, since it would take four major catastrophic events in four different parts of the reactor to cause a problem. This is essentially a defense in depth version of the simplified active safety systems.

The Advanced Boiling Water Reactor is a very reliable, very dependable reactor design, which can be constructed in just over four years. This is a much-needed reduction from the current twelve-year construction time of standard Light Water Reactors. The added safety, and the shortened construction time, make this one of the more favorable construction designs, and it has been used in other parts of the world already, such as Sweden, and Japan

Modular High Temperature Gas Cooled Reactors

The Modular High Temperature Gas Cooled Reactor design (MHTGR) is considered one of the safest on the market today. Its safety stems from the following characteristics–

- An effective inert coolant, liquid helium
- The refractory coated fuel kernels are capable of withstanding high temperatures and pressures
- The crystal structure of the graphite core gives it stability at high temperatures
- The reactor has a strong negative power coefficient

(`http://www.nuc.berkeley.edu`, 1997)

These features provide great safety, because they do not depend on active engineered safety features, or human intervention for the safety of the public or protection of the reactor.

The coolant is one important characteristic that sets the MHTGR apart from other reactors. The Core geometry has been designed such that the decay heat in the core during a transient can be removed by means of convection, conduction, and radiation (`http://www.nuc.berkeley.edu`, 1997). The temperature is controlled, and kept at a level low enough to not harm the reactor, or the fuel, during a transient. This ensures that a core meltdown would be impossible, as the heat can never get high enough to cause problems.

The reactor internals have a very high heat capacity. The graphite fuel elements, and the reactor internals all maintain their strength at temperatures beyond 2760° C (5000° F) (`http://www.nuc.berkeley.edu`, 1997). Since the elements can withstand the great heat demand of the reactor, there is no chance that the core elements will fail due to excessive heat. The elements can not get hot enough to cause any problems. "This causes temperature changes in the reactor core to occur very slowly, and without damage to the core structure in the event of design based transients and accidents" (`http://www.nuc.berkeley.edu`, 1997).

The negative power coefficient is maintained over all times in the fuel cycle, for initial or equilibrium cores over a temperature range that includes accident temperatures (`http://www.nuc.berkeley.edu`, 1997). A negative power coefficient is the ability for a reaction to stop itself when it starts to run away. The reasons that cause other reactions to run out of control are the exact reasons that cause this reaction to stop itself. The more heat that is created, and neutrons that are emitted, the slower the reaction will go. This ensures inherent core feedback characteristics to control heat generation. The power coefficient is negative over all temperatures, which means if the reactor is to have an accident, there would be no run away reaction, because of the negative power coefficient. As time goes on, the reaction will decrease, and eventually stop, without any outside intervention. This makes the reactor completely safe, with no chance of meltdown.

The MHTGR plant is made up of four identical modular reactor units located in a single reactor building (http://www.nuc.berkeley.edu, 1997). The plant is divided into two major areas, the Nuclear Island, containing the four reactor modules, and an Energy Conversion Area, containing two turbine generators (http://www.nuc.berkeley.edu, 1997). Each of the four modules produces 350 MW(t) (http://www.nuc.berkeley.edu, 1997). All modules feed into the two 300 MW(e) turbines, operating in parallel (http://www.nuc.berkeley.edu, 1997).

The MHTGR utilizes a once-through fuel cycle. This means that it doesn't rely on recycling of spent fuel. "Refueling is accomplished with the reactor shutdown and depressurized, utilizing a refueling machine accessing the fuel elements through the appropriate control rod penetrations in the top of the reactor vessel" (http://www.nuc.berkeley.edu, 1997). Once the reactor has been refueled, the spent fuel is sent to a storage pool, where it is held temporarily, until shipping to final storage offsite.

"No public evacuation or sheltering is required for licensing basis events or for severe, low probability accidents, because the consequences are accommodated by the inherent and passive features of the MHTGR" (http://www.nuc.berkeley.edu, 1997).

There is no need for an evacuation procedure, which is evidence of the safety of the reactor. The safety is achieved through the passive safety features of the reactor. This proves that passively safe reactors are, as their name implies, safe.

Political Background

The Nuclear Subgovernment

A subgovernment can be defined as a small group of actors who dominate the development of policy in a given field (Duffy, 1997, p.3). The group of actors is generally comprised of interest groups, congressional committees and bureaucratic agencies. Policymaking within the groups is consensual, with bargaining producing agreements among the involved parties (Duffy, 1997, p.65). Each of the actors has something beneficial to offer the other. The interest groups give votes to members of influential congressional committees in exchange for programs favorable to their cause. The congressional committees give authorization to interpret laws and funding to bureaucratic agencies and the agencies return the favor by interpreting the rules favorably to those people on the congressional committee. The interest groups pressure the politicians who are in charge of handing out funds to the bureaucratic agencies and in exchange the bureaucratic agencies interpret policy favorably to the interest groups. While the even exchange of services binds together the three actors in a subgovernment, there are other factors that support the existence of a subgovernment.

The original members of the nuclear power subgovernment were the Joint Committee on Atomic Energy (JAEC), the Atomic Energy Commission (AEC), a General Advisory Committee, and a large number of contractors hired by the government (Duffy, 1997, p.1). The nuclear power subgovernment was able to distance itself from the public eye, thus allowing the subgovernment to create policy without unwanted outside influences. For example, the nuclear subgovernment contended that because it dealt with a matter of national security, only a few actors would be given detailed knowledge of the program (Duffy, 1997, p.21). The issue may be one that is highly complex in nature further reducing the number of actors (Duffy, 1997, p.21). Those members of a subgovernment can limit the available information concerning the issues that they deal with and filter out the people that see the information.

By limiting available information, a subgovernment eliminates the points of conflict surrounding the policies that a subgovernment writes. One example of the subgovernment's ability to control information flow involved Chet Holifield, chairman of the JCAE. He recognized the need for action concerning thermal pollution and he introduced legislation that would give the AEC authority to regulate thermal discharges (Duffy, 1997, p.57). Because the AEC was so opposed to the measure, it was never reported out of the JCAE (Duffy, 1997, p.57). James Q. Wilson (1989) has argued that agencies frequently resist taking on new tasks if they are seen as incompatible with the agency's own conception of its mission.

Subgovernments do not choose members; rather, they form as a result of people with a common goal coming together. Madison envisioned this in Federalist #10 writing, "...a number of citizens, whether amounting to a majority or a minority of the whole, who are united and actuated by some common impulse of passion, or of interest." In the case of the nuclear subgovernment, the members all had something to gain by a successful nuclear program (Duffy, 1997, p.21).

The Evolution of Factions

The evolution of factions will result in multiple points of conflict. Multiple points of conflict seem to be a necessary evil of American democratic government, in that, they slow the political process. The evolution of factions is important because they prevent the political process from making quick decisions, which could be detrimental in the long run. The existence of multiple points of conflict is also important because a more thorough examination of an issue can be done (Duffy, 1997, pp.12-14). However a subgovernment wishes to eliminate multiple points of conflict, thus accelerating the rate of progress surrounding an issue, by excluding opposing factions.

As a response to increased criticism, the AEC changed its rules concerning the format of its licensing hearings to allow anyone who wished to speak, a chance to speak (Duffy, 1997, pp.72-76). These rule changes came towards the end of the nuclear subgovernment's policy dominance (Duffy, 1997, pp.72-76).

Certain actions are detrimental to the continued operation of subgovernment. In his study on iron triangles, J. Leiper Freeman (1955) notes that issues escalate out of the subsystem and into the larger political settings in several situations. One of those situations is when the issue assumes considerable and increasing relevance for a large segment of the public, as the environment did in the 1960s. Freeman adds that when this escalation occurs, "'little policy' can grow into 'big policy' and move from subsystem toward system," which began to happen to nuclear power in the 1960s.

A subsystem also relies on uniformity of opinion (Duffy, 1997, pp.3-5). As far as those outside the subsystem could tell, there was unanimous agreement among the experts on nuclear power (Duffy, 1997, p.64). When there is dissention among the subsystem members the subgovernment can break down. The nuclear power subgovernment was a special case because it dealt with an issue that was of a highly technical nature. Nelkin and Pollack (1981) argued that the legitimacy of the nuclear subgovernment was sustained by its expertise, and when the experts began to disagree, its legitimacy suffered.

The political system that is currently in place more closely resembles Madison's vision of a multi-layered system with multiple points of conflict on each issue. Today, factions are referred to as interest groups and there are thousands of interest groups. There is an overwhelming amount of available information making the task of a single interest group daunting. The Washington offices of interest groups generally consist of only a handful of people that represent only one interest group in a town that has thousands (Berry, 1984, p.8). With so much available information and so many interest groups, it is difficult to imagine how anything is accomplished.

The Formation of Issue Networks

One strategy interest groups use is the formation of issue networks. Hugh Heclo (1989) defines issue networks as "a shared-knowledge group that ties together large numbers of participants with common technical expertise". Issue networks are not different from subgovernments in their membership. Lobbyists, legislators, legislative aides and agency administrations make up the vast majority of participants. The key difference between the issue network and the subgovernment is their size and accessibility to new members (Berry, 1984, p.25). The issue network more closely resembles Madison's vision of multiple points of conflict than does the subgovernment because the issue network is more easily accessible to new members (Berry, 1984, p.27). Issue networks have come to replace many policy subgovernments (Baumgartner & Jones, 1993, pp.61-82). In the case of nuclear power certain circumstances that will be discussed later surrounded the downfall of the subgovernment and eventual rise of the issue network.

The proliferation of interest groups is the most important source of change affecting policy making communities (Berry, 1984, p.33). As new groups form and demand to be heard, subgovernments are not able to separate themselves from those who want to be included in the policy making process (Berry, 1984, p33).

The rise of an issue network and subsequent fall of a particular subgovernment is important to understand because this is what happened to the nuclear power industry in the late 1960s and early 1970s (Duffy, 1997, pp.18-19).

Changing Perceptions of Nuclear Power

Baumgartner and Jones (1993) claim that new understandings of policy issues attract the attention of new actors and thus contribute to the destruction of policy monopolies. Duffy contends that the atomic subgovernment lost influence because commercial nuclear power came to be understood in new, less positive ways. In the late 1960's nuclear power came to be seen in the context of debates over environmental protection, public health and safety (Duffy, 1997, p.69). The issue of nuclear power escalated into a debate about government regulation of business, citizen participation, and democratic governance (Duffy, 1997, p.49). The subgovernment members lost the ability to define the issue and control the debate over nuclear power as a result of the changing perceptions (Duffy, 1997, p.49).

"As understandings and perceptions shifted and became increasingly negative, new actors were drawn to the nuclear issue" (Duffy, 1997, p.49). The new participants included federal agencies, state and local officials, and some prominent interest groups, many of which were critical of nuclear power. The influx of new participants who carried with them their own opinions shattered the consensus that had existed within the small nuclear subgovernment. "The mobilization of previously uninvolved interests disrupted the traditional patterns of policy making within the subsystem"(Pika, 1983, 304). When the perceptions of the costs and benefits of the nuclear program changed, so did the politics of nuclear power (Duffy, 1997, pp.51-54).

Part of the reason why perceptions changed was that information about nuclear power became more widely available (Duffy, 1997, p.50). "The autonomy of policy monopolies is a factor of their ability to control information about their particular programs" (Duffy, 1997, p.50). Subgovernments are typically small and actors have complementary goals, so it stands to reason that the introduction of new actors and new opinions would threaten this consensus (Duffy, 1997, p.50). Subgovernment members had kept a tight lid on program information for twenty years (Duffy, 1997, p.50).

As the nuclear industry entered its commercial phase during the 1960s, it became difficult to maintain control of program information (Duffy, 1997, p.50). With the increase in the number of reactors being licensed and built, more people became concerned about nuclear power and some even felt that nuclear power could harm them (Duffy, 1997, pp.51-54). When enough information becomes public, perceptions of an issue may change, redefining it in the process, which is what happened in the case of nuclear power (Duffy, 1997, pp.50-51). There was an increase in the amount of information about nuclear power and a dramatic change in the nature of that information (Duffy, 1997, pp.50-51).

The Environment

The boom in the market for nuclear power plants coincided with the rise of the environment as an issue of national importance (Duffy, 1997, p.54). While concern for the environment was not unique to the 1960s, there was widespread attention given to the issue by citizens, the press, and public officials (Duffy, 1997, p.54). "During the 1960s more people recognized that human activities had environmental consequences, many of which were harmful to human health and safety" (Duffy, 1997, p.54).

The increasing concern with environmental issues was perceived by the nuclear subgovernment members as a hindrance to the prospects of nuclear power. The AEC and the nations utilities actively promoted the notion that nuclear power was cleaner than coal and other sources of electricity (Duffy, 1997, pp.54-55). "In fact, utilities often cited nuclear power's projected environmental superiority as one of the key factors in their decision to build nuclear plants" (Duffy, 1997, p.92). The early opposition to nuclear power was essentially local, being directed at particular reactors and not at nuclear power itself. The opposition focused on the thermal pollution caused by nuclear plants' discharge of heated water into nearby lakes and rivers (Duffy, 1997, p.55). The emergence of the thermal pollution issue resulted in outright opposition from some people who were previously ambivalent towards nuclear power. More importantly, though, the AEC's inept handling of the issue helped undermine its credibility with Congress and the American public (Duffy, 1997, p.40).

Fishermen, biologists, several government agencies, and state and local governments began to take interest in the problem of thermal pollution after several fish kills were attributed to thermal pollution between the years 1962-67 (Duffy, 1997, p.55). One agency that took particular interest in thermal pollution was the Department of the Interior's Fish and Wildlife Service (FWS). "Although the FWS recognized that thermal pollution was a problem, it lacked statutory jurisdiction over thermal pollution" (Duffy, 1997, p.54). The AEC insisted that it too lacked the statutory authority to regulate the nonradiological effects of nuclear power, including the environmental effects of thermal discharges (Duffy, 1997, p.55).

“The commission's refusal to consider the environmental effects of thermal pollution can be attributed to its well developed sense of mission” (Duffy, 1997, p.55). Wilson has argued, agencies frequently resist taking on new tasks if they are seen as incompatible with the agency's own conception of its mission (Wilson, 1989, 101). The AEC did not believe environmental concerns were part of its mandate; rather, the AEC believed its primary goal was to encourage the development and use of nuclear power (Duffy, 1997, p.55). "To the extent that consideration of the environmental effects of nuclear reactors detracted from that goal, the AEC had little incentive to take them into account” (Duffy, 1997, p.55).

The FWS labored to convince the AEC to assume responsibility for thermal pollution at nuclear plants, but the commission continued to claim that it lacked statutory authority over nonradiological environmental matters (Duffy, 1997, p.56). In 1966 the dispute erupted publicly in a disagreement over an application for a construction permit for the Millstone Nuclear Power Station in Connecticut (Duffy, 1997, p.56). The FWS notified the AEC that the service would no longer accept the commission's denial of jurisdiction and asked for a Justice Department review of the matter (Duffy, 1997, p.56). "After an internal review of its legal position at the behest of the joint committee, the AEC reaffirmed its stance” (Duffy, 1997, p.56).

As this dispute continued, public and congressional concern grew. By 1967, thermal pollution became an issue in almost every contested licensing proceeding (Duffy, 1997, p.56). One such case involved the application for a construction permit for the Vermont Yankee Nuclear Power Corporation. The power corporation proposed a "once-through cooling" system, in which the water that had been diverted from the Connecticut River would be used to cool the steam in the condenser and then returned to the river (Duffy, 1997, pp.56-57). Some local citizens, along with the Vermont Department of Fish and Game, the state's attorney general, and the neighboring states of New Hampshire and Massachusetts, intervened in the construction permit proceeding, arguing that the proposed discharge of water into the river would raise the water temperature to the extent that irreparable damage would be done to fish and plant life (Duffy, 1997, p.57). The opposition demanded that the utility redesign the reactor to reduce the consequences of the thermal discharge (Duffy, 1997, p.57).

Meanwhile, members of both houses of Congress had seized upon the thermal pollution issue (Duffy, 1997, p.57). In 1966, for example, Representative John Dingell held widely publicized hearings in which he accused the AEC of providing "grossly inadequate protection" for fish and wildlife (Duffy, 1997, p.57). The controversy over the Vermont Yankee plant attracted the attention of Senator Edmund Muskie, who contended that the Water Pollution Control Act 1965 required all federal agencies to take steps to reduce water pollution from any of their actions (Duffy, 1997, p.57).

In December of 1967, the AEC licensing board dismissed the intervention and issued the construction permit for the Vermont Yankee plant. The AEC contended that under the Atomic Energy Act the commission had no authority to consider nonradiological issues. The opposition appealed the ruling to the commissioners, who sided with the licensing board. The state of New Hampshire then filed an appeal in federal court, which upheld the AEC's decision in January 1969, noting that they had the "utmost sympathy with the opposition's argument."

Although the AEC had been vindicated in court, the thermal pollution controversy got worse (Duffy, 1997, p.58). One week after the court announced it decision, Sports Illustrated ran an article that was highly critical of the AEC's handling of the thermal pollution issue. According to Walker, the article "clearly broadened and called attention to the thermal pollution controversy more than any previous discussion had done" (Boyle, 1969). More and more, the AEC was perceived as an agency that was ignoring its environmental responsibilities.

"Although the furor over thermal pollution eventually died down, the controversy fundamentally altered the course of nuclear politics" (Duffy, 1997, p.58). It was the first step in redefining the issue of nuclear power; nuclear power was increasingly understood as an environmental issue, not a national security matter (Duffy, 1997, pp.58-59). When nuclear power was perceived as a national security issue, it was naturally seen as a responsibility of the federal government, but as an environmental issue, state, county, and local governments could claim jurisdiction through their powers to regulate land use. Over the next two decades state and local agencies played a larger role in nuclear policy.

The Radiation Controversy

Another issue that attracted considerable attention from new actors involved radioactive emissions from nuclear power plants. The AEC would soon find itself surrounded in controversy over this issue as it was with the thermal pollution problem. With the case of thermal pollution the AEC denied that it had jurisdiction, but in the case of radiation the AEC argued that it had exclusive jurisdiction. "The seeds of controversy were sown in 1965 when Congress adopted the Water Quality Act, which required states to establish their own water quality standards" (Duffy, 1997, p.59).

The AEC had established regulations for radioactive emissions in the air and water, but some states, concerned about the possible long-term effects of radiation, wanted to impose more stringent emissions standards than the AEC. For example, the state of Minnesota announced that a reactor being built by the Northern States Power Company would have to emit much lower levels of radiation than the AEC allowed. The AEC balked even though the technology existed to control releases at much lower levels. The AEC argued that the states did not have the authority to regulate the radioactive emissions. When Minnesota issued the new standards in 1969, the utility filed suit. The case eventually was decided by the Supreme Court, who found in favor of the utility and the AEC (Duffy, 1997, pp.59-60). As was the victory in Vermont, this was an empty victory for the AEC (Duffy, 1997, p.59). "In resisting efforts to allow states to adopt more stringent standards, the AEC had painted itself into a familiar corner and was once more on the defensive" (Duffy, 1997, p.60).

"The emerging radiation controversy only fueled suspicions that the AEC was being less than honest with the public" (Duffy, 1997, p.60). Dr. Ernest Sternglass drew a connection between reactors and weapons fallout that would have an enormous impact on the public's perception of nuclear reactors (Duffy, 1997, p.60). In 1968 Sternglass, a professor of radiation physics, claimed that there was a strong correlation between fallout and infant mortality rates; later arguing that there was a similar correlation between infant mortality rates and emissions from nuclear power plants (Duffy, 1997, p.60). In an attempt to rebut Sternglass, the AEC asked John Gofman and Arthur Tamplin to study the issue. Unfortunately for the AEC, Gofman and Tamplin (1971) concluded that the AEC's existing standards were indeed seriously inadequate (Duffy, 1997, p.60). The AEC rejected the arguments of Gofman and Tamplin and set out to discredit them (Duffy, 1997, p.60). But the damage had already been done (Duffy, 1997, p.60). Gofman and Tamplin (1971) presented their conclusions to the JCAE and to Senator Muskie's Subcommittee on Air and Water Pollution. The responsibility for regulating radioactive emissions was eventually transferred to the newly created Environmental Protection Agency (EPA). The EPA then lowered the allowable exposure levels from 170 millirems per year to 25 (Duffy, 1997, p.60).

In the controversy over radiation the AEC again appeared to be reluctant to take action that would harm the nuclear power industry, even in the face of signs that public health and safety might be endangered (Duffy, 1997, p.61).

Safety Concerns

"The emergence of the environment as a national issue certainly played a key role in creating a debate over nuclear power, but the most significant factor in the expansion of that debate and in the demise of the atomic subgovernment was the development of reactor safety as a prominent issue" (Duffy, 1997, p.61). Nealey, Melber, and Rankin (1983) note that "even before the accident at Three Mile Island, public opinion surveys showed that when asked about nuclear power, the American public mentioned safety as their biggest concern". This response reflects the fact that at some point the dominant understanding of the nuclear power issue had changed and nuclear power was now a public safety issue.

The safety issue arose in much the same manner as the environmental issue had: as a reaction by local citizens to particular reactors and then expanding to include questions about the safety of nuclear plants in general. Concerns over the safety of nuclear reactors attracted more attention and generated more controversy than the environmental issues because of the characteristics of nuclear technology, which were relatively new and unfamiliar to the American public (Duffy, 1997, pp.61-62). "At a time when the nuclear sector was rapidly expanding, fears of reactors releasing invisible clouds of radiation to the atmosphere were very real" (Duffy, 1997, p.62). The fear of radiation was the opposition's most effective means for attracting attention to the nuclear issue (Duffy, 1997, p.62). The knowledge that radiation could contaminate large areas enabled opponents to argue that the nuclear issue was not merely a local concern (Duffy, 1997, p.62). Thus, when questions of reactor safety arose, the dramatic nature of the consequences of reactor accidents lent the nuclear issue a sense of drama and urgency that concerns about thermal pollution could not (Duffy, 1997, p.62). Because the nuclear issue was so dramatic it gained the attention of the national media and shortly thereafter, the conflict over reactor safety occupied a prominent position on the public agenda (Duffy, 1997, p.62).

The debate concerning reactor safety began in July 1971 when the Union of Concerned Scientists (UCS), held a press conference at which they issued a report detailing the potential consequences of emergency core-cooling system (ECCS) failure (Duffy, 1997, p.62). The report was based on information leaked to the UCS by AEC staff members at Oak Ridge National Laboratory and it contained information that showed AEC regulations surrounding ECCS operation were inadequate. The conference, which was carried by two of the three television networks as well as many newspapers, caused a "sensation" (Primack & Von Hippel, 1974, 214). News stories outlining shortcomings in reactor design, construction and operation became prevalent, as well as stories charging the AEC with regulatory neglect (Duffy, 1997, pp.62-63). The AEC decided to hold public hearings in an attempt to counter the charges that the AEC had something to hide or had been "covering up" reports detrimental to the development of nuclear power (Duffy, 1997, p.63).

During the first month of the ECCS hearings, the opposition revealed considerable disagreements on the importance of some technical issues among researchers at the AEC's national laboratories, the AEC's reactor safety staff, and the commissioners (Duffy, 1997, p.63). The agency had worked hard to create the impression that there was widespread agreement on the adequacy of the ECCS's, but Gillette writes, "the ECCS hearings uncovered a welter of dissent inside the AEC regarding the agency's handling of emergency core-cooling research" (Gillette, 1972, pp.918-919). It was, in fact, the AEC's efforts to suppress the dissent that led scientists and engineers to communicate their concerns to members of the Union of Concerned Scientists (Ford, 1982).

The ECCS hearings revealed serious disagreements between researchers at the national laboratories and the AEC. "Part of the disagreement was undoubtedly the result of the researchers' unhappiness with the more stringent oversight placed on their work by Milton Shaw, head of the AEC's research and development program" (Duffy, 1997, p.63). Under Shaw, the research program emphasized applied research and engineering, which did not appeal to the more theoretical scientists at the national laboratories (Duffy, 1997, p.63). Some of the researchers, particularly those at Oak Ridge, believed that the AEC was going too fast in its efforts to develop nuclear power and was failing to address some tough safety questions because the AEC did not want to impose costly safety requirements on the nuclear industry (Gillette, 1972, 918-919).

The conflict over nuclear power escalated once scientists began to disagree publicly (Duffy, 1997, p.65). Because nuclear power was a technical issue that was understood only by experts, these experts should have a greater say in what goes on. Until the early 1970s all of the experts were in agreement, so there was no room for conflict. Now the experts were arguing amongst themselves, leaving an immense amount of room for conflict (Duffy, 1997, p.65). The UCS played the key role, but other groups such as the Scientists' Institute for Public Information (SIPI), the Federation of American Scientists, Common Cause, Critical Mass, and the Nader-affiliated Public Interest Research Group also raised questions about reactor safety. For the past twenty years scientists had only good things to say about nuclear power, now the news reaching the general public suddenly shifted. Now, scientists could not determine if nuclear reactors were really safe. As Steven Del Sesto (1979) claims, "Nothing serves to escalate the conflict and debate among the public than a scientific and technical debate among the experts; for if the experts can't agree, how can the public decide"?

Baumgartner and Jones (1993) have argued that consensual communities can foster a positive policy image and insulate themselves from outside interference, but communities split by internal conflict are more likely to be subjected to broad political debates. The debate over reactor safety has resulted in nuclear power being subjected to broad political debates (Duffy, 1997, pp.65-69).

The Opposition Takes Action

Venue changes involving the courts provided antinuclear activists with an important wedge to crack open the nuclear subgovernment's policy monopoly (Duffy, 1997, pp.81-83). "Judicial action was predicated on the perception that many regulatory agencies had been insufficiently aggressive in carrying out their statutory responsibilities" (Stewart, 1975, 1669-1803). Judges imposed numerous procedural reforms designed to encourage agency administrators to be more responsive to nonbusiness interests (Duffy, 1997, p.83). These reforms increased citizen access to administrative files and proceedings, which had the benefit of providing more effective oversight of agency decision making (Duffy, 1997, p.83). At the same time, the federal courts were imposing strict procedural mandates on administrative agencies, requiring them to conduct their licensing and rulemaking proceedings with greater formality (Duffy, 1997, p.83). The courts also required agencies involved in rulemaking to seek additional information before making decisions, to allow all interested parties to examine information and data (Duffy, 1997, p.83). The courts also encouraged agencies to grant broad hearing rights, which were seen as a means for the public to have an effective voice in decision making (Duffy, 1997, p.83). By the middle of the 1970s, the new procedural arrangements had created a more open policy-making arena (Duffy, 1997, p.83).

The Courts

For most of the late 1960s and early 1970s, groups seeking to participate in the formulation of nuclear policy were denied access by both the AEC and JCAE (Duffy, 1997, p.84). Critics of nuclear power turned to the courts for assistance. Schattschneider (1960) argued, "that it is the losers in any political dispute that seek to expand the conflict by shifting it into a different arena." Litigation was a favorable strategy because it allowed reformers to expand the conflict without using too many of their scarce resources (Duffy, 1997, p.84). Reformers also believed judges would be more receptive to the concerns of critics than the more scientifically and technologically oriented AEC had been (Duffy, 1997, p.84). Finally, antinuclear forces believed litigation would allow them to frame the legal issue and pick a more sympathetic decision-making forum (Duffy, 1997, p.84).

"On 23 July 1971 the Court of Appeals for the D.C. Circuit issued the single most important decision in the history of the atomic energy program (Duffy, 1997, p.88). In its decision the D.C. Circuit told the AEC that it could no longer engage in narrow, incremental decision making, and that it must consider the environmental consequences of its actions at all stages of its licensing review process (Duffy, 1997, p.88).

The *Calvert Cliffs* decision actually involved two separate cases that had been consolidated for argument by the D.C. Circuit. The Calvert Cliffs Coordinating Committee, a group of local environmentalists, joined by the Sierra Club and the National Wildlife Federation claimed that certain aspects of the AEC's environmental regulations violated the National Environmental Policy Act (NEPA) (Duffy, 1997, pp.88-93). Judge Skelly Wright agreed with the environmental groups and ordered the AEC to make fundamental changes in its licensing process (Duffy, 1997, p.90). According to the court, the AEC would have to conduct detailed environmental reviews for all nuclear plants licensed after 1 January 1970 and the commission would have to consider the environmental consequences of its actions at all stages of the licensing process (Duffy, 1997, pp.90-91).

Concerning the Natural Resources Defense Council v. Nrc: on 21 July 1976, the D.C. Circuit again served notice that it would closely monitor the NRC's decision-making procedures to ensure that it was fulfilling its statutory mandates under NEPA and the Atomic Energy Act (Duffy, 1997, p.94). The court stressed that agencies were to consider a broad range of views when contemplating any significant actions, hoping that forcing agencies to produce a detailed record of their actions would not only make agencies more accountable but would result in better decisions (Duffy, 1997, p.95). The court also emphasized the NRC's obligation to adhere to the standards of due process during licensing and rulemaking proceedings (Duffy, 1997, p.95).

These court decisions lead to an increase in oversight concerning nuclear policy making. "One of the most significant consequences of increased oversight by the courts was that the commission, and its staff, devoted greater attention to procedural rights in an attempt to ensure that its procedures were seen as fair and capable of generating a record that could withstand judicial scrutiny" (Duffy, 1997, p.96). The NRC did not want to risk having their decisions overturned by a reviewing court, so they tried to show that it had solicited and considered many points of view (Duffy, 1997, pp.96-97). The NRC revised its rules to allow greater public input into its decision-making process (Duffy, 1997, p.97). The NRC adopted a new rule in 1977 that allowed parties in contested licensing proceedings to petition the commission for discretionary review of Atomic Safety and Licensing Appeal Board (ASLAB) decisions (Duffy, 1997, p.97). The new rules allowed parties to petition for a stay of all ASLAB decisions or actions pending commission reviews (Duffy, 1997, p.97). Some observers believed that, "the changes were more show than substance and were actually designed to extend procedural due process to the public while not in any way changing the basic structure of the hearings to permit citizen group input to play an important role in the decision-making process" (Ebbin & Smith, 1974, 143).

A second result of increased judicial oversight was a longer and more detailed review process that led to more stringent environmental and safety standards (Duffy, 1997, p.97). The NRC believed that the courts were more likely to overturn their decisions if the commission's decision-making process was procedurally deficient (Duffy, 1997, p.97). As a result, the commission standardized its licensing review process in 1972 (Duffy, 1997, p.98).

These changes were not merely the result of antinuclear groups demanding access to previously inaccessible forums (Duffy, 1997, p.98). During the 1960s and 1970s, the federal courts had become similarly involved in a number of other policy areas dominated by subgovernments (Duffy, 1997, pp.98-99). The fall of many of these policy monopolies, including the atomic subgovernment, suggest that policy communities are not immune to broad social and political trends (Duffy, 1997, p.99).

The Economic Impact of Political Change on The Nuclear Industry

Increased Construction Costs

In the 1960s an average size nuclear plant, 550-850 megawatts, cost $200 million and American utility companies regarded nuclear power as the cheapest energy source (Kaku & Trainer, 1982). Reactor sales continued to grow in the early 1970s, but from 1978-1982 no orders were placed with manufacturers and 44 plants were canceled (Kaku & Trainer, 1982). One reason for the lack of new plants was the soaring construction costs (Kaku & Trainer, 1982).

What is the cause of the increased construction costs? "The utility companies and manufacturers believe that delays brought about by the regulatory environment, specifically the NRC, have caused the industry's misfortunes" (Kaku & Trainer, 1982). The duration for building and opening a plant is eleven to twelve years: four years to obtain local site approval and a federal construction permit and six or seven years to build the plant (Kaku & Trainer, 1982). The nuclear industry also has to deal with costly and time-consuming court interventions during the licensing period (Kaku & Trainer, 1982). "As a rule one year's delay at the construction site adds approximately $100 million to the cost of the reactor" (Kaku & Trainer, 1982).

Another source of costs for the nuclear industry lies in the operation of the plant. Some economists point out that nuclear power plants operate less safely than the industry predicted, which costs money (Kaku & Trainer, 1982). For example, the tubes in the steam generators of the two units at Florida Power and Light became corroded from salt water. Each unit cost an estimated $51 million to repair in addition to the $800,000 a day that was spent on substitute fuels that were bought elsewhere while the reactor was down (Kaku & Trainer, 1982).

The increase in cost of a nuclear reactor paralleled sweeping changes in nuclear power policy. This can be seen in the timing of the changes. It was at the end of the 1970s and into the 1980s that the AEC and JCAE were abolished and replaced by the NRC. Also in the 1970s there were many laws that were passed that spread out jurisdiction over matters that applied to nuclear power. At the same time towards the end of the 1970s orders for nuclear reactors ceased because of increasing costs. Thus, it can be seen that the changes that took place in the 1970s impacted the nuclear industry in a negative manner. The impact was economical and it is based on economics that the utilities determine whether or not they will build a nuclear reactor.

Factors that led to the increased costs

The high costs of building a nuclear reactor that make it an unfavorable means to generate electricity for utilities stem in part from lack of standardization. It is also true that these same costs cut away from the profit margin of the construction companies. "The failure to standardize the nation's nuclear plants reflected the sector's inability to plan effectively" (Campbell, 1988, 22) .

Representatives from the nuclear industries, antinuclear groups, regulatory agencies, and utilities believe that standardization is an effective way to avoid design changes during construction, reduce licensing delays, minimize shortages in the supply of components, and therefore cut construction costs (Campbell, 1988, 28). The irony lies in the fact that the United States is the only major nuclear country in which almost every nuclear plant is largely custom built (Campbell, 1988, 30).

The first stage in the quest for standardization began in 1965 and lasted until about 1971 (Campbell, 1988, 31). The AEC funded a study that found the actual plant costs between 1966-1968 rose 50 percent over those originally expected (Campbell, 1988, 31). There were several reasons for the cost overruns. Some of these reasons were the following: utilities kept building larger plants in hopes of achieving economies of scale, production costs were uncertain at a time when many components were just coming off the drawing boards, and lastly, production facilities were still not perfected for the large plants (Campbell, 1988, 31).

Discussion as to why Nuclear Reactors are not Being Built

Why aren't nuclear reactors being built? The generally accepted answer to this question is cost. What, then, are the causes of the high costs of building nuclear reactors? To answer those questions we have examined the ideas of competition and lack of standardization within the nuclear reactor industry. What follows is a chronological history of standardization within the nuclear reactor industry.

1966-1971

During the mid-1960's there was an increase in electricity demand of about 7 percent annually. Because of this increase in the need for electricity utilities planned to build new generating capacity and nuclear power was their choice of generation. Orders for nuclear power plants began to surge in 1966 with 30 units being ordered in 1968 (Campbell, 1988, 32). There were problems, though. A study performed by the AEC estimated that between 1966 and 1968 actual plant costs rose 50 percent over those originally expected.

There were a few causes for the increase in actual plant costs. The problem with building a larger plant was that the building plans were merely extrapolations of plans for a smaller plant, which in turn created expensive and unexpected engineering difficulties. A second cause of cost increases was uncertain production costs as a result of dealing with the new technology of nuclear power. Third, production facilities were still not perfected for large plants.

Manufacturers also began to worry that the AEC would soon face unprecedented amounts of application requests. This would result in regulatory a bottleneck preventing a steady flow of nuclear plants through construction and operating license reviews. The delay in construction and operating license reviews would then delay construction times and cost those involved more money.

Increasing construction costs and fear of regulatory delays leads the industry to turn to standardization. The nuclear industry believed standardization would reduce production and licensing times, which would reduce overall project and lead times and therefore make nuclear plants less expensive to build. The nuclear industry wanted standardization so that a utility could buy a reactor whose design had already been approved by the AEC, thus avoiding the long and expensive part of the agency's construction permit review that involved evaluating the reactor design's safety.

The AEC rejected the nuclear industry's plan of standardization. They did so for a couple of reasons. First, nuclear reactor technology was still in its developmental stages. Manufacturers were scaling up designs without operating experience. The second reason follows from the first in that because reactor designs were getting larger, the AEC did not want to remove any design from the safety review until they were convinced that it was problem free.

In light of the AEC rejection of their proposal, the nuclear industry began its own form of self-standardization. Westinghouse announced that it had developed standard design packages for each size plant it offered and planned to cut costs by mass producing and stockpiling inventories of components in advance for each of its standard designs (Campbell, 1988, 35). Babcock and Wilcox sold two identical reactors to the Tennessee Valley Authority for their Bellefonte project (Campbell, 1988, 35).

Architect-engineering firms were interested in standardizing the non-nuclear portion of the plant they supplied. Unlike manufacturers, though, architect-engineers were not overly concerned with reducing production costs. Architect-engineers saw standardization as a means of moving along the regulatory process and building a higher quality product. Architect-engineers were not concerned with the costs because they worked on a cost-plus basis (Campbell, 1988, 35). This means that they are guaranteed a certain profit, regardless of the costs of the plant.

The utilities also looked favorably on the idea of standardization. The Tennessee Valley Authority applied a single preliminary safety review for the two identical reactors they purchased from Babcock and Wilcox (Campbell, 1988, 35). The Duke Power Company ordered duplicate licenses for its three Oconee plants. Both companies received construction permits the following year.

The duplication of licensing applications as done by the Tennessee Valley Authority and the Duke Power Company seemed like a good idea. Why did the other utilities not follow their lead? The reason was due to competition within the nuclear industry (Campbell, 1988, 36). Because most utilities did not have any in-house nuclear expertise at the time, they had to rely on the technical advice from the manufacturers. The manufacturers were telling the utilities to purchase the most technologically advanced reactor. The same situation held true regarding the size of the reactor.

Between the years 1966 and 1971 there was a lackluster effort at standardization. On the one hand, reducing regulatory review times and costs was a nice idea, but standardizing a design may hurt sales by not offering newer, bigger, state-of-the-art nuclear reactors. As a result, most utilities bought the newest models, avoiding standardization with the belief that they could achieve economies of scale with larger plants. Furthermore, the AEC refused to freeze design requirements until the nuclear sector gained enough operating experience with the larger reactors to ensure safety.

1972-1975

"A dramatic turn of events occurred between 1972 and 1975 in the nuclear sector" (Campbell, 1988, 36). Utilities ordered a record 34 reactors in 1973 and almost as many in 1974, and suddenly the number of reactors ordered dropped to four in 1975 (Campbell, 1988, 36). The reason behind this was the deteriorating financial strength of the utilities sector since the mid-1960's. Because of the financial problems in the utility sector, financial capital was becoming increasingly hard to come by and more expensive. Nuclear reactors were a financial capital intensive project, and so without the cash, there were few orders for nuclear reactors.

Another event that would affect the nuclear industry was the realization of one of the industry's fears. The AEC was swamped with applications and there was no evidence that there would be a let up. On the heels of the numerous new applications came the Calvert-Cliffs decision. The federal appeal court ordered the AEC to consider the environmental effects and radiological dangers of nuclear power plants in its reviews. This forced the AEC to review 60 reactor projects again.

How did all of this turmoil affect standardization? The AEC acknowledged that there was a problem and proposed their version of standardization as a possible solution. The AEC decided on standardization for the following reasons: they feared that the financial troubles of the utilities threatened their pursuit of nuclear power, the AEC felt standardization would make the regulatory review process more effective and efficient, and the AEC believed that by 1972 the technology was finally mature enough to standardize for short periods of time (Campbell, 1988, 37).

In 1973 the AEC announces its version of standardization. First, they placed a 1300-megawatt restriction on reactor size. The rest of the AEC's plan involved what they called referencing, duplication, and replication (Campbell, 1988, 37).

Referencing provided both manufacturers and architect-engineers a chance to have their designs reviewed and approved by the AEC before a utility purchased them. When utilities used referenced designs in their plants, they would be exempt from parts of the safety review (Campbell, 1988, 37). Duplication, as the Duke Power Company had done, allowed a utility to plan on building several identical plants and submit a single design plan for them all as part of its construction permit application (Campbell, 1988, 37). Replication allowed a utility to submit a design for safety approval that had already been accepted for another plant. The AEC would give scheduling and review priority to applications submitted under these options.

What happened to this plan? Mixed reactions towards this plan within the nuclear sector would eventually undermine the existence of the AEC's plan for standardization. Each of the three main components of the nuclear sector would have had to cooperate for standardization to be successful and that was not what happened.

Nuclear reactor manufacturers supported the AEC's plan for standardization. The manufacturers were working to eliminate cost overruns of at least $1 million per plant, overruns they had to absorb because of the fixed-fee contract they had with utilities (Campbell, 1988, 40). Reactor manufacturers were also concerned that their utility customers were losing money as a result of longer licensing times. It was reported that delaying the initial operation of nuclear plants ready to be used cost a utility from $100,000 to $200,000 per day in interest charges and supplementary power costs alone (Campbell, 1988, 40). Therefore, standardization, particularly the concept of referencing, appealed to manufacturers as a means of reducing licensing times and keeping the utilities interested in nuclear power.

Architect-engineers were also interested in standardization from the standpoint that the utilities would remain interested in using nuclear power. As noted earlier, though, the architect-engineers had a different type of contract with the utilities than did the manufacturers. Because the architect-engineers were guaranteed a certain profit they were more reluctant to submit designs to the AEC for referencing. In fact, only two out of twelve architect-engineering firms submitted designs for preliminary approval, whereas all eight of the reactor manufacturers submitted at least one reference design (Campbell, 1988, 40).

The utilities supported standardization. Six utilities submitted a total of eight construction permits between 1973 and 1975 for twenty-one power plants under the reference option (Campbell, 1988, 40). "The reasons for the enthusiasm were obvious" (Campbell, 1988, 40). The trade journals reported that standardization would reduce licensing times and costs for the utilities. However, not all of the utilities were so excited about standardization, with half the construction permit applications submitted in 1974 and 1975 for non-standardized plants.

The AEC finally came around to the idea of standardization after rejecting it only a few years earlier when everyone in the nuclear sector supported it. The AEC thought in 1972 that standardization would solve some of the problems plaguing the nuclear industry and allow nuclear power to continue on its way. However, some people within the nuclear community had changed their minds. While the reactor manufacturers were all for standardization, the architect-engineers balked at the idea and the utilities only made a half-hearted effort.

1976-1981

After 1974 orders for nuclear plants only trickled in and after 1978 no utility ordered a plant or applied for a construction permit. What followed was an alarming number of canceled projects. During this period the standardization program met resistance from reactor manufacturers, architect-engineering firms, and utilities.

Financial reasons were cited as the reason manufacturers stopped seeking preliminary approval for their designs (Campbell, 1988, 43). Apparently, Westinghouse submitted three reactor designs for preliminary approval, though only one utility ever purchased any of them and then for use in only two plants (Campbell, 1988, 43). One of the drawbacks reported by the manufacturers was that utilities could only reference designs that received preliminary approval for their construction permit applications, but not when they applied for the operating license because designs with only preliminary approval were not defined precisely enough.

Some architect-engineers sought preliminary approval for their designs, but none ever sought final approval. This was another indication that they were not as interest in the standardization program as the manufacturers. In fact, only half of the architect-engineering firms ever chose to participate in the reference program, whereas all of the manufacturers were involved (Campbell, 1988, 43).

Not all of the utilities took advantage of the standardization options, but many did. Sixty percent of the construction permit applications submitted between 1975 and 1977 included either the replication or reference option (Campbell, 1988, 44). Only one utility ever referenced an architect-engineer's design for the non-nuclear portion of the plant, which is odd because the non-nuclear part of the plant constitutes about 90 percent of the plant's design (Campbell, 1988, 44).

"The point is that the sector remained convinced that standardization was a good idea, yet it failed to pursue the plan wholeheartedly. As a result, the benefits of standardization did not materialize" (Campbell, 1988, 44).

Results of the Interviews

We conducted four useful interviews. The interviewees represented groups such as the Sierra Club, the Union of Concerned Scientists (UCS), and Public Citizen. We also spoke with a staff member of a congressional representative whose district is home to a nuclear power plant. We started out with a list of groups that we intended to interview. The Sierra Club and UCS were the first people we spoke with and they gave us the names of people at Public Citizen and name of the staff member we spoke with. They suggested we get in touch with a couple other people, including the groups we had already spoken with. A couple of the groups we were told to contact never returned our calls. The interviews revealed to us some unexpected results.

For one of our interviews we spoke with Richard Ferguson, energy chair Sierra Club California. The Sierra Club is involved with environmental issues and nuclear power is an environmental issue. We began the interview by asking Ferguson about how he first became involved with the Sierra Club and what are the concerns of the Sierra Club. According to the Ferguson the Sierra Club is concerned with protecting wild places and wild animals. The Sierra Club has a relatively broad approach to environmental issues, in that it finds itself dealing with issues that might not immediately seem as environmental threats, but is tied in one way or the other with the environment. Energy is not one of the Sierra Club's most pressing issues, though members will admit the connection between electricity generation and the environment.

Following the general information questions we asked him about nuclear power. Ferguson stated that the Sierra Club does not take a formal stand on nuclear power and has not from the early days of nuclear power back in the 1960's. They do, though, oppose further development pending the evolution of the waste problem. Ferguson said that the generation of waste that is deadly and has no reasonable date of expiration is the major concern of the Sierra Club. Another comment Ferguson made about nuclear power was that "a lot of our members are probably fairly grumpy about [nuclear power], but there is no policy opposing or not opposing [nuclear power]".

When Ferguson was finished speaking about the Sierra Club's stance on nuclear power we asked him about issues of safety. Ferguson started out by stating that the threat of a core meltdown doing damage to the environment was real. He then began referencing the danger of the waste. Ferguson was well versed in the operation of a nuclear reactor and did not seem at all concerned with the threat of a nuclear reactor accident.

During the last part of the interview we spoke with Ferguson about inherently safe nuclear reactors. He had some knowledge of inherently safe designs and commented that there was one built, but "evidently never worked very well". When we finally asked if the development of an inherently safe reactor would have any impact on nuclear regulation, Ferguson was quick to cite that "the waste issue is probably the major one now". The Sierra Club's focus on the waste issue and seemingly lack of concern about a meltdown could lead us to believe that the opposition to nuclear power is attacking the waste issue because it is now the weak link in the chain. The Sierra Club seemed to be of the opinion that the technology has advanced to the point where reactor safety cannot be used as an access point for the nuclear opposition.

Another of our interviews was conducted with David Lochbaum a scientist with the Union of Concerned Scientists (UCS). The UCS follows the nuclear industry's safety standards in an attempt to keep the industry safe and honest. They provide a platform for engineers to alert the Nuclear Regulatory Committee (NRC) of problems with certain nuclear reactors or with the industry as a whole without causing a rift between engineers at the plant and the owners.

While the Lochbaum stated that the UCS was not opposed to nuclear power, he was of the opinion that it was not feasible from an economic standpoint. Lochbaum went on to say that "nuclear power is a very expensive endeavor [and] it is the economics that keeps the utilities from building more plants and caused more than half the plants that ever started to be built to be canceled [and] it is also why we aren't going to see any new plants being built in the immediate future". He mentioned that his "immediate future" was the next twenty years.

We asked Lochbaum about the viability of nuclear power in the future. Lockbaum responded by explaining that nuclear power plants may extend the operating license twenty years, which will extend the license to about the year 2050. He said that "a couple of plants are currently seeking this extension" and he believes that other plants will follow this same path. Lockbaum did not seem to object these license extensions, but he did refer back to the issue of cost and related the costs to the current regulations.

When we were finished asking Lockbaum about nuclear power we asked him questions concerning inherently safe technology. Lochbaum seemed well versed on inherently safe designs and stated that there was "one reactor type we liked...[the reactor] was the high temperature gas cooled reactor that General Atomics was promoting".

Continuing along those lines, we questioned Lochbaum about the impact inherently safe reactors could have on nuclear regulation. Lochbaum did not seem to think that inherently safe reactor designs would alter the path of nuclear power, a path they seem to believe ends in the extinction of nuclear power in this country. Lochbaum stated that "regulations, even for plants that are currently built, are too much of a burden and [the regulations] are making the costs artificially high".

This may actually be a good sign for nuclear power because the UCS is comprised of socially conscious engineers and the only attack they can launch on nuclear power is one that concerns cost.

We also conducted an interview with James Riccio, staff attorney for Public Citizen's Mass Energy Project (PCMEP). They "are staunchly opposed to nuclear power and want to see an accelerated phase out of all nuclear reactors". Their opposition with nuclear power includes cost, nuclear waste, and reactor safety. They point out that the costs are a result of what they consider an expensive way to boil water. It is expensive because of the high level of safety that is necessary.

Because we knew Riccio's stance on nuclear power we briefly asked some background questions and start asking him about nuclear power. We asked first about safety issues. Riccio replied that "the NRC [Nuclear Regulatory Commission] cannot determine that reactors are safe, because they don't have the [plant's design criteria]".

When asked about the inherently safe nuclear reactor designs Riccio returned to his original argument of cost and cited problems building plants that existed in the 1960's and 1970's. Riccio stated "the last [plant built], being the Watts Bar nuclear power plant down in Tennessee took twenty three years to construct and cost nearly 8 billion dollars.

Riccio finally insisted that nuclear power should be aborted no matter what the cost, stating that the waste is a problem. This may be another case of the waste issue being pushed to the front for lack of other solid arguments.

The last interview we conducted was with a staff member for a congressman who has a nuclear power plant in his district. When asked about the problems of nuclear power he immediately suggested the issue of nuclear waste. He also stated that nuclear reactors are generally unpopular, particularly with those residents who live near nuclear reactors. He also mentioned that the economics of today's electricity market do not favor the construction of nuclear power plants.

Concerning the unpopularity of nuclear power plants he suggested that the residents were afraid of nuclear power in general. While he did admit that the average level of understanding for a person was below what is necessary to understand nuclear power, he did not think that an increase in the education of the average person would change their minds.

When asked if the current regulations concerning nuclear power were a reflection of the opinions of the residents he answered evasively. He completed his answer by saying he is not sure who is controlling nuclear legislation, the government or the people. We then questioned him about his knowledge of inherently safe nuclear reactors. He claimed to be somewhat familiar with the designs. His general reaction was that some groups would say that the inherently safe reactors are not really inherently safe. He then quickly moved to the issues of waste and economics.

We finally asked him about what he considered to be the foreseeable future of nuclear power. He seemed content to think that nuclear power would gradually fade from the scene. He was also of the opinion that there would not be any kind of energy crisis and even if there was, it would have no effect on a choice to move forward again with nuclear power.

Conclusions

Based on the political history of nuclear power and the interviews we conducted we believe that the introduction of inherently safe nuclear reactor technology will not be sufficient to alter the political debate and bring about a change in nuclear power policy in the United States.

Our literature review revealed to us the history of the politics of nuclear power. From the beginning of the atomic program and the formation of the atomic subgovernment through the late 1970's when the last order for a nuclear reactor was placed, the people involved in the program have consistently faltered in their attempts to foster a nuclear program. In order to have a successful program of the magnitude that nuclear industry once had in this country, the government and those that are governed must support the program.

Nuclear power in the United States began with positive intentions. The AEC, JCAE, and all those involved wanted nuclear power to succeed. They developed a subgovernment to exclude those parties that would slow down the development and implementation of the nuclear program. For the first twenty years, most everything proceeded as planned. Because of the established subgovernment the policymaking arena was stable. Those who were not directly involved in policymaking were left under the impression that nuclear power was a matter of national security, that it should be handled by only those who are experts in the field. Unfortunately for the nuclear program, this ease of policymaking did not last forever.

Beginning in the late 1960's the public began to notice the effects of the actions of the AEC. By 1969 the AEC had become notorious as a government agency that ignored its environmental responsibilities. With the passage of NEPA in 1969, new laws were passed that began to degrade the AEC's monopoly. A few years later the AEC was abolished and replaced by the NRC.

The NRC was not as supportive of nuclear power as was the AEC. Throughout the 1970's multiple laws were passed concerning environmental protection. These same laws were a hindrance to the continued development of the nuclear program. Aside from the environmental protection laws, there were problems with licensing/operation hearings legislation. The industry found out all too late that all of these problems would manifest themselves as additional costs.

The industry was also misled when it came time to put a price tag on the nuclear power plants. By the time actual costs were realized some of the utilities had lost millions on the construction of their nuclear power facilities. The utilities were therefore hesitant to sink another large amount of capital into a power plant when less expensive alternatives were readily available.

Our literature review demonstrated that the political history of nuclear power was checkered at best. Few people, if any, have been happy with the results of the nuclear program in the United States. Some people felt lied to and were reluctant to support the program that had been kept so secret from them. The utilities felt as though they had been treated unfairly by the government for having to pay excess costs relating to regulatory problems and no longer wanted to dump more money into a nuclear program. Because of the lack of support from the American public and the utilities, we do not believe inherently safe reactor technology alone can change their feelings about the past. Even if the inherently safe reactor technology dispels every single person's fear of a core meltdown, the regulatory process is still going to take longer than is necessary because of the waste issue and construction costs of the nuclear power plant are going to remain at unacceptable levels.

The waste issue seems to present itself whenever there is nothing left for the anti nuclear side to say. In conducting our interviews we found that the anti nuclear people concerned themselves with the issue of nuclear waste. When we mentioned inherently safe nuclear reactor designs they went back to the waste issue. Thus, even if nuclear reactors were one hundred percent failsafe, the opposition would take action over the issue of nuclear waste.

The regulatory process, the one that requires public hearings for all stages of the licensing processes, will take much longer because the anti nuclear groups will see to it that the process takes as long as possible. The anti nuclear groups know that time-delays in achieving a fully operational plant cost the utilities vast amounts of money. The utilities are not in business to lose money, so they do not enter into nuclear power.

In conducting our interviews we found that the anti nuclear movement seemed to be more focused on the waste issue rather than safety. This could be interpreted a couple of ways. One way is that the anti nuclear faction is truly more concerned about the waste than the threat of a core meltdown. The nuclear industry, with the exception of Three Mile Island, has a near flawless record, so it is possible that few people even consider the reactors themselves dangerous. In light of the nuclear industry's clean record on safety, the anti nuclear group may be concentrating on the waste issue because it has now become the Achilles heel of the nuclear industry. If the anti nuclear faction is attacking the waste issue because it is all that there is to attack, then the inherently safe reactor technology will prove to be useless.

The nuclear industry is fading away because there is no acceptable solution to the costs that plague the industry. Those costs are a result of the political processes surrounding the construction and operation of a nuclear power plant. Much time is devoted to obtaining construction and operation permits. Public hearings must be held and any group that opposes the construction is given time to be heard. The freedom for everyone who wants to be heard to speak is one of the benefits of the American political system. Listening to all of the protesters can time consuming. Whatever the reason is for protesting, safety or waste, the protesters can use the political system to increase construction times and thereby increase the capital costs. With the development of inherently safe nuclear reactors one of the stumbling blocks has been removed, but as long as the waste issue exists, the political system does not allow for swift allotment of construction and operation permits.

In Japan it takes about four years to construct a nuclear power plant and then fire it up. In the United States it takes over a decade. The fact that it takes longer to build a reactor in the United States is an example of the double-bladed sword that characterizes the American political system. In the case of nuclear power, the political system works so much against its further development. Even if nuclear power was the most productive achievement since the assembly line, it would go nowhere because the opposition is vehemently against its success. Because the opposition is so passionate about nuclear power, all of the legislation concerning nuclear power becomes entangled in the politics.

For example, there are laws that prevent the recycling of the fuel for nuclear reactors. Because of this law, there is an abundance of spent fuel rods sitting in casks at nuclear power plants. The mere existence of these spent fuel rods gives the opposition something to complain about. By allowing the fuel rods to be recycled, the government would begin to alleviate the pressure on the nuclear industry from those who oppose the disposal of nuclear waste.

The removal of the law prohibiting the recycling of nuclear fuel rods would give anti nuclear groups a point of attack because they will oppose the repeal claiming national security issues; if the law is changed the argument against nuclear power, based on the high level waste, is weakened. Other than the existence of a permanent location for the storage of the spent fuel, recycling the fuel is the best option for the nuclear industry for dealing with the waste issue.

Three of the people we interviewed indicated that the capital costs of building a nuclear power plant make nuclear power unattractive. Our literature review revealed that the capital costs increase dramatically with the increase in time it takes to build the plant. We also found that the delays in construction were a result of the political process of obtaining construction and operation licenses.

The nuclear power industry must therefore remove the politics from the political process. The development of inherently safe nuclear reactors is a significant step in the right direction. The inherently safe nuclear reactor should silence the opposition's argument about core meltdowns. With the quieting of the safety issue, the nuclear industry needs to become involved in the waste issue. Should the nuclear industry be somewhat revived in the future, it would still have to contend with the existence of highly radioactive waste. To this end, the industry should focus some of its efforts on legalizing the recycling of spent fuel rods. Eliminate the politics in the political process. The development of inherently safe nuclear reactors is a step in the right direction, but to remove the politics from the political process the nuclear industry has to remove all of the points of conflict. The most significant conflict the industry must resolve is the waste issue; until the waste is dealt with the inherently safe nuclear reactor designs will sit on the shelf.

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