

**Radioactive Waste Transport:  
Managing Risk Perception and Communication – 9228**

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**ABSTRACT**

The implementation of a national transportation system for spent nuclear fuel and high-level waste that merits public trust and confidence will require the delivery of consistent, accurate and timely transportation messages; stakeholder and public understanding of the need for, and safety of, shipments; and effective two-way communication to address stakeholder concerns in its decision-making processes. Building the trust and consent of stakeholders and the public is complex and challenging. In order to accomplish this goal, it is imperative to understand how and why members of society develop various perceptions of risks and assessments of benefits with regard to the nuclear energy cycle. Understanding the basis and reasons for the public's beliefs concerning the nuclear energy cycle will allow OCRWM to more effectively address concerns regarding the national transportation program. This paper will examine how a person's gender, sources of information, worldview, culture, emotion, cognition, and other factors affect their beliefs and perceptions of risk. It will also explore the reasons why nuclear energy and nuclear waste are viewed with such a distinctly different attitude than other hazardous materials that pose a comparable or greater hazard. Drawing on research from prominent experts in risk perception and communication methods, this study will conduct a unique investigation into the perspectives of a diverse set of key stakeholders and experts involved in the transportation process. This paper will present several hypotheses on why there are unique challenges involved in communicating about transportation of spent nuclear fuel and other nuclear fuel cycle activities, and also present recommendations for remediating such challenges.

**INTRODUCTION**

The issue of radioactive waste management has hindered a more widespread public acceptance of nuclear power generation in the United States. Until the public is absolutely confident that such wastes are going to be safely managed, they are less likely to support the licensing and construction of new power plants. The uncertainty over what constitutes the best way of handling spent nuclear fuel (SNF) and high-level waste (HLW) remains an obstacle, despite increased calls for energy sources that do not contribute significantly to greenhouse gas emissions, such as nuclear energy.<sup>1</sup>

A central component of the government's radioactive waste management strategy is the transport of SNF and HLW from the generator sites to the proposed disposal site at the Yucca Mountain Project (YMP). The public's high perception of risk associated with waste transport has made the process more difficult to complete.

A key factor in the completion of the project will be addressing and mitigating the concerns of the public by acquiring their trust and confidence – an extremely difficult task[1]. To accomplish this goal, it is first necessary to better understand the extent to which and why the public perceives the risks of the YMP and SNF/HLW transport as being unacceptable.

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<sup>1</sup> For example, several states such as CA, WI, and MN, have bans on the construction of new power plants until a repository is built.

## DIFFERENCES IN PUBLIC PERCEPTION OF RISK

Risk perception is not uniform for all individuals. For example:

- Several researchers have found that women frequently perceive higher levels of risk than men [2,3,4].
- Other research has shown that minorities are more fearful of risks in their immediate area than their white counterparts [5]. In fact, white males tend to have such reduced levels of perceived risk that the term “white male effect” has been coined within the social sciences literature. Individuals subject to this effect are comprised of the thirty percent of white males who tend to be more trusting of institutions and authorities, more conservative, less egalitarian, less fearful of technology, and less supportive of putting decision-making power in public control. These men also tend to have higher levels of education and incomes [3]. Experts have hypothesized that this is because white men typically have greater opportunity to reap the more benefits of new technology and industry than other groups [5].
- Risk perception among minorities is subject to a more muted gender effect, as black men and women have similar perceptions of risk [4].
- Scientists, as a subset of the general public, also hold distinctive perceptions and assessments of risk [6]. Scientists are more concerned with actual quantifiable risk, while the general public is concerned more about *potential, emotion based* risk [4,7]. This “dread” factor plays an essential role within the public in the formulation of their risk perceptions, while risk perception among scientists is more closely associated with mortality rates<sup>2</sup>[8].
- The probability of a serious nuclear-related accident may be immeasurably lower than the probability of a car accident, but the effects of a potential nuclear-related accident are much greater – people see them as catastrophic [9,10]. This explains why arguments based on statistics will be less persuasive with the general public -statistics will never be able to quell fears of a *potential* accident.
- Gender has a strong effect, not only with the general public, but also with well-informed scientists [11]. Research has shown that female scientists are generally more fearful of technology, and more pessimistic of technologies overall. Conversely, male scientists are much more willing to impose involuntary risks on the public, similar to their white male counterparts.

Although this list is not comprehensive, it does show the unique differences in risk perception among different groups. Therefore, to be successful, a risk communication strategy must employ different approaches when communicating with different audiences.

## HOW BELIEFS ARE FORMED

The research findings discussed above should not be interpreted as suggesting that any particular group lacks the necessary information or intelligence to accurately assess risk – instead, it points to differences in how people formulate their beliefs. Risk perception goes beyond quantifiable probabilistic risk

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<sup>2</sup> The “dread” factor is associated with things that are particularly feared by people, such as cancer due to radiation or dying in a terrorist attack. Even if the odds are extremely low of a “dreaded” event occurring, the public will still feel rather susceptible and have an increased perception of risk.

assessment. It extends deep into normative beliefs about how society should allocate risks and society's capability to manage risks [11]. This is vital for those without extensive knowledge of the YMP or SNF/HLW transportation (e.g., the general public), as they will use their general outlook on technology and the cues provided to them by groups who have more in-depth knowledge on such issues. On the other hand, those who do have extensive knowledge on the topics rely on ideology as an important factor when performing risk assessments [12]. Such persons are also much less likely to be swayed by other involved groups.

Although scientists and the public have different perceptions of risk, the basis of their assessments share a common thread via the two interactive models of information processing [13]. The first model uses a heuristic to make initial assessments of risk, allowing people to make quick assessments based on emotional response cues<sup>3</sup>[14]. This has come to be known as the affect heuristic, and sets the frame for future information processing that is difficult to reverse [41]. Additionally, this implicit response is holistic, emotional, and intuitive, relying on the formulation of images to generate assessments. Such images tend to include strong feelings of dread caused by years of negativity associated with all things nuclear that have become deeply ingrained in the public's mind [15,16]. In a 1991 study by Slovic, Flynn, and Layman, thousands of nuclear-related images were presented to respondents who were then asked to report their initial feelings [41]. Of all the responses to the images, only three and a half percent were positive and "safe" was a response less than one-half of one percent of the time. Based on the responses to the images, the public seems to consider a nuclear reactor accident as negative as nuclear war. Everyone uses the affect heuristic to some extent in the evaluation of risks, and as one could expect, this emotion-driven implicit "knowledge" is actually quite compelling.

The initial heuristic response subsequently triggers the cognitive response, the second model, which focuses on logic rather than images. According to a 2006 study by Siegrist, Keller, & Cousin, the initial affective, implicit assessments take place independently from subsequent cognitive judgments. But it also claims that even people who have positive cognitive assessments of nuclear energy may very well have negative implicit, or affective, responses [17]. Furthermore, research by Loewenstein et al. concluded that when the affective response differs from the cognitive response, the affective response can actually carry greater weight in risk assessments [42]. Sometimes, affective evaluations are made and subsequent cognitive evaluations serve only to justify the decision or risk assessment. Nuclear energy is viewed so negatively in America that even supporters are not immune from pessimistic implicit responses. This has precarious implications, as another serious accident could irreparably damage the industry's image. It also helps explain why explicit risk communication strategies, such as past information campaigns, have not been as successful as one might expect.

But what drives these cognitive and emotional judgments? According to Thompson, Slovic, and many others, societal and cultural factors play a huge role in the formulation of risk assessments [18,19]. As such, these factors create a strong bias that people maintain with overwhelming confidence. Research shows that even experts are not immune to such biases. Therefore, it is very difficult to use factual evidence to change people's beliefs, because their initial attitude shapes how they interpret information. Instead of investigating the validity of conflicting information, people are much more likely to consider it erroneous to preserve their belief system. But if there is no previous opinion, then the framing of the question becomes key. For example, presenting the public with a table entitled "mortality rates" will elicit a far different response than one entitled "survival rates".

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<sup>3</sup> A heuristic is a method to help solve a problem, commonly informal. It is particularly used for a method that often rapidly leads to a solution that is usually reasonably close to the best possible answer. Heuristics are "rules of thumb", educated guesses, or intuitive judgments.

Additionally, whether a risk is voluntary or involuntary will greatly influence the assessment of such risk. The public will accept risks from voluntary activities that are one thousand times as great as involuntary hazards [19]. Voluntary risks are seen as controllable, even if the public actually has very little control (e.g., driving a car). Familiarity will also greatly reduce perceptions of risk [20]. For example, since driving a car is familiar, voluntary, and also part of a well-understood system, the risks are considered acceptable and an accident causes little disturbance. But as the nuclear energy cycle is a poorly understood, unfamiliar, and is mostly seen as involuntary system, even the slightest accident has the potential to result in an enormous disturbance [19]. This was exemplified with the partial core meltdown at Three Mile Island, where although no one was injured, the entire worldwide industry was adversely affected.

Achieving a better understanding these effects could have a meaningful impact on future public policy. Therefore, a survey of stakeholders was conducted during the month of June 2008 to further explore their attitudes and opinions regarding the risks associated with the transportation of SNF/HLW and the YMP.<sup>4</sup>

## **METHOD**

A telephone and online questionnaire comprised of 66 items (32 open-ended, 34 closed-ended), was used to obtain the data for this study. A total of 298 stakeholders were contacted via email, resulting in 42 completed responses. The survey sample included recent Transportation External Coordination Working Group (TEC/WG) meeting attendees, representatives from various nuclear, transportation, State and Regional groups (SRG's), environmental groups, tribal organizations and other interested parties.<sup>5</sup> The response rate for the survey was 14 percent.<sup>6</sup>

Of the 42 respondents, 33 percent were classified as holding anti-nuclear views based on their answers to questions regarding nuclear energy. Sixty-three percent were considered to have pro-nuclear sentiments based on the same criteria, while the remaining four percent were undecided. It should be noted again that the respondents are classified as stakeholders (i.e., they are actively involved in the YMP program or the issues associated with transportation of SNF and HLW).

## **DISCUSSION OF RESULTS**

The questionnaire was designed with approximately half of the items as open-ended questions. This was done to facilitate an assessment of the overall concerns, attitudes, and opinions of respondents. It should be noted that the support rates (roughly two-thirds pro-nuclear respondents, one-third anti nuclear respondents) are not representative of the national population; they are simply for reference purposes when interpreting the results from this particular study. The survey was designed to help identify and better understand concerns, attitudes, and opinions among specific stakeholder groups; it was not designed to test support levels of the general public. As such, when a percentage of respondents answer a question in a particular manner, it is only relative to the other respondents, and not to the general public as a whole. For example, one-third of the country may not be anti-nuclear. But if the one-third of anti-

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<sup>4</sup> In this paper, a "stakeholder" is defined as "a person with an active involvement in the transportation of SNF/HLW or the YMP".

<sup>5</sup> TEC/WG is a group designed to improve coordination between the U.S. Department of Energy (DOE) and external groups interested in the Department's transportation activities

<sup>6</sup> This was due to several reasons. Average response time was about 20 minutes (not a short survey), there was no compensation offered, many emails were returned as "undeliverable" for various reasons, many people had auto-replies, and several chose not to participate due to a personal sensitivity to the matter. Also, the survey was sent to business accounts, so many potential respondents did not have spare time during a busy workday.

nuclear respondents in this study consistently have similar concerns, attitudes, and opinions, it can be assumed that the anti-nuclear persons in the public will share similar concerns, attitudes, and opinions to an extent.<sup>7</sup> Therefore, although the sample size is small, it achieves the goal of helping to better understand attitudes and opinions of the respondents.

Although demographic trends are difficult to accurately identify due to the nature of the sample and the sample size, it is interesting to note that anti-nuclear respondents were 60 percent female, compared to only 16 percent for pro-nuclear respondents. As expected, ideology played a significant role, as only ten percent of anti-nuclear respondents reported themselves to be conservative. And of the 42 respondents, only three reported themselves as smokers – and they all were quite concerned about radiation doses from SNF/HLW. Also, respondents were asked how certain they were that their responses were correct on two key questions. The first question related to the dose-response scale, and the second to a hypothetical situation regarding a safety issue with the YMP. Although neither question could actually be answered with strong certainty based on scientific evidence, a great majority of respondents nevertheless felt their answers were definitely correct.<sup>8</sup> While it cannot be concluded from only two examples that respondents felt so certain of all their answers, such an interesting response should still be noted.

### **5.1 Viability of Alternative Energy**

Based on all respondents, over half feel there are alternative energy sources that will be able to produce a base load output of power similar to that of nuclear energy within the next 25 years. Seventy percent feel nuclear power is safer than the traditional sources of electricity (coal, natural gas), and 63 percent favor a role for nuclear energy in America's future. Combined with responses from various open-ended questions, there is obvious support for increased use of nuclear energy in America and a decrease in use of fossil fuels. But there is also a strong push for conservation and alternative energies as a solution to growing energy needs – not just as a supplement, but as a primary source of power. However, the current estimates do not project advancements in alternative fuels sufficient to be able to produce the amount of electricity generation that many respondents seem to expect [21].

### **5.2 Comparison to Chlorine**

When respondents were asked to compare the dangers of transporting SNF/HLW to the dangers of transporting chlorine, 90 percent considered chlorine the more dangerous chemical. When asked for an explanation, most respondents stated chlorine transport was more dangerous due to the significantly higher volumes transported and the overall greater safeguards associated with SNF/HLW transport. But very few specifically mentioned the robustness of the casks or the transport record.

Furthermore, only one person thought if a routine transport accident were to occur, it would be more likely for radiation to be released than for chlorine to be released. Interestingly, 44 percent of respondents claimed they would not buy a home within five miles of a chlorine transport route, and 27 percent claimed they would actually move if a chlorine transportation route was designated within five miles of their home.

In contrast, only 27 percent of respondents stated they would not buy a home within five miles of a SNF/HLW transport route, and only 17 percent stated they would move if a SNF/HLW transport route was designated within five miles of their home. Yet when asked to determine the benefit/necessity of

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<sup>7</sup> Note that stakeholders do tend to be more polarized than the general public.

<sup>8</sup> The dose-response scale represents the effects of increased levels of radiation on the human body. The effects of large radiation doses are well-documented, but the effects of very small doses are not. It is unknown whether the relationship is linear or if a type of threshold exists.

nuclear energy, it was marginally lower than the benefit/necessity of chlorine. In fact, 29 percent stated that nuclear energy had little or no benefit, while only 23 percent made the same statement for chlorine.

These results seem to suggest a response bias, and also show the effects of the negative implicit response associated with nuclear energy. The questions comparing chlorine to SNF/HLW were placed on the 4<sup>th</sup> and 5<sup>th</sup> pages of the survey, and respondents were not permitted to return to previous pages that asked about their general attitudes toward nuclear energy issues. This was purposely done to assist in testing the implicit responses against cognitive responses. Although the nuclear energy cycle is viewed with such implicit negativity, when it is compared to chlorine, the cognitive response seemingly takes over and forces risks to be viewed from an “actual risk” standpoint instead of an emotion-driven standpoint. Respondents were also motivated by their inherent bias to “look smart” and pick the correct answer based on actual risk, which would appear to explain why chlorine transport suddenly became much more dangerous and commanded less support than SNF/HLW transportation, even though the perceived benefit/necessity was still greater for chlorine [22]. This was particularly evident for the anti-nuclear respondents, of which none perceived any benefit from nuclear energy, although over 1/3 reported benefit/necessity for chlorine. But seventy percent of such respondents still rated chlorine transport as more dangerous than SNF/HLW transport.

### **5.3 Levels of Trust**

Slightly more than 20 percent of respondents claimed to trust the federal government or their local government regarding information related to nuclear energy topics. But only 1 person claimed to have any trust in the media’s reporting of nuclear energy topics. When asked what entity a person felt was most trustworthy of reporting information related to nuclear energy topics, however, the answer was not as clear. Several felt the U.S. Department of Energy (DOE) or the Nuclear Regulatory Commission (NRC) to be most trustworthy, while several others listed specific groups such as the Nuclear Energy Institute, the Council of State Governments, or a university. These responses may have been biased depending on their present employer. But taken as a whole, people preferred information from independent sources, although many respondents suggested that all organizations would be biased in some way.

Approximately 64 percent of respondents stated that they trusted the federal government’s ability to safely develop a transportation program for Yucca Mountain. Moreover, respondents generally held favorable opinions of the safety measures implemented by the federal government regarding Yucca Mountain. When confronted with the hypothetical scenario of a major safety issue arising in the YMP, 75 percent believed the government would stop work on the project and resolve the issue, and 81 percent felt certain their response to the question was correct. Only 22 percent felt the government would simply cover up the issue and continue work.

Anti-nuclear respondents were not as skeptical of the government as one might expect. Although 54 percent expected the government to cover up the issue and continue work, 39 percent believed the government would stop work and resolve the issue. It appears that although people have legitimate concerns about the safety of the YMP, there is some degree of optimism that it can be completed in a safe manner should the project continue.

### **5.4 Transport Safety**

Respondents also showed confidence in the ability of SNF/HLW to be safely transported to Yucca Mountain, as 88 percent believed that it was at least possible. But respondents were very concerned about the consequences of potential accidents. Twenty percent of respondents expected at least one major transportation accident to occur that would result in the release of radiation and subsequently kill over 50 people due to such radiation release. And slightly below 20 percent worried a routine transport accident

could result in the release of radiation. Moreover, one-quarter of respondents were more concerned about a potential terrorist attack on a SNF/HLW shipment than on a chlorine shipment. This again shows the dread factor and expected probability of accidents with catastrophic effects associated with SNF/HLW [10]. Generally, it appears that people expect far more accidents to occur than experts predict – not only in the area of transportation, but in the broader domain of SNF/HLW disposal as well [2].

### **5.5 Respondent's Recommendations**

A variety of open-ended questions were posed to respondents asking them to identify issues they felt to be important to the YMP and transportation of SNF/HLW. Respondents were also asked to identify possible changes and improvements.

There was no consensus on a single concern relating to the YMP, but funding and public perception issues were the most prevalent. The data also suggest strong support for reprocessing both as an alternative for the YMP and a future energy source. A Monitored Retrievable Storage (MRS) facility or on-site storage was also supported to a lesser extent, but many saw no alternative to Yucca Mountain. However, it seems as if many respondents expect other areas to willingly accept some type of MRS facility or permanent repository, or feel that reprocessing will eliminate the need for Yucca Mountain altogether. Close to 75 percent of respondents assumed an alternative repository to Yucca Mountain would be accepted by another area, as long as it was proven to be safe.

As for the transportation of SNF/HLW, respondents seemed slightly less concerned. The most dominant sentiment was a need for extensive emergency response training – respondents want very specific plans and procedures for the handling of an accident. Respondents also supported shipping by rail, and desired readily accessible shipment information be made available to the public. Most respondents lacked detailed knowledge of transportation issues. For example, OCRWM estimates between 250 and 400 annual combined rail and truck shipments of SNF/HLW if Yucca Mountain begins operations [23]. But of 35 respondents to answer a question asking for an estimation of the number of annual shipments of SNF/HLW that would take place should Yucca Mountain open, only 3 had estimates that were close to actual estimates. A small number of respondents also replied with “hundreds” or “it depends”, but the overall pattern of responses pointed to a lack of knowledge on the subject.

Respondents also expressed a desire for more transparency. Less than half felt the YMP has been sufficiently transparent, and some expressed desire for more easily understandable information. Many stated that expanded access to better information should be a priority, but about half of respondents also believe that other people have already formed their opinions of the YMP and probably cannot be swayed.

## **IMPLICATIONS AND RECOMMENDATIONS**

Numerous studies have demonstrated that the federal government suffers from a perceived lack of credibility in the eyes of the public, and therefore lacks the trust essential for undertaking complex and potentially hazardous programs such as nuclear waste disposal [24]. Furthermore, the public consistently believes that the current period of time is always riskier than the past, while constantly expecting a zero-risk society [19]. One-third of respondents in the present survey believed “all significant risks are preventable”. As long as such tendencies towards zero-risk sentiment remain, it may be difficult to expect the public to accept what they perceive to be an extremely dangerous (and possibly preventable) risk associated with the YMP.

Trust is a key component in the perception of risk. In areas where people have little knowledge, such as SNF/HLW transport, they will rely heavily on trust [12,17]. This effect has been noted in numerous studies, including recent research of global warming risks, where increased levels of public trust in

scientists reduced their concerns related to global warming [5]. As such, credibility and trust are vital in alleviating the public's concerns related to the nuclear energy cycle. But gaining the trust of the public is a complicated and difficult task.

Further complicating the situation, the mass media covers issues related to the transportation of SNF/HLW and the YMP, where it is treated as a political issue as opposed to a scientific issue [5]. At this point, the media often presents "expert vs. expert" arguments as they dispute one another's claims using different risk assessments. This only further erodes trust as the public worries that the experts are in constant disagreement regarding safety issues. In addition, there is a tendency among people to perceive all things nuclear in a negative light due to several factors:

- Positive events are not as visible as negative events (i.e., "If it bleeds, it leads");
- Positive events are viewed as having a lower benefit than the costs associated with the opposite negative event;
- Sources providing information regarding negative events are viewed as more credible; and
- Distrust is re-enforced by distrust [3].

These factors are especially vital considering how the media reports nuclear-related issues.

But the public is not oblivious to the presence of bias – they are capable of anticipating the stance of scientists involved in the YMP debate and they can use the expected biases of scientists to aid in the interpretation of information. As a result, credibility is increased when scientific research is independent from funding [25]. Furthermore, credibility must be the main goal from the very beginning. Using organizations with established credibility, such as the National Academy of Sciences (NAS), is useful, as is engaging in thorough public peer review. Program transparency should also be promoted to the greatest extent.

Furthermore, the public and all stakeholders need to be involved early and often [24]. Allowing the public to assist in formulating solutions will be extremely helpful in establishing trust [26]. This public input will allow better understanding of why the experts favor particular viewpoints, while increased public involvement in the process also makes it more acceptable and credible to other members of the public who did not actually provide input [27]. Communication lines must be established, while the messages need to be clear and easily understandable [28].

Concerning stakeholders in general, they tend to be slightly more supportive of nuclear energy issues than the general public, but also possess more extreme viewpoints [29]. In addition, stakeholders opposed to SNF/HLW transport tend to answer more "strongly" and be more vocal than proponents [29]. All stakeholders will bring a different position to the negotiating table, and most will not allow much room for compromise. DOE officials responsible for planning and implementing the Waste Isolation Pilot Plant (WIPP) had to address similar issues, but they were able to reach an acceptable compromise. In some instances, DOE elected to adopt additional safety measures that were not originally planned in order to maintain stakeholder's comfort level. But by doing so, WIPP officials gained the confidence and trust of the stakeholders, as they viewed the concessions as a commitment to ensure future safety measures [30]. Maintaining the comfort level among the public and stakeholders is of utmost importance to gaining trust and credibility. Therefore, some measures that would be considered unjustifiable based on purely technical factors must be pursued by OCRWM in order to promote current and future public trust.

But trust is not the only key component to implementing a successful SNF/HLW transportation program. Affected areas need to experience tangible benefits from the risks they are undertaking. Presently, SNF/HLW transportation is viewed as having little benefit, which inversely affects risk. Essentially, the



public perceives high risk = low benefit [19] This also means that when people understand the benefits, their perceived risk is lowered [31]. But past information campaigns by DOE have not always provided easily understood and tangible benefits – a crucial issue to improve on in the future [24]. For example, 180(c) funds are designed for training of emergency management personnel related to SNF/HLW transportation. But by doing so, OCRWM should explain how it will improve the quality of their emergency responders in the public's day-to-day life; not just in the case of an accident.

Compensation funds are a tangible benefit, but it is difficult to use them successfully<sup>9</sup>. They are more effective when employed early in the process, as it is viewed to be compensation for a perceived risk. If compensation is offered after a performance assessment determines a procedure to be safe, then it is viewed as a bribe and the procedure is perceived to be more dangerous than initially thought, therefore decreasing support [32]. It is important to give the appropriate compensation, not just compensation in general.

But in many instances, it does not appear that people understand the benefits of nuclear energy in their daily lives. If they do not recognize the benefits of nuclear energy, they will be more likely to oppose both SNF/HLW transport and the YMP altogether. However, recent research has indicated that the general public is beginning to see the link between the use of nuclear energy and reduction of greenhouse gas emissions [33]. But in the current study, almost all anti-nuclear respondents were concerned about global warming, yet only one respondent supported the increased use of nuclear energy as a means to reduce greenhouse gas emissions. Similarly, only one supported nuclear energy as a means to reduce reliance on foreign energy sources. Anti-nuclear respondents also strongly believed in the current viability of alternative energies and conservation, as mentioned earlier. And no anti-nuclear respondents disagreed that nuclear energy was too expensive compared to alternative energies.

Furthermore, through the present study and general experience with the public, it has been noted that many feel nuclear energy to be extremely dirty and produce a large amount of carbon emissions. But according to a University of Wisconsin study, the life-cycle carbon emissions of nuclear energy are extremely similar to those of alternative energies [34]. While coal produces about 970 tons of carbon emissions per gigawatt-hour, nuclear energy and wind only produce about 15 tons per gigawatt-hour. Therefore, DOE should emphasize the role of nuclear energy as a source of power that does not produce greenhouse gases – a “clean” energy. Doing so would help continue the trend of greater public understanding of the benefits of nuclear energy related to the reduction of greenhouse gas emissions.

Pro-nuclear respondents were (by definition) more supportive of nuclear energy, but were still concerned with the ability of transport casks to handle a possible terrorist attack. Many of these pro-nuclear respondents openly expressed their fear of a potential terrorist attack resulting in the release of radiation. It appears that even proponent stakeholders do not fully understand the robustness of transportation casks. Furthermore, past research notes that the public believes there is a relatively high probability of environmental contamination from radiological release during storage [35]. Full-scale testing could be very beneficial to illustrating the strength of transportation casks and subsequently reduce perceived risk among the public. It should be a priority for OCRWM to help the public understand the extreme robustness of transport casks and storage containers, the fact that every transportation accident will not result in radiation release, and the comparative benefits of nuclear energy (both cleanliness and cost-effectiveness) in future information campaigns.

Comparative analysis of SNF/HLW transport to chlorine transport can also be beneficial, but not if it is performed in a way that “points the finger” at the chemical industry [24]. Instead, OCRWM should

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<sup>9</sup> Compensation funds are those designated by the Nuclear Waste Policy Act, P.L. 97-425. This does not include 180(c) grants. <sup>(40)</sup>

explain how the shipments are similar and point to the unblemished safety record of SNF/HLW transportation. The public needs to be ensured that OCRWM has a primary focus of maintaining this record. As mentioned earlier, DOE has credibility issues among many members of the public, so they should (where possible and appropriate) delegate message delivery responsibilities to trusted local officials [36]. It has been noted that the public places trust on their local officials to look out for their best policy interests, so persons such as emergency response team leaders could be quite effective [32]. As mentioned earlier, organizations with established credibility, such as the NAS, will be especially useful as well. In all information campaigns, however, DOE must be sure to make clear the connections between risks and benefits.

But information campaigns can only be effective to a certain point. The law of diminishing returns is especially apparent in the issue of SNF/HLW transportation and the YMP, as more information and compensation are highly unlikely to achieve a strong majority of consent or support within the public [4,5,12,17,19]. A study by Kunreuther and Jenkins-Smith, 2001, reported that less than 43 percent of respondents would accept a repository in their community, even when provided with a full benefits and safety measures package [31]. The current study has found a similar result. Respondents were presented with a hypothetical situation where the amount of radiation that would be detrimental to human health had been identified (a threshold). They were then asked whether they would support the YMP or the transport of SNF/HLW as long as doses stayed under the identified level, or threshold. In essence, it would be as close to a zero-risk procedure as possible. Yet 80 percent of the anti-nuclear respondents and 29 percent of the overall respondents still would not support either the YMP or the transport of SNF/HLW. It also should be noted that respondents were addressing a hypothetical choice. Should a situation of this kind become a reality, actual support levels could be significantly different than those obtained in polling results for a hypothetical situation.

To such persons described above, there is essentially no amount of benefit or safety that will result in their approval. More money, time, and effort expended on outreach efforts will likely yield only marginal results. This does not mean public information campaigns are not useful – they are necessary to raise awareness among members of the public who have not yet formulated an opinion on specific issues, provided they are conducted using the proper methods. But the public's opinions on issues related to nuclear energy are not solely based on technical safety and health concerns; they involves several types of risk and benefit assessments within larger social and cultural “discussions” that are far less technical [18,33,37].

It has been said that, in the context of risk perceptions, “familiarity breeds consent” – a statement that is especially true in the debate over SNF/HLW transportation and the YMP. When the Savannah River Site began accepting SNF from foreign countries through the Atoms for Peace program, the residents of South Carolina reported high levels of perceived risk from such shipments. But over time, as the public became more familiar with the shipments and better understood the actual risks, their perceptions of risk associated with the shipments decreased [38]. Such an experience also occurred during the opening of WIPP in New Mexico (although the host community had past experience with nuclear materials and were much more initially supportive) [30]. Combined with such case studies and other research, it can be hypothesized that as areas affected by SNF/HLW transport and the Yucca Mountain repository become more familiar with the associated risks, and as public fears fail to be realized, the public's perceptions of the risk should decrease.

But realistically, a High-Level Nuclear Waste (HLNW) repository will never earn the consent of all individuals. It is unreasonable to expect everyone to believe a particular site is the best option, and there will always be cries of procedural flaws [39]. To further complicate the situation, risk assessments that determine the decision making process will focus much more on *possibility* rather than *probability* since the situation is usually perceived to be uncertain [43]. Also, certain groups (as described earlier) will

inherently report lower levels of support regardless of safety precautions or other types of mitigation. Therefore, the best course of action *may* be to initiate a procedure relating to the transport of SNF/HLW or the YMP even if a majority of public approval has not been achieved, *provided that* the procedure has been reviewed and the performance assessment deems it safe, while also providing proper compensation in the appropriate forms.

But it would be unwise to attempt to make a decision on the acceptability of a procedure before a performance assessment (PA) is completed. Completion of the PA first, prior to selection of a procedure, is necessary to reassure the public that the research is unbiased and credible, and therefore can be trusted. Additionally, it would be unwise submit an incomplete or faulty performance procedure, as it will result in negative effects for future performance assessments [25].

Finally, there needs to be a concrete plan for handling of potential accidents, and it must be made accessible to everyone involved. The public is not irrational, but since there is a potential for accidents, there will always be a residual expectation of serious disasters. Even if there is little chance of a major accident actually occurring, showing the public that any incident (even a small leak from within Yucca Mountain) will be promptly handled and serious risks will be quickly eliminated could significantly boost consent.

## CONCLUSION

Historically, DOE's efforts with public information campaigns have met with mixed results. There are a variety of techniques to enhance these efforts, but the effects will likely be too small in the *near future* to be a major factor in facilitating the implementation of policy. This is because the beliefs and risk perceptions of the public extend beyond technical safety issues; they are shaped through social and cultural interactions over lifetimes. These personal preferences and general worldviews play an enormous role in the debate regarding transportation of SNF/HLW and the YMP, and once formed, are highly resistant to change.

Different risk assessments will continue to result in different perceptions of risk among both scientists and the public, but perceived risk can be mitigated by measures that enhance trust and credibility, define benefits, provide proper compensation, better address the public's concerns, and other aforementioned factors. The general perception of nuclear energy can change – but it is likely to require extended periods of time. The common image and implicit response to nuclear energy needs to become significantly more positive in order for related procedures to gain general *initial* acceptance. As such, it appears public consent may only be gained after-the-fact for many procedures related to the transportation of SNF/HLW and the YMP. Further research utilizing a far larger sample size is highly recommended.

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