

THE PERCEPTION OF RISK: A SUMMARY OF STUDIES
AND HOW THEY PERTAIN TO THE FUTURE OF
NUCLEAR ENERGY

By

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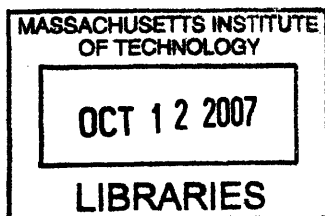
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**Submitted to the Department of Nuclear Science and Engineering on May 11, 2007
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ABSTRACT

One of the most interesting aspects of nuclear power is the perceived risk that the public infers from its existence. This paper explores the public's response to risk in general and specifically to nuclear power by reviewing behavioral studies examining how risk is perceived. The paper also discusses important themes relevant to nuclear power and risk perception, including trust, stigma, the difference between experts and the public, and ways of informing and educating the public. The current political status of nuclear power is discussed by examining the roles and opinions of three groups dealing with nuclear energy: 1) the Nuclear Regulatory Commission, 2) the nuclear energy industry, and 3) experts in the field of nuclear power and environmentalists who are concerned with the subject. Finally, conclusions are drawn based on the research into the public's perception of risk and the current status of nuclear energy in order to develop suggestions that may aide in the development of nuclear technology and a resurgence of nuclear power, while addressing the public's concerns and furthering the public's understanding of nuclear technology.

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1. Introduction:

For years, the nuclear community has had to combat the fears of the public in order to secure a place for nuclear energy in the future, fighting a negative image that resulted in significant part from the accidents at Three Mile Island and Chernobyl. To the public, nuclear power has often been seen as too dangerous and too risky. However, the public does not perceive risk in the same way that it is perceived by the engineers in charge of such systems as nuclear power plants.

To come up with a formulation of overall risk, engineers use a model consisting of the probability of an accident occurring per unit time multiplied by the number of fatalities that accident would cause. In this formulation, systems with the same product of probability and consequence have the same risk. Thus, for example, engineers would see a system with a low probability of failure with high casualties as having the same risk a system with a very high probability of a low casualty event.

There are many other factors that influence public opinion. Some of these include qualitative measures of things like “dread” and “fear”, and were studied in the late 1970s with several articles published on the matter. These studies point to a definite distinction between different systems in the public’s mind, where a system with high casualties and low probability is seen as more risky than those with low casualties and a higher probability. An example of this is the common fear of airplane crashes, while automobile fatalities are accepted.

The goal of the thesis will be to analyze the different ways engineers and the public approach risk, and the implications that these differences have for technology as a whole, specifically nuclear power. These results will be relevant to the way that

industries, especially the nuclear power industry, make decisions on how to affect public opinion and convince the public that its technologies are safe (or whether industry sees this step as a necessity at all.) This is becoming more important to the nuclear industry as the U.S. is again looking at nuclear power as a sustainable energy source. In a democratic society, the public must be considered when making these decisions, because if the public does not support them, there are many ways for actions to be blocked.

1.1 History

Risk perception studies can be seen as an application of the judgmental heuristics work of psychologists Tversky and Kahneman [1]. Tversky and Kahneman argued that people do not make intuitive judgments of probabilities by means of probability calculus but are influenced by seemingly irrelevant factors and whatever evidence is available to them [2]. The authors concluded that the social and political problems of the acceptability of technologies such as nuclear power were related to “small probability/large consequence”[1], and that the problem was that the public didn’t understand how small the probabilities were and should be educated on the subject [1].

Subsequently, a series of studies began looking at risk-benefit analyses of different technologies, asking whether the technology is acceptably safe, and how safe is safe enough? Fischhoff et al. [3] suggest that there are two ways to answer the question: the revealed preference model proposed by Starr [4] and the expressed preferences model developed by Fischhoff et al. [3]. In his revealed preference model, Starr suggests that the most important contributing factors to risk acceptability are utility and voluntariness [4]. Utility is the level of usefulness of a technology or action, while voluntariness is defined

as the freedom (or lack of freedom) an individual has to choose whether to be exposed to that risk. Fischhoff et al. built on the work of psychologists Tversky and Kahneman and introduced the expressed preference model (or psychometric approach)[3]. Based on the use of questionnaires, Fischhoff et al.'s study combined the idea of the heuristics work of Tversky and Kahneman with a broader range of factors than simply utility and voluntariness as proposed by Starr [1].

More recently, Siegrist, Keller, and Cousin have developed another approach to risk perception analysis called the Implicit Attitude Test (IAT) [5]. The purpose of the IAT is to reveal any attitudes people may have toward a specific technology that are not revealed through explicit measures such as questionnaires. Studies of this kind are generating new insights into the subconscious thought processes that go into a perception of risk.

1.2 Importance of Risk Perception Work to Nuclear Power

Risk perception has been shown to be an important factor in public reactions to hazards and hazardous technology, especially where nuclear power is concerned. The public's perception of risk from nuclear technologies has been studied extensively, and research on the topic continues to play an important role today due to the many difficult policy problems in the nuclear field, such as nuclear waste and proliferation concerns [6]. Policy makers have turned to forms of risk-benefit analysis to weigh the benefits against the risks [3]. The common idea is that the level of perceived risk is directly related to the level of perceived benefit of the technology [3]. However, research has shown perceived risk to be much more important than expected benefits, an example being that people

have been found unwilling to trade health risks in accepting a risky facility in exchange for generous donations to their community [1]. Those trying to lower the public's resistance to a technology, especially those in the nuclear power industry, must understand the way that the public's ideas on risk are formed. A failure to understand the public can hinder the progress of any technology.

1.3 Topics for discussion

By analyzing research on the subject of risk perception and nuclear power, it is evident that several topics come up with great frequency in the discussion. The topics of trust, stigma, the difference between experts and laypeople, and educating the public are all essential for understanding the topic of risk perception and will be discussed in depth.

Trust is essential in dealing with the public on matters of risk, as acceptance of risks is dependent on confidence in risk management. The public must be able to trust those in positions of power or they will not accept the risks that they perceive. Polls conducted in the past have shown that government and industry officials responsible for managing nuclear power are not highly trusted [7]. While this condition has improved somewhat over the years, it is important to note the similarities between low levels of trust and low levels of support for nuclear power.

Stigma is often defined as the shame or disgrace associated with something that is socially unacceptable. The stigma associated with nuclear power is a serious impediment to its progress. Several reasons that people fear nuclear power will be discussed, but one of the most important issues is the public reaction to nuclear accidents such as Chernobyl

[9]. Freudenberg & Pastor note that people react much more strongly to man-made risks and disasters caused by human error or negligence than to natural disasters [8].

Experts often have different views of risk than the public, and getting the two groups to share the same view is essential for the success of nuclear power. There are some impediments to this process, however. From the 1970's to the 1990's, our society has, on average, grown healthier and safer, and spent billions of dollars on safety, and yet the American public has grown even more concerned with risk [7]. Experts commonly assert that the public simply does not understand the risks, and the public and political opposition to nuclear power is based on irrationality and ignorance [10]. However, Slovic [7] suggests that the public's concerns cannot be dismissed so easily. A former administrator for the Environmental Protection Agency (EPA), William Ruckelshaus, wrote: "To effectively manage risk, we must seek new ways to involve the public in the decision-making process... They [the public] need to become involved early, and they need to be informed if their participation is to be meaningful. [11]."

2. Important Studies

Few studies have had as great an impact on the field of risk perception as those conducted by Fischhoff et al. [3] Slovic et al. [12] and Siegrist et al. [5]. Due to the complicated nature of their results and the importance of their work to others in the field, their studies will be examined in depth. This examination will lend itself to a better understanding of factors important to risk assessment, and will lead to recommendations for the improvement of the study of risk perception as well as the nuclear power industry.

2.1 The Psychometric Approach

Fischhoff et al. [3] suggested that there are two ways to answer the question of how safe is safe enough: the revealed preference method proposed by Starr [4], and the expressed preference method proposed by Fischhoff et al. [3]. The revealed preference method assumes that society has arrived at an optimum balance between the risks and benefits of any activity, and that acceptable risk for a new technology is defined as the level of safety associated with ongoing activities having similar benefit to society [4]. The expressed preference method, on the other hand, uses questionnaires to measure the public's attitudes toward risks and benefits from a number of activities [3].

The revealed preference method [4] assumed that the measure of risk for hazardous activities could be calculated by the expectation of fatalities per hour of exposure to the activity. The benefit from an activity was assumed to be equal to the average contribution that the activity made to a person's income, or the average amount of money spent on the activity by an individual person. Given these assumptions, Starr derived what Fischhoff called 'laws of acceptable risk' [3]:

- The acceptability of risk is roughly proportional to the third power of the benefits;
- The public seems willing to accept risks from voluntary activities roughly 1000 times greater than it would tolerate from involuntary activities that provide the same level of benefit;
- The acceptable level of risk is inversely related to the number of persons exposed to that risk; and
- The level of risk tolerated for voluntarily accepted hazards is quite similar to the level of risk from disease.

The revealed preference approach is not without its critics, however. According to Fischhoff et al. [3] “revealed preference assumes that people not only have full information, but also can use that information optimally, an assumption that seems quite doubtful in the light of much research on the psychology of decision-making.”

The expressed preferences method, or psychometric approach [3], looks at the issue of risk perception differently. Psychometric questionnaires are used to investigate issues pertaining to risk-benefit trade-offs. The use of psychometric questionnaires has been criticized, as some believe that the answers to hypothetical questions may not be representative of actual behavior, but Fischhoff et al. believe that these criticisms appear to be overstated.

Fischhoff et al. conducted a study [3] to test the usefulness of the questionnaire technique in examining risk perception. Each participant evaluated 30 different activities and technologies ranging from alcohol, skiing, and motorcycles to commercial aviation, pesticides and nuclear power with regard to either its perceived benefit to society or its perceived risk. Participants were not asked to evaluate both the perceived benefit and the perceived risk of an activity or a technology. Instead, one group was asked to evaluate the perceived benefit of the activity, while another group evaluated its perceived risk. This was done in order to separate the results and avoid having the weight of one contaminate the other. Each participant was also asked to evaluate the acceptability of its current level of risk, and its position on each of nine dimensions of risk [3]. When preparing to perform the study, the instructions read:

This is a difficult, if not impossible task. Nevertheless it is not unlike the task you face when you vote on legislation pertaining to nuclear power, handguns or highway safety. One never has all the relevant information;

ambiguities and uncertainties abound, yet some judgment must be made. The present task should be approached in the same spirit [3]

When examining the perceived benefit of a particular activity or technology, participants were instructed to consider all types of benefits: “how much money is generated directly or indirectly, how much of a contribution is made to the people’s health and welfare, and so on”. Participants were also told not to consider risks when considering the benefits. Those participants tasked with considering perceived risk were instructed to consider the risk of dying as a consequence of the activity or technology, as a function of total risk per year, not risk per hour of exposure.

All participants were asked to judge the acceptability of the level of risk currently associated with each item to determine the risk adjustment factor. Their instructions read: “The acceptable level is a level which is good enough, where good enough means you think that the advantages of increased safety are not worth the costs of reducing risk by restricting or otherwise altering the activity”. Finally, the participants were asked to rate each activity or technology according to nine dimensions that were thought to influence perceptions of risk. The dimensions included voluntariness of risk, immediacy of effect, knowledge about risk (by those exposed), knowledge about risk (by scientists), control over risk, newness, chronic-catastrophic, common-dread, and severity of consequences.

Participants were members of the Eugene, Oregon League of Women Voters and their spouses, accounting for 76 individuals, 52 women and 24 men. This set of participants was chosen as the opinions of the League members were likely to be similar to the private citizens most heavily engaged in the public policy-making process.

The results from the perceived risk and benefit analysis showed a great difference between evaluations of non-nuclear and nuclear electric power. In general it was observed that perceived risk only declined slightly with overall benefit. The authors were able to conclude from the results that society tolerates a number of activities that were rated as having very low benefit and very high risk such as handguns, motorcycles, smoking, and alcoholic beverages as well as activities with great benefit and relatively low risk such as prescription antibiotics, railroads, and vaccinations. However, society does not appear to accept the possibility of high casualty events, even with extremely low risk.

The risk adjustment factor results do not lend themselves to much discussion, except that there were few items that people believed should be made much safer, including alcoholic beverages, handguns, motorcycles and nuclear power [3].

Results from rating activities and technologies with respect to the nine dimensions found that perceived risk correlated with dread and severity but not with any of the other characteristics. Fischhoff et al. applied factor analysis between the dimensions that were highly inter-correlated, and came up with two factors: Factor 1 – technological risk, and Factor 2 – severity. Figure 1 plots the 30 activities and technologies on a graph consisting of Factor 1 as the y-axis and Factor 2 as the x-axis [3].

The high end of Factor 1 was associated with new, involuntary, highly technological items, which have delayed consequences for masses of people. The low end of Factor 1 was familiar, voluntary activities with immediate consequences at the individual level. The high end of Factor 2 was associated with events whose consequences are certain to be fatal (often for large numbers of people). An important

item to note on Figure 1 is the isolation of nuclear power, which is plotted high on the technological risk scale and the severity scale. Fischhoff et al. [3] investigated this further by comparing the ratings of nuclear power on the nine dimensions of risk to the ratings for x-rays and non-nuclear electric power. The results are plotted in Figure 2.

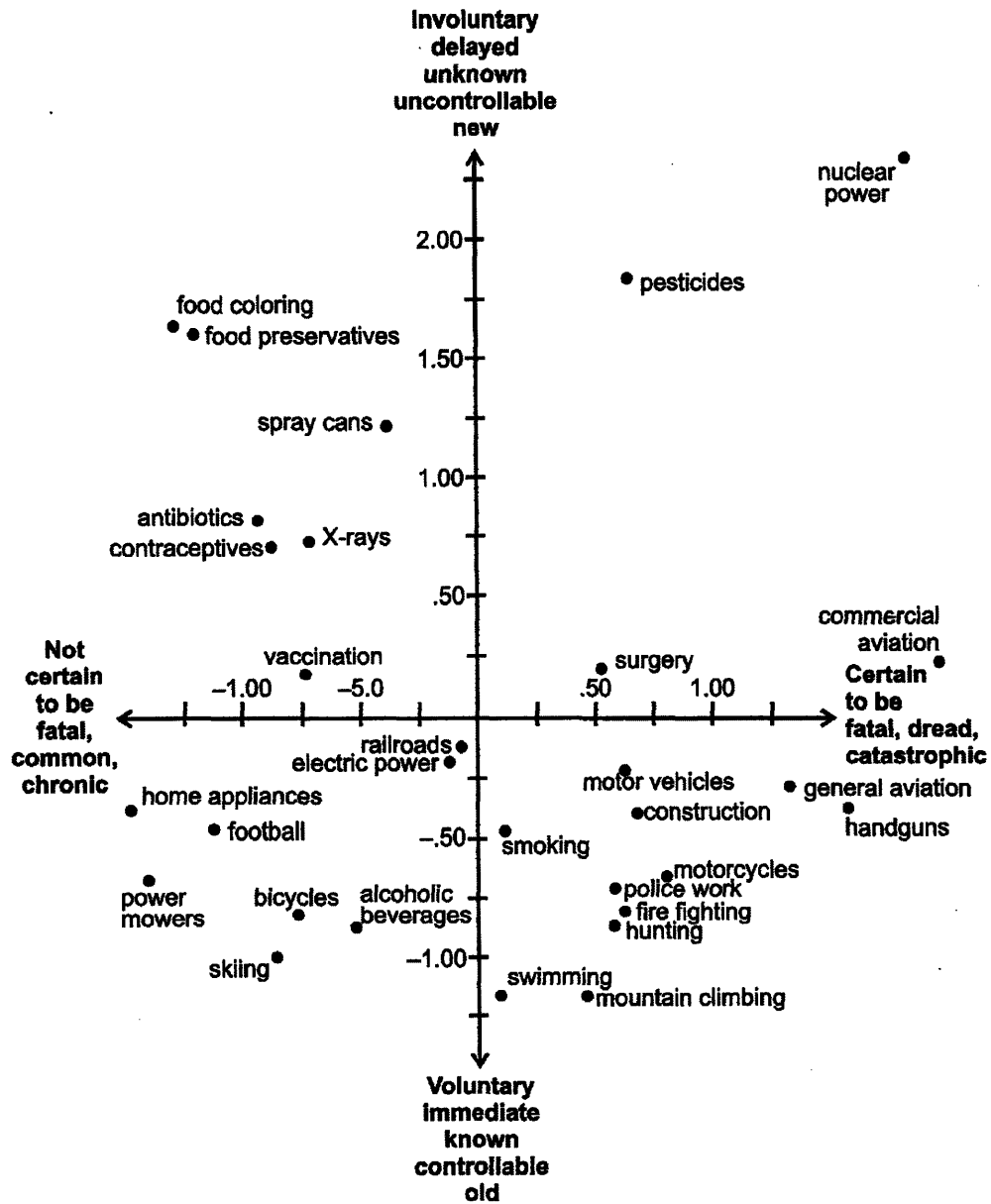


Figure 1: Risk Items in Two-Factor Space

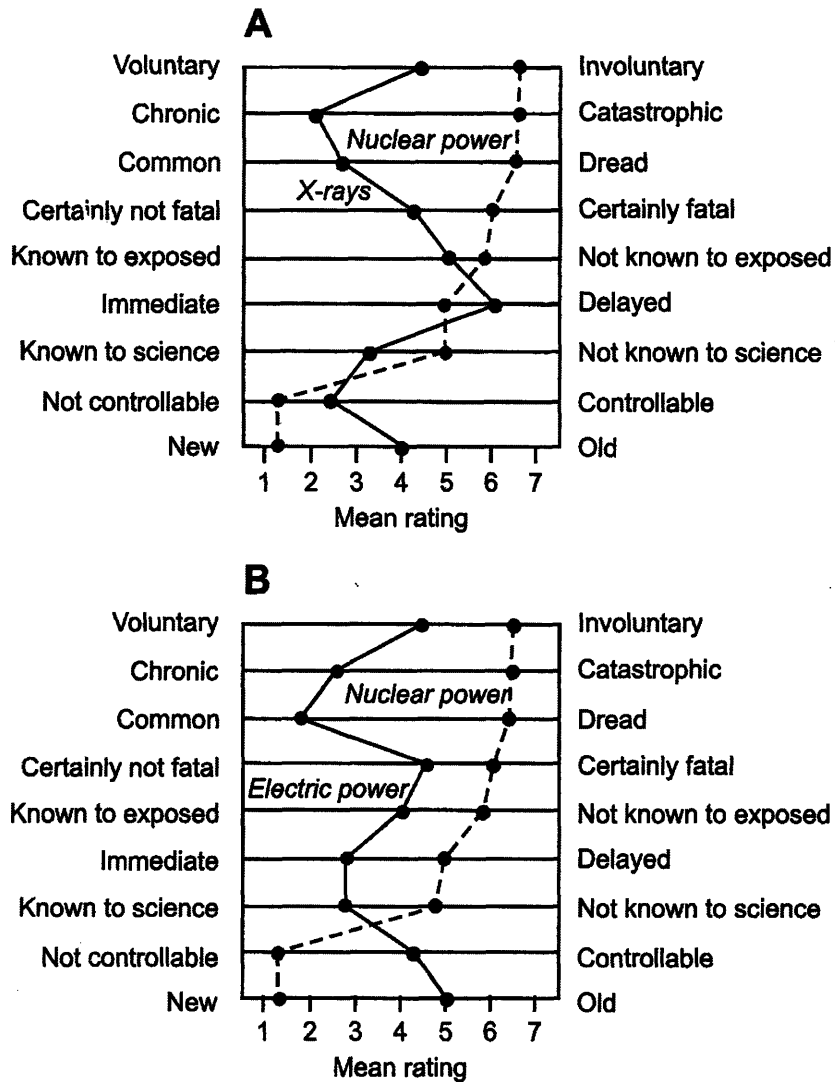


Figure 2: Nuclear Power and Related Technologies

The results shown in Figure 2 explore the difference in public perception to nuclear power as compared to X-rays and electric (non-nuclear) power. Even in comparison with X-rays, another nuclear technology, nuclear power is seen as having more dread, being more catastrophic, and being more involuntary and less controllable than x-rays and electric power. This speaks to the issue at hand, understanding why the public views

nuclear power as having greater risk than other forms of nuclear technology and other forms of power production.

Through the results of the psychometric study [3], it was determined that current risk levels were viewed as unacceptably high. Participants wanted the risks from different activities to be considerably more equal, and wanted the most risky item on the list of 30 activities to be only 10 times as risky as the safest. Fischhoff et al. also found a consistent, although not overwhelming relationship between perceived benefit and acceptable level of risk, with the relationship being characterized by an inverse relationship between perceived risks and benefits. It was also concluded that society tolerates higher risk levels for voluntary, than for involuntary activities, and that expressed preferences indicate that determining acceptable levels of risk may require consideration of characteristics other than just benefits.

2.2 Extended Psychometric Study

Slovic et al. conducted an extended study [12] of risk perception a few years after Fischhoff et al.'s first psychometric study. This new study kept the basic principles of the original study but used a broader set of hazards, 90 instead of 30, and 18 risk characteristics instead of 9. The hazards were selected to show a wider range of activities, substances and technologies, and the subject pool was taken from college students. All of the hazards were rated on a 0-100 scale for both risk (from not risky to extremely risky) and benefit (from no benefit to very great benefit), and then the respondents were asked to rate the degree to which the risk would have to be adjusted to make the risk acceptable to society. As in the study by Fischhoff et al. [3], one group

evaluated the perceived risk and the other evaluated perceived benefit to prevent the weight of one contaminating the other. The 18 risk characteristics included 8 from the previous psychometric study, and all hazards were rated according to each characteristic to determine the extent to which the characteristics described the hazard.

As the analysis of the results in Slovic et al.'s study was more extensive and covered more risks, some time will be devoted to the results, though the study is very similar to Fischhoff et al.'s. Slovic et al. found that respondents judged risks from most hazards to be at least moderately well known to science, and they furthermore believed that most of these risks were better known to science than to those who were exposed. The only risks that the respondents believed were better known to those affected than to the scientists were risks from police work, marijuana, contraceptives, boxing, skiing, hunting and other sporting events. The respondents were also asked to judge whether they thought the risks were decreasing in riskiness, increasing in riskiness, or staying the same. Of the 90 hazards, only 25 were judged to be decreasing, and 62 hazards were judged to be increasing. Nuclear power, crime, warfare, and nuclear weapons were judged to be increasing the most. One of the most striking results is that of the hazards judged to be increasing the most, none of them were judged to be easily reducible.

As in the first study, the ratings of the risk characteristics were found to be highly inter-correlated. Slovic et al. followed a similar factor analysis as Fischhoff et al. to group highly correlated characteristics into three factors. Factor 1, called "dread" was made up of 12 characteristics whose severity was believed to be uncontrollable and be seen as dread, catastrophic, hard to prevent, fatal, inequitable, threatening to future generations, not easily reduced, increasing, involuntary and threatening to the rater personally. Factor

2, called “familiarity” was made up of 5 characteristics dealing with how well the hazard was known, and consisted of observability, knowledge, immediacy of consequences and familiarity. Slovic et al. also isolated a single characteristic, the number of people exposed, and called it Factor 3. Similar to Fischhoff et al., Slovic et al. plotted all of the hazards on a graph of Factor 1, “Dread” on the x-axis and Factor 2, “Familiarity” on the y-axis. Their results are shown in Figure 3.

Important to note in Figure 3 is the fact that just as in the previous study, nuclear power is isolated on the high end of both Factor 1 and Factor 2, showing both high dread and low familiarity.

From the results of the ratings of risks and benefits, Slovic et al. were able to conclude that respondents do not believe society has worked to limit risks from less beneficial activities. The authors also noticed that the greater the perceived risk, the larger the adjustment judged necessary to bring the risk to an acceptable level, while the more beneficial items were thought to need less risk adjustment. Table 1 shows an excerpt from Slovic et al.’s results of risk and benefit ratings.

Table 1 shows the perceived risk assigned to each hazard on a scale from 0-100, with 100 being the riskiest. It also shows perceived benefit, also on a scale from 0-100 with 100 being the most beneficial, and adjusted risk is shown, which is the amount by which the risk would have to be reduced in order to be accepted by society. From this excerpt, it can be seen that the level of adjusted risk for nuclear power is on par with handguns, warfare, crime, terrorism and nerve gas, with similar levels of perceived risk. This supports the conclusion that nuclear power is greatly feared and could benefit from a better understanding of its risks by the public.

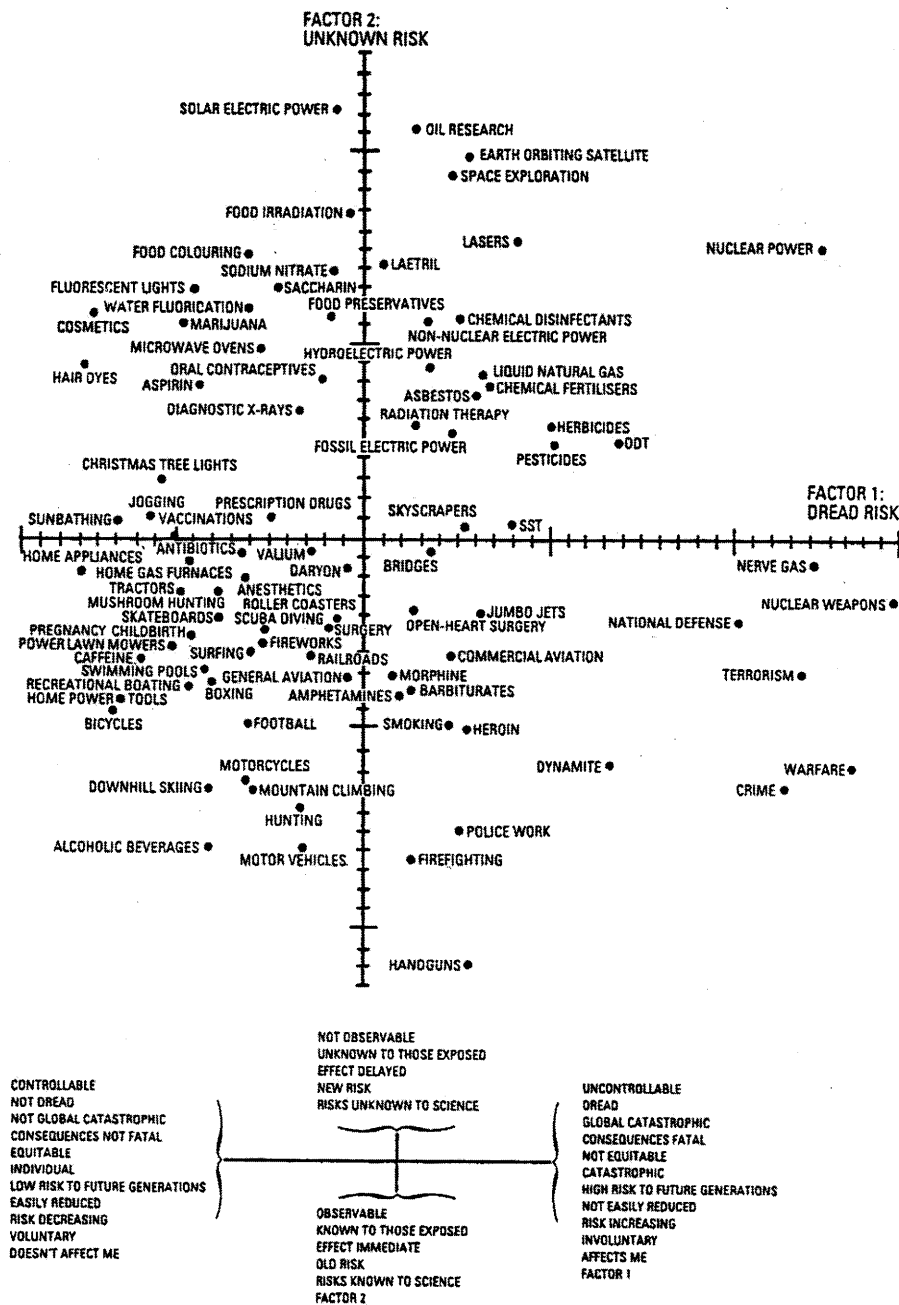


Figure 3: Extended Risk Factors in Two-Factor Space

Table 1 - Risks and Benefits Ratings

		<i>Perceived risk</i>	<i>Perceived benefit</i>	<i>Adjusted risk</i>
1	Nuclear weapons	78	27	49.1
2	Warfare	78	31	26.2
3	DDT	76	26	8.8
4	Handguns	76	27	15.2
5	Crime	73	9	19.2
6	Nuclear power	72	36	22.2
7	Pesticides	71	38	4.2
8	Herbicides	69	33	6.3
9	Smoking	68	24	6.6
10	Terrorism	66	6	26.3
11	Heroin	63	17	7.6
12	National defense	61	58	4.7
13	Nerve gas	60	7	17.4
14	Barbiturates	57	27	4.8
15	Alcoholic beverages	57	49	2.9
16	Chemical fertilizers	55	48	2.8
17	Motor vehicles	55	76	3.1
18	Amphetamines	55	27	4.9
19	Open-heart surgery	53	50	2.1
20	Morphine	53	31	4.4
21	Radiation therapy	53	36	3.6
22	Darvon	52	38	3.9
23	Oral contraceptives	51	67	3.8
24	Asbestos	51	51	4.9
25	Liquid natural gas	50	56	1.5
26	Chemical disinfectants	49	47	2.2
27	Valium	48	37	2.6
28	Surgery	48	64	2.4

From their results, Slovic et al. suggest that accepted views of the importance of voluntary nature of risk and the impact of catastrophic losses of life might need revision. In their first psychometric study, Fischhoff et al. [3] introduced the idea of a “Voluntariness Hypothesis” that stated “respondents believed that greater risk should be tolerated for more beneficial activities, and a double standard is appropriate for voluntary and involuntary activities.” The results of the extended psychometric study clarified their conclusions. Six of the ten hazards rated the most involuntary were also among the ten

most catastrophic hazards, suggesting that other factors may be the cause of the aversion to involuntary risks [12].

Slovic et al. introduced an example of the voluntariness hypothesis by discussing the differences in safety associated with a car driven for pleasure by a subject, versus a chauffeured car for business travel where the subject is merely a passenger. In this example, the chauffeured car represents an involuntary risk, in that the subject is not the one controlling the car and its use is required for work, while the car driven by the subject is offered as an example of a voluntary risk due to its controllability and use for pleasure. The authors claimed that the subject would want the same level of safety in both automobiles; regardless of who is driving the car, or for what purpose it is being used. They went on to claim that society's apparent aversion to involuntary risks might be an illusion due to the characteristics involuntary risks share with potentially catastrophic hazards.

This calls to question exactly how much weight the potential for catastrophic consequences holds with the public's perception of risk. Slovic et al. argue that too much emphasis is placed on the public's aversion to involuntary risk, and that not enough emphasis is focused on how catastrophic potential determines societal responses to hazards. One of the most obvious fears of catastrophic potential is that from nuclear power. In both of the psychometric studies, respondents believed that nuclear power posed greater risk of death than any of the other hazards under consideration. Further research conducted by Slovic et al. has linked this perception to the perceived potential for disaster. This is supported by the fact that while X-rays utilize the same nuclear technology as nuclear power, the public does not perceive X-rays as having the same

potential for catastrophic consequences. From this information, Slovic et al. concluded that beliefs about the catastrophic potential of nuclear power are the major determinant of public opposition to the technology.

Slovic and his colleagues noted that demonstrating the improbability of catastrophic accidents requires large amounts of data, and that without definitive evidence, weaker data tend to be interpreted according to the individual's prior beliefs. They also claimed that the differences between pro-nuclear experts and the anti-nuclear public are not likely to be resolved, "leaving frustration, distrust, conflict and costly hazard management as its legacy". They foresaw the potential for similar disputes between experts and the lay public in the area of other low-probability, high-consequence hazards such as liquefied natural gas, pesticides, industrial chemicals and recombinant-DNA research.

Another aspect that has been examined by Slovic et al. on the issue of catastrophe is the public's reaction to catastrophic loss of life. Society reacts more strongly to large, infrequent losses of life than to small, frequent losses. This has led to the proposal of a weighting factor that takes into account the greater impact of N lives lost at one time relative to the impact of one life lost in each of N separate incidents [12]. Wilson [13] suggests that N lives lost at once are N squared times more important than the loss of a single life, while Ferreira and Slesin [14] suggest that it may be closer to a function of N cubed. Slovic et al. [12], on the other hand, suggest that a single weighting function oversimplifies the effect of catastrophes on the public and "cannot adequately explain, predict or guide social response to catastrophe."

2.3 Implicit Association Test

The psychometric approach to risk perception is not the only way to look at the issues. A more recent approach by Siegrist, Keller and Cousin [5] puts more emphasis on affect as an important factor in risk perception. They have devised a new method to assess implicit attitudes to examine the affect-related component of risk perception.

The affect heuristic is the idea of combining affect and risk perception, and its framework distinguishes two different modes of thinking, the experiential system and the analytical system. The analytic system relies on probabilities, logical reasoning and hard evidence, while the experiential system relies on images, metaphors and narratives. It is Siegrist et al.'s claim that lay people use the experiential system and not the analytic system when asked to evaluate a set of hazards. They claim that implicit measurements may provide insight for a better understanding of lay people's risk perception.

The Implicit Association Test (IAT) developed by Siegrist et al. measures implicit attitudes by assessing the response latencies (the delay in responses to the stimulus) of evaluations in order to overcome the problems associated with asking people directly about their attitudes toward an object. According to the authors, one problem with the psychometric approach is that respondents may not be willing to honestly answer questions posed to them. The benefit to the IAT, on the other hand, is that it indirectly measures strengths of associations between concepts and evaluative attributes, and may measure attitudinal differences not captured by more explicit methods such as questionnaires. This is accomplished by requiring the participants to respond very quickly, which leads to experiential processing [5].

One part of the IAT study examined the implicit attitudes toward nuclear power, based on the assumption that nuclear power is perceived as a dreadful hazard. Participants' implicit reactions to nuclear power were compared to their implicit reactions to hydroelectric power. Siegrist et al. hypothesized that “even those who are indifferent to or in favor of nuclear power do not associate positive affect with the technology”. They discovered that for most participants, nuclear power was more closely related to negative concepts than was hydroelectric power. In addition, the expected relationship between explicit attitudes and implicit attitudes toward nuclear power was observed: those who had positive explicit attitudes towards nuclear power showed lower IAT effects than those who had negative explicit attitudes toward nuclear power.

Siegrist et al. concluded that people who are indifferent to the building of new nuclear power plants have negative implicit attitudes toward nuclear power, or very positive implicit attitudes toward hydroelectric power. They argued that negative or neutral implicit attitudes toward nuclear power might pose a problem for the long-term acceptance of the technology, and warned that people would quickly change their views should another accident in a nuclear power plant occur.

3. Important Themes relevant to Nuclear Power and Risk Perception

Looking at the previous studies by Starr [4], Fischhoff et al. [3], Slovic et al. [12], and Siegrist et al. [5], revealed a number of important themes including trust, the stigma associated with nuclear power, and the difference between the experts and the public, as identified and defined in section 1.3. Each of these themes warrants greater discussion.

3.1 Trust

Trust is such a familiar concept that it is not often explored as a factor in risk management. Society has a tendency to trust technologies in the medical field, while remaining wary of those in an industrial setting, even if they rely on the same technology. For instance, medical technologies based on radiation and chemicals are seen as high in benefit and low in risk, while industrial technologies based on radiation and chemicals are seen as low in benefit and high in risk. The field of risk assessment has developed to assist in the management of technological hazards, and the Environmental Protection Agency (EPA) and the Nuclear Regulatory Commission (NRC) have made risk assessment the center of their regulatory efforts. However, studies have shown that the public perceptions are not necessarily influenced by technical risk assessment. Slovic [7] argues that the solution lies in a new field, the field of risk communication, whose role is to bring experts and laypeople into alignment and make conflicts easier to resolve. Trust is fundamental to conflict resolution. It is also the most important factor to the success of risk communication, for without trust, the risk communication will not work.

One of the fundamental characteristics of trust is that it is created slowly but can be destroyed in an instant by a single mistake. In his article entitled "Risk, Trust, and Democracy," Slovic quoted Lincoln as saying "If you once forfeit the confidence of your fellow citizens, you can never regain their respect and esteem" [7]. Rothbart and Park conducted a survey supporting this idea [15]. Respondents rated 150 traits in terms of the number of instances required to establish or disconfirm the trait. Favorable traits were judged to be hard to acquire and easy to lose, while unfavorable traits were judged to be easier to acquire and harder to lose.

Slovic et al. [12] argued that the occurrence of a rare, catastrophic event contains information regarding the probability of its recurrence, an effect he deemed the event's signal value. They claim that the number of people killed appeared to be unimportant in determining the signal value of an event.

Slovic [7] has also proposed the so-called asymmetry principle, claiming that mechanisms of human psychology make it easier to destroy trust than to create it. He suggests that negative events are more visible or noticeable than positive events, and that negative events carry more weight than positive events. In a study by Slovic, Flynn Johnson & Mertz [16], 103 college students were asked to rate the impact of 45 hypothetical news events pertaining to a large nuclear power plant nearby. They were instructed to indicate whether their trust in the management of the plant would be increased or decreased, and how strongly it would be increased or decreased on a scale from 1 to 7. Slovic plotted the percentages of category 7 ratings (very powerful impact on trust) for each of the news events. His results are shown in Figure 4.

It is interesting to note that while "Record keeping is good" could account for only a negligible increase in trust, "poor record keeping" would decrease trust by 18% and "records were falsified" had the greatest percentage of impact for decreasing trust. The only event that had any substantial impact on increasing trust stated, "an advisory board of local citizens and environmentalists is established to monitor the plant and is given legal authority to shut the plant down if they believe it to be unsafe" [16].

Slovic [7] argued that sources of bad news are also seen as more credible than sources of good news. He chose as an example the fact that positive '(bad news)' evidence from animal bioassays is assumed to show evidence of a risk to humans,

whereas negative evidence that the chemical was not found to be harmful, carries little weight in proving its safety.

Another aspect of dealing with trust is that once any distrust is initiated, it tends to reinforce and perpetuate distrust. Distrust prevents the formation of personal contacts and experiences needed to overcome that distrust. Any initial trust or distrust will cloud the interpretation of new events, and will only serve to reinforce the prior belief. For example, those who supported nuclear power saw the accident at Three Mile Island as proof that the system worked, noting that the multiple-safety systems shut down the plant and contained most of its radiation. Those who distrusted nuclear power to begin with perceived that those in charge didn't know what was wrong or how to fix it, and it was only luck that prevented a major catastrophe [7].

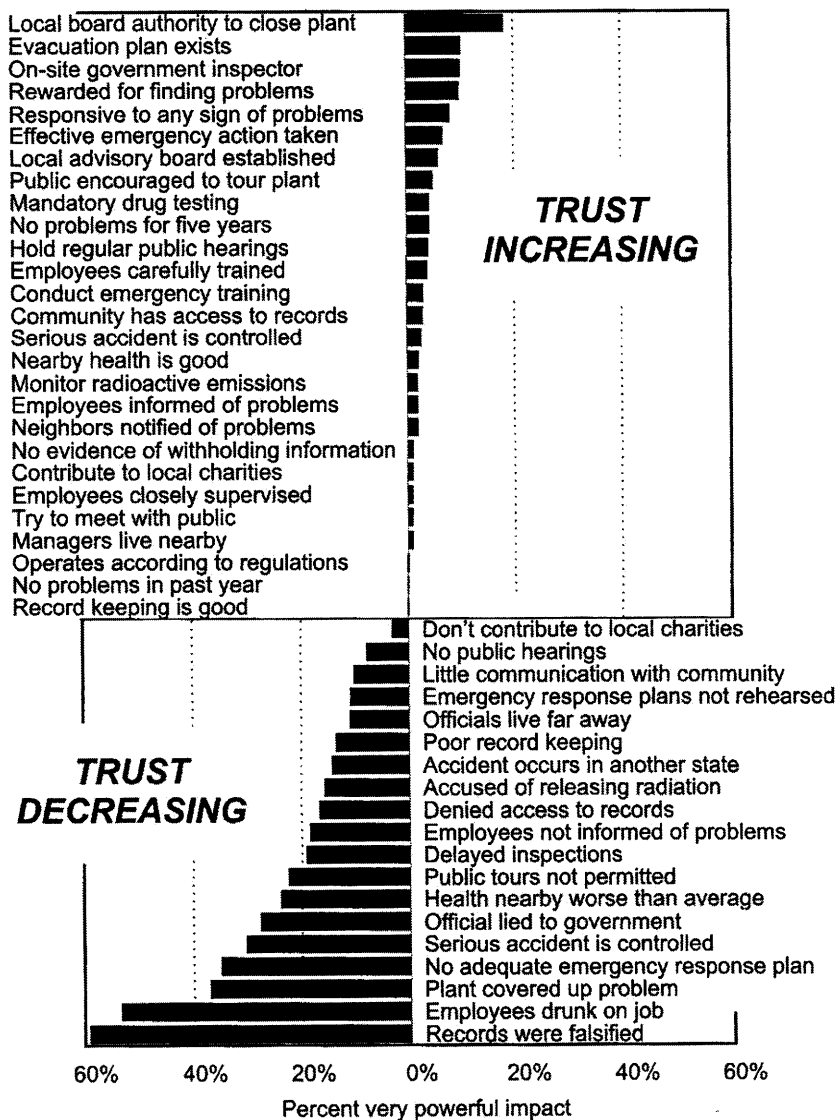


Figure 4: Impact of Events on Increasing and Decreasing Trust

3.2 Stigma

Stigma is most often associated with concerns society has about health risks of technologies, including nuclear power, hazardous waste storage, genetic engineering, and electromagnetic fields [17] and is most often brought about by some critical event, accident or report of a hazardous condition [18]. Stigmatization represents an

increasingly significant factor, which influences development of risk management policies as well as the general acceptance of technologies [17]. In the 1950s, nuclear energy was said to be clean, cheap, and safe, but is now subject to stigmatization [18]. This reflects the public's perception of abnormally great risk and their distrust of management.

There are many aspects of nuclear power that have been stigmatized, but one of the most notable is the debate on nuclear waste. Slovic et al. [10] argue that the lack of a suitable solution to the problem of nuclear waste is an obstacle to the development of nuclear power, and threatens the operation of existing reactors, as well as being a safety hazard. The question of stigma has been studied with relation to the proposed nuclear waste repository in Yucca Mountain, Nevada and some have argued that Nevada will lose some of its attractiveness to tourists with the presence of the repository. It is their argument that places, technologies and products become stigmatized and as a result suffer economic losses due to the negative characterization [17]. It is for this precise reason that in 1992, the supreme court of New Mexico upheld an award of \$337, 815 to a couple for diminished property value due to the proximity of their land to a proposed transportation route for transuranic wastes [18].

The stigmatization of nuclear waste is greatly unfounded, according to some. Lewis [19] argued, "The risk from a properly constructed repository is as negligible as it is possible to imagine... It is embarrassingly easy to solve the technical problems, yet impossible to solve the political problems... High-level nuclear waste disposal is a non-risk". Yet the stigma surrounding nuclear power and nuclear waste remains.

In a study conducted by Slovic, Flynn, & Layman [10], 2500 respondents were questioned by telephone about their perceptions of the risks and benefits associated with a nuclear waste repository, their support of or opposition to the Department of Energy (DOE) repository program, their trust in the ability of the DOE to manage the program, and their views on a variety of other issues pertaining to radioactive waste disposal. The average distance that the respondents were willing to live from a nuclear waste facility was 200 miles, which is twice the distance they were willing to live from a chemical waste landfill. To further investigate these feelings surrounding nuclear waste, Slovic, Flynn & Layman conducted another study [10] in which 3334 respondents were asked to freely associate about the concept of a nuclear waste repository. Their responses were assigned to 13 general categories, the largest of which were “negative consequences” and “negative concepts”. Of note is the extreme negative quality of the images, where a general category labeled “positive” only accounted for 1% of the images. Also of note is that when responding to a prompt of nuclear waste repositories, there were no positive associations to energy and other benefits of nuclear power. This led Slovic, Flynn & Layman to the conclusion that the images people had towards a nuclear waste repository showed an aversion so strong that “to label it dislike hardly does it justice.”

Nuclear fears are deeply rooted in our social and cultural consciousness, centered around the use of “uncanny rays that brought hideous death or miraculous new life” [10]. The general fear of nuclear technology may stem from the destructive power of nuclear weapons witnessed in the bombings of Hiroshima and Nagasaki; in fact Fiske, Pratto and Pavelchak [20] found that people’s images of nuclear war were similar to the images they obtained for nuclear waste repositories. Even before the accidents at Three Mile Island

and Chernobyl, people expected nuclear accidents at nuclear power plants to lead to disasters of immense proportions. People asked to describe the consequences of a typical reactor accident came up with ideas like the aftermath of nuclear war [21]. This shared imagery of nuclear weapons, nuclear power and nuclear waste may explain why the idea of a nuclear waste repository is so feared by the public.

Another aspect of stigma surrounding nuclear technologies is the idea of “tampering with nature.” There is a basic assumption that what is natural is safe and healthy, and what is artificial or manmade is the opposite. A dimension of the “tampering with nature” variable may include a moral component, and there is a well known link between morality and risk as well as risk acceptability. Sjoberg [6] suggests that the main fear from nuclear technology is connected with the specific fear of radiation and cancer.

Despite the stigma surrounding nuclear power, there is still hope, as recent studies indicate that those living closest to nuclear power plants approve of them. A study conducted by Morrison, Simpson-Housley & De Man [22] focused on how people living near a nuclear plant cope with the threat of nuclear emergency at the plant. They discovered that certain traits that individuals use to defend themselves against threats could be used to place them on what they termed “the repression-sensitization continuum.” At one end of the spectrum are the repressors who use defense mechanisms such as avoidance, denial, rationalization, and repression to avoid anxiety-producing circumstances. Morrison et al. [22] claim that repressors deal with threat by minimizing or denying its existence, and do not express their feelings about the danger or contemplate its consequences. On the other end of the spectrum, sensitizers use

intellectualization, obsessive thinking and ruminative worrying when confronted with a threat. They freely communicate their feelings of anxiety and attempt to achieve control over the danger by over-contemplating its possible consequences.

Their study was conducted in the town of Pickering, Ontario, Canada and consisted of 66 men and 93 women selected at random within a radius of 5 kilometers from the nearby Pickering Nuclear Generating Station. The study consisted of a five-question survey to ascertain their feelings about the nuclear power plant. Ninety-One percent of those responding reported no family history of employment at the nuclear plant. The results of the study showed a much higher density of repressors in the area, which was explained by the fact that that the plant had been in existence for more than three decades and that repressors would be more likely to live near a nuclear power plant. The results also showed that repressors, neutrals and sensitizers in the area all reported low levels of worry about nuclear accidents and the probability of disaster happening, as well as elevated levels of confidence in the utility company in charge of the station. It is important to note that repressors and sensitizers shared a lack of confidence in the government's ability to cope with nuclear disaster.

3.3 Experts and the Public

In his article, "Risk Perception: Experts and the Public," Lennart Sjoberg [1] claims that the reason risk perception is a cause of social conflicts is because different groups perceive risks in different ways. He claims that experts and the public differ in their perceptions of risk according to three basic cases. In Case 1, cases involving well-known and common risks, the public makes basically correct risk judgments, and there is

agreement between experts and the public. In Case 2, experts are concerned, but the public is less worried, as in the case of radon in homes. Finally, In Case 3, risks are judged by experts as being very small, while the public feels that the risks are very large. Figures 5 and 6 show the extent to which Case 3 applies to nuclear power, and the difference in perceptions between experts and the public. Figure 5 shows the responses to the question of whether there is a satisfactory solution to the nuclear waste problem. Figure 6 shows the attitude of the respondents toward nuclear power in general.

Sjoberg [1] suggests several explanations for the observed disparity: 1) The public may be misinformed and the experts may be making realistic risk assessments 2) They may have different definitions of risk, where experts pay more attention to probability and the public pays more attention to consequences 3) Experts directly involved in an area may perceive that they have control over its risks 4) There may be a general political ideology that causes each group to perceive risk in their own way and/or 5) The public may be more sensitive to risks, and may tend to make higher risk ratings, as they are the ones that will be affected.

Experts also differ in their development and understanding of trust. Experts develop their trust in technology before they have any experience in the field. This points to a difference between experts and the public, before the 'experts' have received their professional training. Experts also often assume trust in social and psychological circumstances; as an example, it is the contention of the expert community that a nuclear waste repository would not create stigma on the community [1].

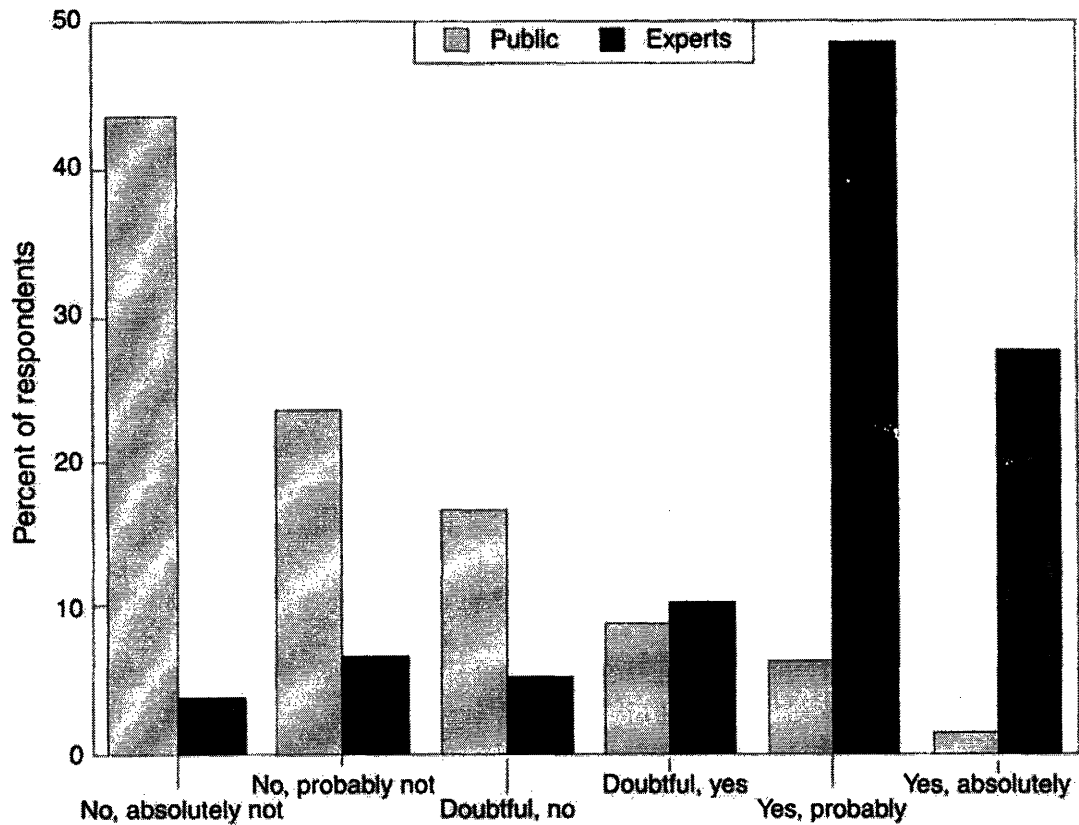


Figure 5: Is There a Satisfactory Solution to the Nuclear Waste Problem?

Sjoberg [1] conducted several studies to examine the difference between experts and the public, especially where nuclear waste is concerned. In his studies, he included a group of graduate engineers from non-nuclear fields, and found that they gave risk judgments midway between nuclear experts and the public concerning the risks from nuclear waste. He concluded that the level of education could not fully explain the difference in perceptions of experts and the public.

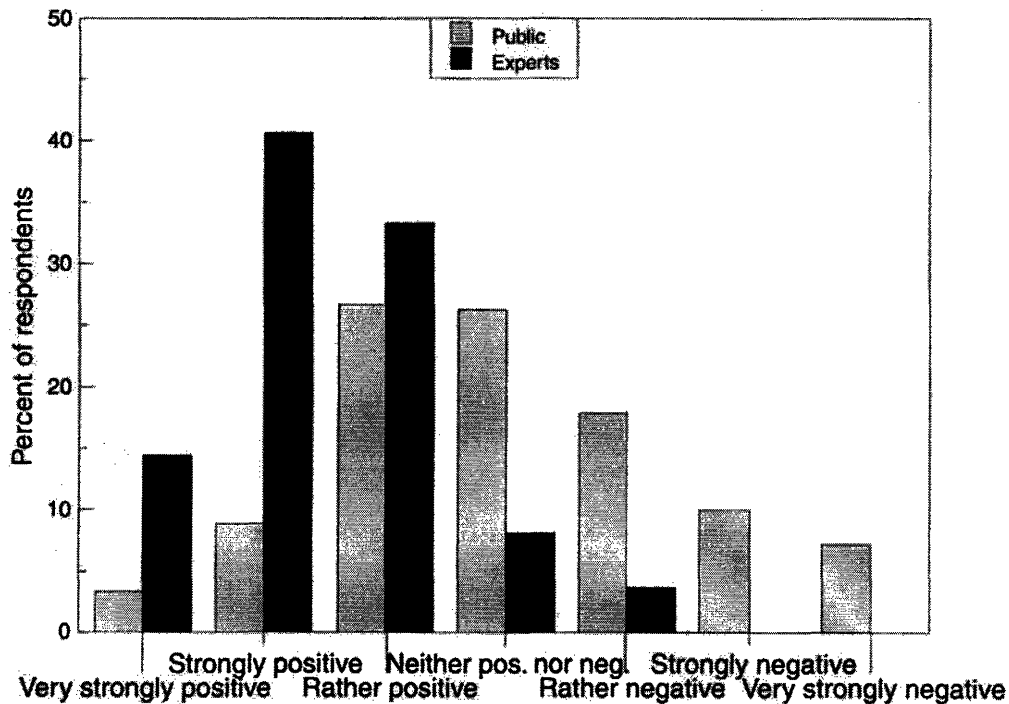


Figure 6: Attitudes Toward Nuclear Power

In another study, experts on nuclear waste disposal and members of the general public were asked to rate a large number of risks. The average ratings are shown in Figure 7. Of interest in Sjoberg's results is that the nuclear waste experts rated risks similarly to the general public, except for risks in their own field of work. They even agreed with the public on the risk from radon, a radiation risk that is not associated with nuclear technology. From these results, Sjoberg concluded that perceived control and familiarity account for the low risk ratings the experts assigned risks in their own field. This supports the importance of attitude to the risk-generating agent as a factor of risk perception. As can be seen from Figure 6, experts in the nuclear field have a very pro-nuclear attitude.

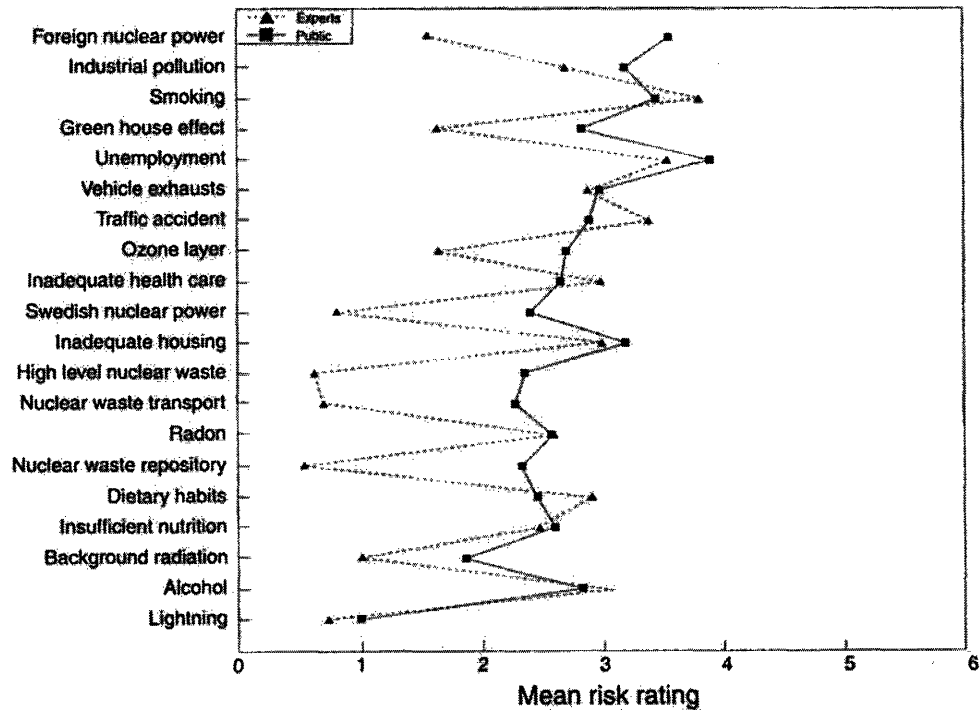


Figure 7: Mean Risk Ratings by Nuclear Waste Experts and the Public

Another approach to understanding risk perception and the need for mitigation (adjustment of the risk to be acceptable by the public) is to include trivial, everyday risks in a study with fatal and very serious risks. It was found that the trivial risks, such as getting a cold or not having your newspaper delivered on time, were judged to be just as large or larger than the fatal risks. Sjoberg [1] argues that this shows two fundamental things about risk: 1) risk is mostly related to probability, and 2) the demand for risk mitigation is related to the severity of the consequences.

It is important to understand the implication that these results have for the understanding of public risk perception. Groups that are different in regard to education, interest, and employment differ greatly in how they perceive risk. So far, there have been no suitable explanations for the differences. The idea that it depends solely on the level of knowledge or education fails to account for the whole picture. It is essential that

experts understand the differences between their perception of risk and the public's in order to set up a dialog rather than one-way communication from the experts to the public.

3.4 Educating the Public

On his return to the EPA for a second term as administrator, William Ruckelshaus called for a government-wide process for managing risks that thoroughly involved the public. In an article he wrote for *Science* he argued:

To effectively manage ... risk, we must seek new ways to involve the public in the decision-making process... They [the public] need to become involved early, and they need to be informed if their participation is to be meaningful [11]

He also argued that the government must accommodate the will of the people, by quoting Thomas Jefferson's famous dictum: "If we think [the people] not enlightened enough to exercise their control with a wholesome discretion, the remedy is not to take it from them, but to inform their discretion" [23]. This proved more difficult than Ruckelshaus had expected. Informing the public about risk issues is surprisingly difficult to accomplish. The challenge is to find ways of presenting complex technical material that is clouded by uncertainty and is inherently difficult to understand in a way that the public can easily understand.

There are definite limits of risk assessment according to Slovic [23]. He argues that risk assessments are constructed from theoretical models based on assumptions and subjective judgments, and if these assumptions are deficient, the resulting assessments may be inaccurate as well. The problems with risk assessment are most evident in the

assessment of chronic health effects due to low-level exposure to toxic chemicals and radiation. There are also problems in the way that engineers estimate probability and severity of accidents in complex systems such as nuclear reactors. Most often, risk estimates are devised from theoretical models such as fault trees or event trees used to depict all possible accidents and their probabilities. However, any limitation in the quality of the analysis, the quality of the judged risks, or improper rules for combining estimates can compromise the assessment.

Similar to the limits of risk assessment, Slovic [23] introduces three major limitations of public understanding: 1) People's perceptions of risk are often inaccurate, 2) Risk information may frighten and frustrate the public, and 3) Strong beliefs are hard to modify, while naïve views are easily manipulated.

People's perceptions of risk are influenced by the memorability of past events, and as such, anything that makes a hazard unusually memorable or imaginable will distort their perception of risk. Risks from dramatic causes such as homicide, cancer, and natural disasters tend to be overestimated, while risks from un-dramatic causes such as asthma, diabetes and emphysema tend to be underestimated. This may be due to the fact that the un-dramatic causes of risk take one life at a time and are common in non-fatal form. The effect of this weighting of risks is magnified by the fact that media coverage of hazards is biased in much the same direction [23].

The inaccurate perceptions of risk by the public suggests the need for educational programs, however, mentioning possible adverse consequences of an activity or technology to the public might make it seem more likely to happen, regardless of the probability associated with the event. A study by Morgan et al. [24] provides evidence of

this. In the study, people's judgments of the risks from high voltage power lines were assessed, and then reassessed after they had read a neutral description of findings from studies of possible health effects due to such lines. The results found by Morgan et al. showed a definite shift toward greater concern. It appears that the mention of potential risks raises concerns, but the use of worst-case scenarios creates extremely negative reactions in people because they have difficulty appreciating the improbability of the event, but can easily imagine the consequences [24]. People attempt to reduce their anxiety about the uncertainty of an event happening by imagining that the risk is so small that it can be ignored, or by imagining that it is so large that it should be avoided. The public generally rebels against being told probabilities instead of facts. Ideally, people would prefer to know that the risks are being managed by competent personnel, and that they don't have to worry about the risks, but if they can't get these assurances, they would want to be fully informed [23].

Another important limitation of public understanding deals with people's beliefs. People's beliefs change very slowly and are persistent even when confronted with contrary evidence [25]. When new evidence is presented, people only find it reliable and informative if it is in line with their previous beliefs, and evidence that is contrary to their beliefs is dismissed as unreliable, erroneous or unrepresentative [23]. On the other hand, when people lack a strong opinion initially, they are easily swayed by the way that the information is presented. By representing risks in terms of how many people died instead of how many lived in a form of treatment for lung cancer, McNeil et al. [26] observed a drop from 44% of respondents approving of the treatment to 18%. This shows that those

responsible for information programs can manipulate perceptions and behavior based on their method of presentation.

The news media has an important role in informing people about risk. Critics of the media note that there is a great deal of misinformation dealing with hazards such as recombinant DNA research, nuclear power, and cancer. Some blame the media for the public's apparent overreaction to risk [23]. Bernard Cohen argued:

Journalists have grossly misinformed the American public about the dangers of radiation and of nuclear power with their highly unbalanced treatments and their incorrect or misleading interpretations of scientific information... This misinformation is costing our nation thousands of unnecessary deaths and wasting billions of dollars each year. [27]

However, some argue that it is not entirely the journalists' fault. Slovic [23] argues that journalists lack the scientific background necessary to sort through the complex information that they gather. He argues that because of the technical complexity of the subject matter, journalists must depend on expert sources. But even this is not infallible, as the journalists may not be able to identify which experts they need to interview.

There are two directions for further research Slovic suggests that require additional focus: informed consent, and risk and the media [23]. Most of the efforts to communicate risks are based on the rights of the public to be informed about hazards to which they are exposed. Research is needed to find out what people know and what they *want* to know about risk, and to determine the best way to communicate that risk to them. Ideas that at first appear to be useful often turn out to make the problem worse. One example is discussed by Slovic [23], "an attempt to convey the smallness of 1 part of toxic substance per billion by drawing an analogy to a crouton in a 5 ton salad seems likely to enhance one's misperception of the contamination by making it more easily

imaginable". Testing the message can provide a necessary insight into the impact it will have on the public. It is also of great importance to discover whether a message will adequately inform its recipients. According to Slovic, "an informer who puts forth a message without testing its comprehensibility is guilty of negligence" [23]. It is still a question of how one can accurately test a message, and how the communicator knows when a message is good enough. Further research is needed on this front to explore these aspects of informing the public.

Further research is also needed on the front of risk and the media in order to improve the media's role in communicating risk. Incidents involving hazards perceived to have Slovic's characteristics of "unknown", "dread", and "catastrophic potential" appear to receive greater news coverage than other incidents. It has been hypothesized that these stories arouse negative affect and influence public perception of the risks associated with the technologies or hazards [23]. This requires further study in order to understand exactly how media coverage influences our perceptions of threat.

4. Present Political Status of Nuclear Power

One of the goals of this thesis is to examine how the research that has been done on risk perception has been applied to nuclear power, if it has been applied at all. In order to understand the current political status of nuclear power, the roles and opinions of three important groups dealing with nuclear energy were examined: 1) the NRC, 2) the nuclear energy production industry, and 3) experts in the field of nuclear power and environmentalists concerned with the subject. I looked specifically at the impact that

nuclear technologies have on the public, and the efforts being made to understand and mitigate that impact.

4.1 The Role of the Nuclear Regulatory Commission

In a recent speech, the Chairman of the NRC, Dr Richard Meserve [28], discussed the current state of nuclear power, and where he saw the duties of the NRC going in the future. Meserve claimed that nuclear power is currently experiencing a “quiet renaissance” in the United States due to the rising cost of electric power and more stringent limits on conventional power production due to environmental concerns. He used the term ‘quiet renaissance’ to express the fact that though more interest is being generated about nuclear power, it has been mostly overlooked by the public. However, the benefits of nuclear power are being brought to the public’s attention through increased efficiency and an ever-improving safety record. Meserve argued that the economic success of nuclear power is intimately related to the safety and reliability of the plants:

the data show that strong economic performance goes hand-in-hand with strong safety performance: attention to safety serves to make plants more reliable. Safety and economic performance are not merely compatible; they are mutually reinforcing. It is no accident that the steadily improving economic performance of nuclear plants over the past decade is accompanied by remarkable improvements in the safety performance indicators -- fewer scrams, greater availability of critical equipment, fewer unplanned shutdowns, and reduced radiation exposure of workers [28].

Meserve sees the role of the NRC in the future to maintain acceptable safety performance while eliminating what he termed “needless regulatory burden,” not needed to assure public health and safety, to protect the environment, or to safeguard nuclear

materials. He recognizes the importance of public attitudes in the success or failure of nuclear energy, and argues that it is an obligation of nuclear regulators to understand and confront public concerns about nuclear technologies. Meserve argued that this does not mean that it is the NRC's job to promote the use of nuclear power, but that the NRC has a significant impact on public attitudes and "must be seen as a rigorous, independent and capable regulator". In fact, it is one of the NRC's major goals to enhance the public confidence in the abilities of the NRC [28].

In order to increase the public's confidence, Meserve identified the need to enhance communication and openness. He argued that the most important aspect to instilling confidence is to provide open process so the public has the opportunity to voice their concerns and see that they are being listened to. There must be an effort to involve the stakeholders in the development of the regulatory processes. One way this can be accomplished is by ensuring that the information is available to the public. It is important to remember, Meserve cautions, that it is not possible to force everyone to agree, but that the goal should be to offer the information and show that no concern has been ignored [28].

Many of these principles advocated by Meserve are in line with the suggestions put forth by Morgan et al. [24] on educating the public, and Meserve's conclusion shows definite promise for the future of nuclear power regulation and its understanding of public perceptions:

I believe that, in order for nuclear power to play a significant role in sustainable development, there must be a demonstrated commitment to safety. To this end, the industry and the NRC both have a responsibility to ensure safe operations. Moreover, the fulfillment of nuclear technology's potential is dependent on its acceptance by the public. The NRC's

responsibility is to ensure that the public has reason to be confident in the NRC's capabilities as a strong, competent, and fair regulator. Other issues, such as waste disposal, must also be dealt with promptly and forthrightly. If these issues can be resolved, the renaissance of nuclear power that appears on the horizon may be realized [28].

4.2 The Role of the Nuclear Power Industry

In preparing a discussion of the current status of the nuclear power industry, I interviewed Craig Nesbit, Director of Communications for Exelon Nuclear Operations. I chose to explore the practices of Exelon Nuclear as it operates the largest nuclear fleet in the country, providing more than 18,000 megawatts, or 20% of the U.S. nuclear industry's power capacity [29]. I contacted Mr. Nesbit by phone and was able to get a general sense of how the nuclear industry, specifically Exelon Nuclear, deals with public perceptions of nuclear power, and what the future holds for nuclear energy from an industry standpoint.

Nesbit began the interview by cautioning that the premise that the nuclear power industry acts as a whole may be incorrect. He suggested that while some companies practice proactive outreach programs, others do not. He warned against assuming that Exelon represents the entire nuclear power industry. Nonetheless, an examination of the practices of one of the largest operators of nuclear power plants does provide insight into the industry, and offers a glimpse into what is being done by the larger companies at least.

While Exelon Nuclear has been around for less than 10 years, the nuclear power industry has a long memory, and the consequences of the accidents at Three Mile Island

and Chernobyl have not been forgotten. Nesbit agrees with Slovic et al.'s discussion of the signal value of events [12]. It is not always the event itself that affects the public's perception, but the idea that it may happen again elsewhere. It is this idea that the nuclear industry must combat, and Nesbit claims that it is not entirely a question of public relations. Public acceptance has more to do with good operation than public relations. By operating safely and efficiently, nuclear power plants can prove that they are safe. The efficiency of nuclear power plants, measured in output and operating time, is very important to public acceptance, as the technology is seen as worthless if it is safe but doesn't produce any power. However, even with a long history of safe and efficient operation, Nesbit admits that perception can change in an instant with one mistake. This idea is echoed by Siegrist et al. [5], who concluded that people would quickly change their views about nuclear power should another accident in a nuclear power plant occur.

The only way to combat the risk of an accident at a nuclear power plant is by emphasizing safety to an extreme level. Safety is ingrained in the minds of workers at nuclear power plants, and is emphasized and rewarded by management. At Exelon, there is no penalty for conservative shutdowns. In fact, conservative thinking is stressed because it is understood that conservative thinking is important in order to prevent any accidents from occurring. Nesbit claims that the incident at the Davis-Besse plant is an example of when conservative thought processes were not encouraged, and output was given priority over safety. The risk in the nuclear power industry is that mistakes have much greater magnitude, so there is far greater pressure on those managing the plants to prevent accidents from happening. A mistake at a coal-fired plant may cause damage to

components and may shut down the plant, while a mistake at a nuclear plant could cause serious damage to the industry as a whole.

This introduces the question of how it is possible to convince people of the safety of nuclear power. Nesbit claims that the major issue at hand is that people fear what they don't understand. The more they understand, the less they will fear. He suggests that getting the public to understand how things operate in a nuclear plant is at the heart of aligning their ideas of the risks of nuclear power with those of the experts. If they are able to observe the mentality of those working in nuclear power facilities and gain an understanding of the training the workers receive, the public may be able to better appreciate the efforts of the industry, and may begin to show more trust in the managers of nuclear plants.

Education programs and plant tours may account for the fact that those living in close proximity to nuclear power plants tend to accept them more, and approve of nuclear power. Nesbit claims that being around the plants on a daily basis and interacting with plant employees decreases the unknown dimension of nuclear power. The work done by Morrison et al. [22] affirms that though there is a stigma surrounding nuclear power plants, those living nearby do show greater support for the technology.

One aspect of risk communication that Nesbit stressed was that it is essential that everyone know everything. He argued that each nuclear plant must do an excellent job of keeping the public informed about every detail of the day-to-day operations of the plant. If there is ever any instance that could cause alarm, the public must be told immediately. This goes all the way down to an ambulance coming to the plant. If someone trips and breaks their leg, and an ambulance is called to take him/her to the

hospital, people at the plant contact every stakeholder to explain why they will be hearing an ambulance siren. This constant communication sets up a foundation of trust, so that people will understand what is going on at the plant, and not fear that they are being kept out of the loop. If people know that something's going on, but don't know the specific facts, they will fill in the blanks with their imaginations.

This strategy of communication is very much in line with a degree of openness and involvement with the public that Slovic [7] claimed is necessary to restore a degree of trust. I believe that this level of communication is an example of what Slovic [7] meant by going "beyond public relations and two-way communication to encompass levels of power-sharing and public participation in decision-making" that hadn't been seen at the time. Nesbit claims that for a nuclear plant to be successful, the people must have confidence in the leadership and management of the plant.

When asked about the future of nuclear power, and what pitfalls he foresaw with a possible increase of nuclear power plants being built in the country, Nesbit replied that he expected no change in the focus on safety with the addition of more plants, arguing that the emphasis on safety is too ingrained in the minds of nuclear engineers. However, he believes that there is a risk of taking public support for granted, assuming that public support for nuclear power means that their fears have dissipated, and there is no need for communication. He claims that the danger is that the plant managers will stop dealing with their neighbors. There is the possibility of repeating the "bunker mentality" seen after the accident at Three Mile Island, where the public was kept out of the loop, and left out of the decision-making dealing with the plants, while the industry pretended to keep them informed by offering school visits and plant visitor's centers rather than

communicating with them. As more plants begin to appear, the public must remain informed and in control for nuclear power to continue to be successful.

4.3 Expert Opinions and the Role of Environmentalists

In the current political environment, it is a strange coincidence that experts in the field of nuclear technologies are actually thinking along the same lines as environmental activists. Current concerns over global warming and greenhouse gases have caused a resurgence of interest in nuclear power as a clean energy source. One of the only issues preventing the widespread acceptance of nuclear power is the question of what to do with nuclear waste, but this issue is being discussed by experts in the field and environmentalists alike to determine a solution.

In an interview with Environment & Energy Daily [30], Robert Rosner, the director of Argonne National Laboratory, made a claim that nuclear energy is unavoidable at some level in the long run. He argued that it is not possible to contain all of the carbon dioxide being emitted from the use of fossil fuels if there is not a significant change. This is not a new argument for experts in the nuclear energy field, but what is new is Rosner's argument for the reprocessing of spent fuel. Rosner argued for the implementation of the Global Nuclear Energy Partnership (GNEP) program put forth by the Bush administration, which aims at reducing waste through the reprocessing and recycling of nuclear waste. Once reprocessed, what is left can be characterized as low-level waste, and alleviates problems with storing it. Rosner argues that the reprocessing of nuclear waste is essential due to the fact that 2,200 tons of radioactive waste is created annually in the United States. That means that by the year 2050 the US will have

produced more than 94,600 tons of nuclear waste in addition to what is currently being stored at plants across the country, and the proposed nuclear waste repository at Yucca Mountain will only have a capacity of 77,000 tons.

An interesting case to examine in the area of experts and environmentalists is that of Patrick Moore, one of the founding members of Greenpeace, a decidedly anti-nuclear environmental group, who recently left Greenpeace to become co-chairman of the Clean and Safe Energy Coalition (CASEnergy) a group that supports nuclear power [31]. Moore points out that Greenpeace and other environmental groups were founded on the principle of lumping civilian nuclear energy and nuclear weapons together, but he argues that principle is a mistake. Even though he was one of the founders of Greenpeace, he recognizes that a distinction needs to be made between nuclear power and nuclear weapons. He argues that one of the downsides of environmental groups like Greenpeace and the Sierra Club is that they do not foster freethinking, or the reevaluation of their principles. Moore claims that if you are in Greenpeace you are not allowed to support nuclear power, it is seen as heresy. However, Moore argues that there are many benefits to nuclear power and discusses some of the public's resistance to it, from the perspective of a former anti-nuclear activist.

Moore argues that fossil fuels have many other uses such as fertilizers and plastics, but we are burning through them at a ridiculous rate, while there is only one use for uranium, and that is for the production of energy. He argues that a reduction of fossil fuel consumption is necessary, but he does not believe that renewable resources can be used alone. Eighty-six percent of the country's energy supply currently comes from fossil fuels, and Moore claims that the only ways to dramatically offset the use of fossil

fuels is hydroelectric power and nuclear power. While hydroelectric power has the potential for large amounts of energy, Moore notes that it is already built almost to capacity in industrialized nations, reducing the choice to between fossil fuels and nuclear power. Given this choice, Moore argues that support should clearly be given to nuclear power.

One aspect of public concern that Moore discusses is the fear of proliferation of nuclear weapons. Moore argues that the public too often associates nuclear power with nuclear weapons, and that the two technologies are very different. He also argues that an increase in nuclear power plants would not pose any increased risk of nuclear weapon proliferation, as nuclear reactors are not necessary to enrich uranium for nuclear weapons. In fact, Moore argues that it is harder to make a bomb from used nuclear fuel than it is to enrich uranium with centrifuge technology. He suggests that even if we shut down all of the nuclear power plants in the world, it would not prevent military use of nuclear weapons, and that an increase in nuclear power plants would not hurt the situation.

Another aspect of concern is the issue of nuclear waste, but Moore argues that the issue is not as pressing as one would believe. Moore claims that nuclear waste is fully contained, and that it is not going anywhere, the much more important issue is respiratory problems caused by the burning of fossil fuels. Moore claims that nuclear waste is safely and securely stored, and that at some point in the future it will be recycled to get at some of the energy still in the waste. He claims that a feasible recycling program may not happen for 30 to 50 years, but that engineers are fully capable of keeping the waste safely stored until then, just as it is being done every day at 103 reactors around the country.

5. Recommendations for the Future of Nuclear Power

Research into the public's perception of risk and insight into how the nuclear power industry operates today makes it possible to draw conclusions pertaining to the nuclear industry's public relations. Recommendations can be drawn from this research that will aid in the development of nuclear technology and a resurgence of nuclear power, while addressing the public's concerns and furthering the public's understanding of nuclear technology. These suggestions are all inter-related, and have been presented in an attempt to build on the discussion of each into the next.

5.1 Decrease Dread, Increase Familiarity

In Slovic et al.'s study [12] one of the major results was shown visually by plotting the hazards on a graph as a function of Factor 1 (Dread) and Factor 2 (Familiarity) shown in Figure 3. This figure shows nuclear power isolated from the other hazards being both high dread and low familiarity. The first recommendation is a general one that will be built off of in subsequent recommendations, and that is that the position of nuclear power on the graph of dread and familiarity must be improved. It is necessary to decrease the dread the public feels toward nuclear power, and to increase their familiarity with the technologies being utilized. Many cues can be taken from section 3.4 on ways of informing the public about risk, but most important to this suggestion is understanding the limitations of public understanding. Great care must be taken to avoid frightening the public or an increased familiarity may have the negative effect of increasing dread. Coupled with educating the public to increase its familiarity with the

technology, continuing safe operating procedures at existing nuclear power plants will have a profound impact on lowering the public's perceived dread from the hazard.

5.2 Conducting Studies from an Industry Perspective

To date, the majority of research available on the subject of risk perception has been done from a psychological point of view. The psychological view is useful in understanding the way that people think about risk and how their perceptions of risk affect their decision-making abilities; however, a more focused look at risk pertaining to the nuclear power industry may be of greater use. The nuclear power industry has not explored such a dimension, and has thus far relied on outside research to understand how the public reacts to risk. While some of the studies have looked specifically at nuclear power, there has been little research done by the nuclear power industry itself. Such an examination could be useful to the industry as it may offer a perspective specifically important to the goals of the industry. Research should be conducted directly by the industry to explore aspects that reflect efforts the industry has made to affect public opinions, and could be repeated in order to gauge the success or failure of their efforts. This may aid in a better allocation of resources toward programs that are getting the message across to the public, and could improve the overall image of nuclear power.

5.3 Work with the Media

The news media can greatly affect public perceptions of how risky a technology is. Slovic [23] argues that the media has a tendency to misinform the public about technological risks, and that this may cause the public to overreact to certain risks. In

order to improve the performance of the media, he argues that the first step is to acknowledge the potential the media has for informing the public about risk, and commit to improve the quality of information. This can be accomplished by enhancing science writing and developing science news clearinghouses. One way to do this is by increasing scholarships to induce students and young journalists to pursue science writing as a field, and recognizing and rewarding good science journalism when it occurs. Science journalists will also need access to knowledgeable and cooperative scientists, and so science news clearinghouses should be developed to help journalists get reliable information about risk topics [23]. It is also necessary to reach out to the media to communicate the issues that nuclear power is dealing with. As public opinion is starting to shift more toward nuclear power as a clean energy source, the media will be essential in relaying information about nuclear power to the public, and as such, it falls on the nuclear power industry to ensure that the media understands the information and is relaying it correctly. This means working with the media to educate the public and share information about risks without misinforming the public.

5.4 Focus on Safety and Performance to Restore Trust

Due to the accidents at Three Mile Island and Chernobyl, the public has developed a lack of trust in the nuclear industry. Trust takes a very long time to regain once it is lost. Restoring the public trust will be a long and exhaustive process. According to Carter [32], “trust will be gained by building a record of sure, competent, open performance that gets good marks from independent technical peer reviewers and that shows decent respect for the public’s sensibilities and common sense”. The focus for

the nuclear power industry must be on safety, but also on efficient performance. Fortunately, strong economic performance is closely tied with strong safety performance. Attention to safety makes plants more reliable. It is not an accident that steadily improving economic performance is accompanied by fewer scrams, fewer unplanned shutdowns, and reduced radiation exposure of workers. According to Nesbit, the industry is already focusing on safety and performance as ways to gain the public's trust. I claim that the effort will have to be maintained indefinitely, and that a continued focus on safety and performance will be necessary for the success of any growth of nuclear power in the future.

5.5 Communication is Imperative

Communication is another aspect that is currently being practiced well in the industry, but must continue or even expand to improve the public's perception of nuclear power. Nesbit shared an anecdote showing the level of communication required of the nuclear power industry: when the mayor of Middletown, PA was asked if he was worried about what might happen at the nearby nuclear power plant at Three Mile Island, he responded, "Why should I worry? Not a fish jumps out of the water at Three Mile Island without my knowing about it." The idea is that no matter how small the detail, the plant will make sure all of the stakeholders know about it, and this will help to build trust in the industry. Communication is absolutely essential to keep the public informed and prevent any irrational fears from taking hold.

That being said, communication is only effective if the communicators understand their audience and attempt to communicate risk, not just deal with public relations. It is a

common pitfall of risk communication that the risk managers assume that the public shares their views of risk. This must be avoided, as it will only show the public that the risk communicator does not truly understand them. On the other extreme is the public relations approach, which can be designed to placate the public, and sees them as ignorant, emotional and superficial, and employs tricks in the presentation such as the attire of spokesperson and their body language. Risk communication is about more than just winning over the audience; it is about sharing knowledge and helping the public to understand the risks associated with the technology.

5.6 Cultivate Support from Environmental Agencies

One of the most promising areas of support for nuclear power is in environmental agencies that are beginning to look to nuclear power for a clean alternative to fossil fuels. It is essential that their support is cultivated and that the industry does everything it can to ensure that it can allay any concerns the environmental groups may have. One of the biggest concerns is that many groups, including Greenpeace, still group nuclear power together with nuclear weapons. This thought process must be dispelled. The nuclear power industry must do everything it can to distance itself from the negative imagery associated with nuclear weapons, and help to educate the environmental groups on the differences. The assistance of nuclear industry groups such as CASEnergy and the Nuclear Energy Institute (NEI) should be sought in this endeavor. If the nuclear power industry can gain the support of environmental groups like Greenpeace, previously one of its biggest opponents, the considerable lobbying power of these groups could be used to gain public support for nuclear power as a clean sustainable energy source.

5.7 Encourage Public Participation

Slovic [7] proposes that new approaches to risk management are necessary. He claims that there are two options: 1) take away public participation and impose more centralized control as is done with the French nuclear power program, or 2) restore trust by imposing a degree of openness and involvement with the public that goes beyond public relations and communication, and employs power-sharing and public participation in decision-making. It is doubtful that the first option, the French method, would work in the United States, though the second option has great potential for increasing trust in the nuclear power industry. As shown in Figure 4, the only event that had any substantial impact on increasing trust stated, “an advisory board of local citizens and environmentalists is established to monitor the plant and is given legal authority to shut the plant down if they believe it to be unsafe” [16]. Forming such an advisory board would serve two purposes: 1) it would require the members to go through a training or education program so they can better understand the issues at hand, and 2) it would empower the community and give them a sense of involvement in the process. While this option would require the most effort to bring about, it also has the potential for the greatest positive effect, if conducted properly.

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