

Public Beliefs, Concerns and Preferences Regarding the Management of Used Nuclear Fuel and High Level Radioactive Waste

Hank C. Jenkins-Smith
Center for Risk and Crisis Management
Center for Applied Social Research
University of Oklahoma

February 2011

Blue Ribbon Commission on America's Nuclear Future: Disclaimer

This material was prepared at the request of the Blue Ribbon Commission on America's Nuclear Future ("the BRC"). The contents herein do not necessarily reflect the views or position of the BRC, its Commissioners, staff, consultants, or agents. Reports and other documents reflect the views of the authors, who are solely responsible for the text and their conclusions, as well as the accuracy of any data used. The BRC makes no warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information disclosed, or represents that the use of any information would not infringe privately owned rights. Any reference to a specific commercial product, process or service by trade name, trademark, manufacturer, or otherwise, does not constitute or imply its endorsement, recommendation, or preference by the BRC.

1. Overview

US policy for management of used nuclear fuel (UNF) and high level radioactive wastes (HLRW) is at a crossroads, and the success of new policy directions will depend in part on broad public acceptance and support. In this paper I provide an overview of the evidence concerning the beliefs and concerns of members of the American public regarding UNF and HLRW. I also characterize the evidence on American's policy preferences for management of these materials. Findings from a number of recent sources of evidence on public views are synthesized for this purpose, but the discussion chiefly relies on data provided by an on-going time-series analysis of public beliefs and preferences concerning energy and environmental issues, called the National Security and Nuclear Policies (NSNP) project that is sponsored by the Sandia National Laboratories and conducted by the University of Oklahoma.¹ I conclude with recommendations for additional research efforts that would serve to enhance understanding of public preferences for UNF and HLRW management.

The discussion is organized to flow from general to more specific beliefs.² I first summarize available evidence on public beliefs and concerns about nuclear energy, focusing on public understandings of radiation and current UNF management practices. I then trace the evolution of public attitudes about nuclear energy over the past decade, including perceived risks and benefits as well as preferences for continued reliance on nuclear energy for the generation of electricity. The paper then turns to evidence concerning preferences for UNF management. I discuss data from several sources regarding preferences for general strategies, such as continued on-site storage or centralized deep-geologic storage. Available measures of more specific preferences

¹ The Sandia National Laboratories and the University of Oklahoma jointly sponsor the National Security and Nuclear Policies project. The NSNP surveys are collected annually by the University of Oklahoma's Center for Applied Social Research, in May and June. Internet surveys are collected every year. The surveys are designed to permit the application of relatively complex and lengthy (over 100 items) to a representative cross-section of adult residents of the US. Many of the questions are asked repeatedly over time, using the same question wording and placement within the questionnaire. Because incidence of phone and internet use are changing over time in the US, we employ companion telephone and internet surveys to permit assessment of the effect of mode of collection on responses. For sample details, see Herron and Jenkins-Smith 2010; and Jenkins-Smith, Herron and Silva (forthcoming) 2011.

² This paper draws heavily on the analyses presented in Jenkins-Smith, Herron and Silva (forthcoming 2011) and Jenkins-Smith, Silva, Herron and Rechar (forthcoming 2011).

concerning issues of retrieval capabilities for repository design and reprocessing are also considered. I then describe the available evidence on the effect of proximity of a proposed repository on public support within a host community. Finally, the concluding section of this paper turns to the question of what more needs to be understood about public beliefs and preferences for managing UNF and HLRW.

In summarizing what is known about public beliefs regarding the management of UNF and HLRW, this paper relies on measures of public views and perceptions that are derived from systematic survey data (that is, data derived from surveys utilizing recognized standards of commercial or academic survey research) collected within the decade. The available evidence is uneven: while a number of systematic survey research initiatives concerning general attitudes about nuclear energy have been maintained over recent years, those focusing on public preferences for managing UNF and HLRW have been relatively rare. In characterizing the body of evidence, I describe general results with attention to technical matters (e.g., survey design issues, question wording, survey modes) only in those instances in which such matters bear directly on understanding of the results.

2. Public Opinion Findings on Nuclear Energy Issues

Public attitudes concerning the management of UNF and HLW are coupled with attitudes about nuclear energy more generally. Understanding how perceptions of nuclear energy and its byproducts have evolved in recent years provides necessary context for making sense of the beliefs, concerns and preferences for managing UNF. This section evaluates recent data on beliefs about radiation, nuclear materials and nuclear energy, with specific attention to the balance of perceived risks and benefits from nuclear energy. I then address public preferences for nuclear energy in the overall mix of energy sources in the US.

Few on-going studies have sought to determine the level of public knowledge about important aspects of nuclear energy. The NSNP asked a set of questions in May of 2010 that are indicative of the beliefs that underlie and shape perceptions of nuclear energy. Survey participants were asked to agree or disagree with a number of statements concerning the nature of radiation, the threat of nuclear explosions posed by UNF, and the relationship between nuclear energy production and greenhouse gas emissions. The statements and

responses are shown in Table 1. While a sizable majority of the adults in the US understand that a suntan results from radiation damage to the skin, only a minority understand that it is the radiation dose – regardless of whether the source is manmade or naturally occurring – that determines health effects. Americans are split on whether UNF can accidentally “explode like a nuclear bomb”, and only 35% agree with the proposition that operating nuclear power plants produce significant quantities of greenhouse gasses. In short, there is considerable confusion about the nature and extent of the hazards (and benefits) associated with nuclear energy.

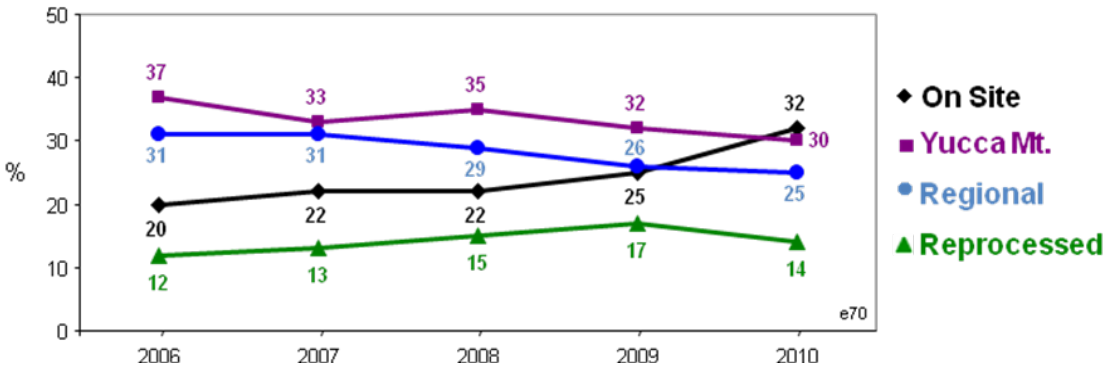
TABLE 1: BELIEFS ABOUT RADIATION, UNF, AND CARBON EMISSIONS

	Response to Statement		
	Disagree	Unsure	Agree
A suntan is caused by radiation damage to human skin.	18%	17%	64%
Even if the dose is the same, man-made radiation is more toxic to humans than naturally occurring radiation.	27%	25%	48%
Spent nuclear fuel can accidentally explode like a nuclear bomb.	38%	23%	40%
Nuclear power plants produce significant amounts of greenhouse gases.	39%	26%	35%

Public understanding of current UNF management practices is also quite modest, though the trend is in the direction of increasing knowledge. From 2006 to 2010 the NSNP has asked respondents to indicate, from four randomly ordered options³, what is currently done with most of the UNF from nuclear power plants in the US. The results are shown in Figure 1. Awareness that most UNF is stored on-site at operating plants has grown from 20% in 2006 to 32% in 2010. The belief that UNF is being sent to a repository in Yucca Mountain, Nevada, has declined modestly over the same period.

³ The question is worded as follows: “As nuclear fuel is used to generate electricity, it becomes contaminated with radioactive byproducts. When it can no longer efficiently produce electricity, it is called used or spent nuclear fuel. To the best of your knowledge, what is currently being done with most of the spent nuclear fuel produced in the US?”

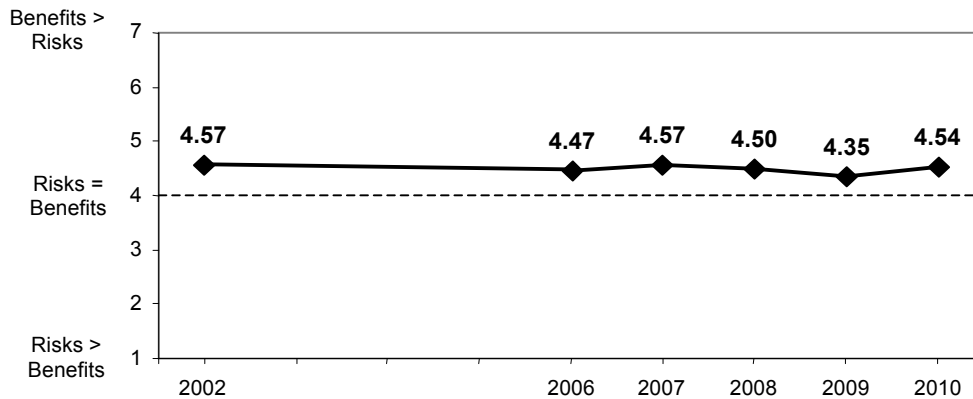
FIGURE 1: PUBLIC BELIEFS ABOUT THE DISPOSITION OF UNF



Modest knowledge of radiation and nuclear materials management practices conditions perceptions of the risks and benefits of nuclear energy. The greater the proportion of misinformed answers about radiation and nuclear energy provided by a survey respondent, the greater was the perceived risk of, and opposition to, nuclear energy.⁴ Nevertheless, over the past decade the NSNP survey findings indicate that the perceived benefits of nuclear energy (as reliable domestic source of energy, minimal carbon emissions) have consistently outweighed the perceived risks (terror attacks on facilities, reactor accidents) for roughly 75% of survey respondents. Figure 2 shows the average assessments of the balance of risks and benefits for nuclear energy from 2002 to 2010 for independent yearly samples of the adult population of the US. Note that, on average, perceived benefits outweighed perceived risks by statistically significant margins in each year. The stability of these perceptions parallels the safety record of the nuclear industry over that time, characterized by the absence of incidents and accidents on the scale of Three Mile Island or Chernobyl that might have been expected to undermine public confidence in nuclear reactor safety.

⁴ This effect was both substantively and statistically significant. For example, perceived risk of nuclear energy, as measured on scale ranging from 0 (no risk) to 10 (extreme risk), averaged 6.76 for the least informed (unsure or wrong answers to all four items in Table 1) and 4.05 for the most informed (all four correct).

FIGURE 2: BALANCE OF PERCEIVED RISKS AND BENEFITS FOR NUCLEAR ENERGY



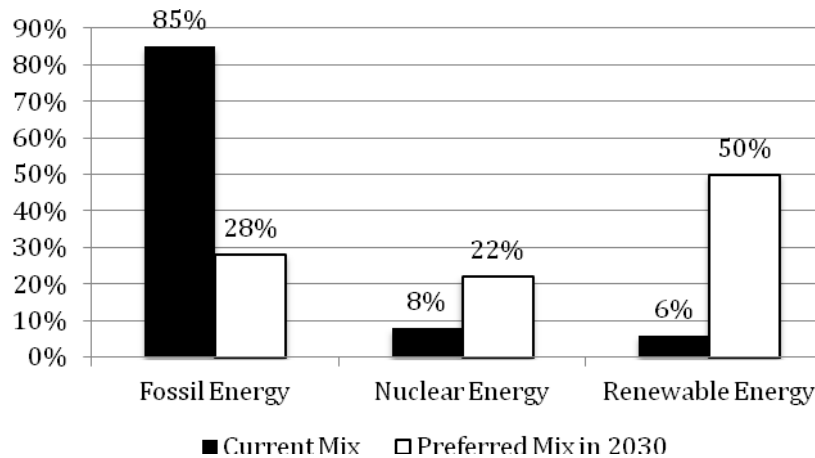
Given that the perceived benefits of nuclear energy modestly but consistently outweigh the risks, it is not surprising that the weight of the available evidence shows that the public supports continuing utilization of nuclear energy. Several studies have measured increasing levels of public support for continued reliance on nuclear energy as part of the overall mix of energy sources. Over-time measures by the Gallup survey organization indicate that support for continued reliance on nuclear energy in 2010 was at the highest level since that organization began measuring attitudes about nuclear energy; 62% of a national sample of adult respondents favored “reliance on nuclear energy as one of the ways to provide electricity for the US.” (Jones 2010: p. 1). A study conducted by Ann Bisconti and the Roper survey organization found even higher levels of support (NEI 2010).

Evidence about preferences for future utilization of nuclear energy provides interesting variations based on how the question is framed. When survey participants have been asked whether the government should promote increased use of nuclear energy, public support is nearly evenly split. An October 2010 survey by the Pew Research Center found that 45% of adult respondents supported government promotion of greater use of nuclear energy, while 44% were opposed (PEW 2010).⁵ When the question is asked more directly, without reference to promotion by the government, the NSNP has consistently

⁵ These differences in measures of support for nuclear energy should be interpreted with question meaning in mind. Questions that ask whether “government” should “promote” the use of nuclear energy raise evaluative questions about both government and nuclear energy. For example, increased support for nuclear energy might be offset by decreased trust and confidence in government, or vice versa. In any event, continued reliance on nuclear energy and government promotion of increased use of nuclear energy are substantively different propositions.

found public support for increasing the share of energy provided by nuclear power plants. After describing the current shares of energy provided by fossil fuels (85%), renewable sources (6%), and nuclear energy (8%), NSNP respondents were asked what share they would prefer to have each source provide 20 years in the future. Over the 2006-2010 period, the average expressed preference is to increase the proportion of nuclear energy from 8% to about 22%, as shown in Figure 3.

FIGURE 3: PREFERRED OVERALL MIX OF ENERGY SOURCES BY THE YEAR 2030



In summary, survey data indicate that most members of the public currently have a modest understanding of facts relevant to nuclear energy and UNF, but that understanding may be increasing over time as the policy debate concerning nuclear materials management has become more salient. Based on that level of understanding, the perceived risks posed by nuclear energy are substantial but nevertheless outweighed by the perceived benefits. Measures of public preferences about nuclear energy garnered from multiple sources indicate that the public supports continued reliance on nuclear energy, and would prefer to see the proportion of electricity produced by nuclear reactors increased in the future.

3. Public Preferences for UNF and HLRW Management

In contrast with studies of attitudes on nuclear energy, systematic analysis of public attitudes, beliefs, concerns and preferences regarding the management of nuclear materials

has been episodic. A substantial volume of research was undertaken in the late 1980s through the mid-1990s, particularly concerning public risk perceptions and efforts to site the Yucca Mountain repository in Nevada.⁶ A variety of nation-wide and regional surveys were also undertaken in the 1990s to evaluate perceptions of nuclear waste siting more broadly (Bassett, Jenkins-Smith and Silva 1996; Jenkins-Smith and Bassett 1994) and for other repositories such as the WIPP in New Mexico (Jenkins-Smith and Silva 1998; Jenkins-Smith, Silva, Nowlin and deLozier 2011). The focus of much of this research was on the role of perceived risks of the transport and storage of radioactive materials; the importance of trust in program and governmental officials; and the effect of proximity in shaping public responses to hypothetical repository siting decisions (see, for example, Jenkins-Smith et al 1999). A broad synthesis of the social science research on nuclear materials disposal, in the US and elsewhere, is described in Soloman et al (2010).

Few recent studies have sought to focus on public preferences regarding management of UNF and HLRW management.⁷ Most of this work has asked very general questions, exploring the connection between resolving the management of UNF and support for nuclear energy (Ansolabehere 2008), or public preferences for continued storage of UNF on-site at nuclear power plants or at centralized repositories (Nuclear Energy Institute 2009). Generally these studies find that the public would express greater support for nuclear energy if the UNF storage and disposal issue were satisfactorily resolved (Ansolabehere 2008). Among residents of communities proximate (within ten miles) to operating nuclear power plants, majorities expressed preference for centralized UNF storage and disposal over continued on-site storage (Bisconti 2010). However, beyond general inquiries, these studies did not undertake more nuanced evaluations of public preferences for alternative strategies for UNF and HLRW management.

In part the absence of more in-depth studies of Americans' preferences for UNF and HLRW disposal reflects the difficulty of eliciting useful survey measures for an issue about

⁶ Much of this work was sponsored by the State of Nevada, as part of its assessment of the potential socioeconomic and perception-based impacts of the repository (see, e.g., Mountain West Research 1989; Flynn, Mertz and Slovic 1991; Flynn, Slovic and Mertz, 1993; and Mertz, Flynn and Slovic 1994).

⁷ Some recent work bears indirectly on issues of UNF and HLRW management, such as the study by Greenberg (2009) of facility siting preferences (for reactors, nuclear laboratories and repositories) of survey respondents near existing nuclear facilities.

which many respondents are not well informed (as illustrated by the results shown in Table 1, above). While members of the public are capable of developing reasoned policy preferences in complex policy domains, (Herron and Jenkins-Smith 2006; Lupia and McCubbins 1998) public understanding of such issues tends to evolve from inchoate and variable opinion toward stable judgment as policy debates mature (Yankelovich 1991). As discussed above, evidence collected by the NSNP Project indicates that public opinion on the UNF issue has yet to fully mature. Nevertheless there may be a modest trend toward broader public understanding of UNF issues, as indicated by the increasing awareness that UNF is most often stored at or near civilian nuclear reactors (as shown in Table 1).

Given the current level of public understanding of the issue, measuring public preferences to analyze prospects for acceptance of UNF management facilities requires that a basic level of background information be provided to survey respondents. While it is, in practice, very difficult to provide objectively balanced background information, our strategy is to use as guidance the kinds of arguments the array of media sources transmit to the public⁸, vetted by technical experts in the relevant field for accuracy. Once the background information is provided, members of the public are able to express differentiated and stable opinions that are grounded in their broader beliefs and values (Herron and Jenkins-Smith 2006). The NSNP project has used this approach to evaluate public assessments of current policies and to measure variations in public acceptance of UNF management options across alternative design elements for policy and facility characteristics (Jenkins-Smith and Herron 2011; IHLNW paper 2011).

Evaluations of current UNF storage practices require that the survey participants be apprised of the primary points of view of both proponents and opponents of continued on-site storage. The information should be provided in a manner that is not overly lengthy and technical, and that will not privilege one argument over another.⁹ With that intent, the following background was provided to NSNP survey respondents in 2010:

⁸ This mix of arguments, after all, will be the basis upon which most members of the public reach judgments about the policy issues.

⁹ The objective in survey design of this kind is to provide, in brief and accessible form, the range of arguments that the public is likely to encounter in public debate on the issue.

Spent nuclear fuel is highly radioactive and must be safeguarded for thousands of years or chemically reprocessed. If it is reprocessed, the uranium can be separated from the waste and reused to make new fuel rods for generating electricity, but the remaining elements are highly radioactive for a very long time and must be safeguarded and isolated from the environment for thousands of years.

In 2010 the government halted construction of a deep underground facility inside Yucca Mountain in Nevada that had been intended for long-term disposition of spent nuclear fuel, and very little spent nuclear fuel is being reprocessed in the U.S.

Currently, US spent nuclear fuel is being temporarily stored at over 100 sites in 39 states. Most of it is stored at nuclear power plants where it is placed in secure cooling pools. In some cases, the spent fuel is transferred to specialized concrete casks stored above ground near the nuclear power plant. At each site, the cooling pools and storage casks are protected at all times by security forces. Some people think this is an acceptable solution for the foreseeable future, while others think such practices are risky and other options need to be adopted.

The following arguments were then presented in randomized order:

Opponents argue that some nuclear power plants where spent nuclear fuel is stored are near rivers, oceans, and large population centers. On rare occasions spent fuel has leaked radiation into the cooling pools. Moreover the cooling pools¹⁰ and containers are located at ground level, and therefore might be vulnerable to terrorists. They note that these storage practices do not provide a permanent solution for managing spent nuclear fuel.

Supporters argue that transporting spent nuclear fuel by train or truck to consolidated storage facilities is risky, that storing spent nuclear fuel at nuclear power plants is less expensive than consolidated storage, and that it buys time for finding future solutions. Moreover, storage at nuclear power plants has not caused any accidents that have exposed the public to radiation.

Survey respondents were then asked: “Using a scale from one to seven, where one means strongly oppose and seven means strongly support, how do you feel about the current practice of storing spent nuclear fuel at or near nuclear power plants?” The mean responses from 2006-2010 have consistently been below mid-scale (3.3 – 3.7). In 2010, 40% of respondents opposed indefinite on-site storage and 34% were undecided. The remaining 26% favored continuing the current practice.

¹⁰ It is the case that some cooling pools are located above grade, rather than below or precisely at ground level. The use of the term “ground level” in this question is meant generally, in contrast with storage in mines or deep-boreholes, as described in other survey questions.

The responses from the NSNP surveys are consistent with the findings of other researchers. One project focused on the opinions of those who live within 10 miles of an operating nuclear reactor (Bisconti 2009). These respondents would be expected (on average) to be more familiar with nuclear energy and nuclear waste issues. Among these “plant neighbors”, 85% agreed with the following statement: “It is appropriate that nuclear waste be stored at 1 or 2 volunteer sites where it can be stored more securely and efficiently.” A smaller majority (59%) also perceived that interim storage on site at operating power plants was safe, but the number taking this position had declined significantly from 71% two years earlier.

These results indicate that the public is uneasy about indefinite on-site storage, with preferences leaning in the direction of centralized storage options. There also is significant latitude for continued policy development, with substantial fractions of the public undecided whether they prefer on-site or centralized storage, and majorities (albeit declining majorities) of those living near operating reactors viewing continued on-site storage to be safe. However public support for in UNF management strategies is shaped significantly by possible variations policy design options.

4. Retrievability of UNF

Analysis of results from the most recent NSNP data, and of the policy debate concerning UNF in Europe, suggests that two related considerations currently exert substantial influence over public acceptance of UNF management strategies. These include (a) whether the UNF is defined as a waste or a resource, and (b) whether society should retain the capacity for future amelioration or enhancement of the safety of the materials in the long-term storage/disposal facility. Both of these considerations directly bear on retrievability in UNF repository design.

The issue of retrievability has become a central factor in public debates over initial acceptance of UNF disposal siting in Europe (OECD 2001; 2009). In the Finnish debates over facility siting, the addition of the requirement for integrating retrievability into the design of disposal facilities for UNF was one of the few concrete results of very extensive public engagement on the issue (Hokkanen and Kojo 2003), and subsequently Finland was the first state to successfully site a permanent repository near the host community of

Eurajoki. In the US the issue of retrievability of UNF has received little public consideration, though focus group discussions undertaken in the late 1990s suggested that members of the public believed that future generations should be given the option to remove UNF from disposal facilities if new knowledge or changed circumstances warranted such action.¹¹

The 2010 NSNP survey queried the implications of retrievability in repository design for public acceptance of UNF facility siting by presenting balanced arguments for and against. The wording was as follows:

Now we want you to consider the issue of whether stored radioactive materials should be managed in a way that allows authorized personnel to gain access to them and retrieve the materials in the future, or that seeks to permanently block access to them. One option is to build facilities where the stored materials are continuously monitored and can be retrieved for reprocessing, or possibly to make them less dangerous using future technological developments. This option requires greater security efforts and may be more vulnerable to attack or theft. Another option is to attempt to seal off storage sites in such a way that people cannot readily gain access to the materials in the future. This option is more secure, but does not allow reprocessing or treatment by future technological advancements.

Using a scale from one to seven, where one means strongly oppose and seven means strongly support, please indicate how you feel about each of the following two options.

The two options were presented to the respondent in random order:

Construct sites so that stored materials are monitored and could be retrieved for reprocessing or further treatment in the future.

Construct sites so that stored materials are permanently sealed away and cannot readily be retrieved in the future.

Overall, 67% of respondents supported the retrievable facility design (with a mean response 4.98), while 38% expressed support for the non-retrievable design (mean response 4.14). When asked to rank the two options, 69% preferred the retrievable option. In sum, though neither option generates strong opposition, inclusion of retrievability in repository design is preferred by a two-to-one margin.

¹¹ These focus groups were conducted in Nevada, New Mexico and Illinois as part of a research project undertaken by the University of New Mexico's Institute for Public Policy in 1998. The results were summarized in Bassett et al (1998).

5. Waste or Resource?

Available evidence suggests that broad public support for retrievability stems from two distinct considerations. The first is the matter of whether UNF is understood by the public to be a waste or a potential future resource, via reprocessing. The NSNP surveys asked respondents to indicate their preferences for reprocessing beginning in 2008.¹² The responses have been consistent since we began measuring attitudes about reprocessing; a substantial majority has expressed support for the reprocessing option (ranging from 59-67% in favor). Less than 20% have expressed opposition in any year (those opposed made up 13% of all respondents in 2010). Note that these results were obtained despite reminding respondents that the uranium and plutonium, when separated in the reprocessing, could be used to make nuclear weapons.

Other research programs have also sought to evaluate public preferences regarding reprocessing. In a 2010 nation-wide survey fielded by Bisconti Research, Inc., 79% of the participants said they supported plans to “recycle” nuclear fuel to “make more electricity and reduce the amount of nuclear waste” (Bisconti 2010). In a separate sample taken in 2009 from adults living within 10-miles of an operating nuclear reactor, fully 91% said they supported “recycling” used nuclear fuel (Bisconti 2009).¹³ An MIT study undertaken in 2007 had similar findings (Ansolabehere 2007), in which 60% of the respondents in a nationwide survey supported expanding the DOE’s program for reprocessing used nuclear fuel. While the terms used to describe reprocessing across these studies differed, and the

¹² The reprocessing option was described as follows: “Next we want you to consider the issue of reprocessing, which involves the chemical separation of radioactive materials in spent nuclear fuel. After reprocessing, most of the uranium and plutonium can be captured and reused to generate electricity, reducing the amount of uranium that must be mined in the U.S. or purchased from other countries. Remaining materials are radioactive and must be safeguarded and isolated from the environment. However, reprocessing may also separate the plutonium which, like uranium, could be used to make nuclear weapons.” Respondents were then asked to register their support or opposition to “the option for reprocessing spent nuclear fuel”.

¹³ Question wording is important for this issue. The Bisconti, Inc. survey questions linked “recycling” UNF to increased electricity production and reduced waste. The NSNP questions noted that “reprocessing” reduces the amount of fresh uranium that must be mined or purchased from abroad, but also made clear that reprocessing generates toxic wastes and separates plutonium that can be used to manufacture nuclear weapons. The support in the NSNP surveys, while still a sizable majority (ranging from 59-67% over the 2006-2010 period), is lower than that found in the Bisconti, Inc. surveys.

level of explanation varied substantially, the general results of the surveys were consistent: the public tends to perceive UNF to be a potential resource, and favors reprocessing. Whether these results would change over time as the merits of reprocessing, and collateral issues such as plutonium production and nuclear proliferation, are raised more forcefully will require further research.

6. Retaining Future Options

The second consideration made by members of the public that leads to support for a retrievable UNF repository design is that of potential future improvement in safety. In the European public debate over UNF disposal, the distinction has been made between *retrievability*, which is restricted to physically retrieving the UNF from the repository, and *reversibility*, which can be taken to mean retaining the option to change the disposal policy should better options become available (OECD 2001, p. 11). In the American context, focus group findings have suggested a substantial technological optimism that future developments in science and engineering will lead to new options that current technologies do not yet support,¹⁴ and hence permanent closure of a repository would preclude taking advantage of those options (Bassett et al 1998). More conclusive evidence of a public preference for retaining the option to employ future learning is available from the 2010 iteration of the NSNP project, which in 2010 asked whether support for siting a repository would change if the repository was co-located (or “bundled”) with a research laboratory that focused research on finding ways to more safely and efficiently manage UNF. Inclusion of such an option substantially increased support for the facility, even among those initially opposed to siting the facility, as will be discussed in greater detail in the subsequent section.

7. Repository Design Factors

Given the broad public sensibilities concerning retrievability, how do specific repository design factors shape public support for UNF management facilities? Given that DOE has sought to withdraw the license application for the repository at Yucca Mountain, it is

¹⁴ One such example is deep-borehole disposal, which has become more promising over the last decade with advances in deep drilling.

possible to consider a wide range of options.¹⁵ Primary policy design features that may have significant implications for public acceptance include (a) the number of sites to be considered, (b) the type of storage and storage depth for the UNF at the sites, and (c) whether the repository function is combined with other activities and objectives at the proposed facilities. The NSNP project investigated the implications of each of these design features for public acceptance in 2010.

8. How Many Storage Sites?

While the range of options for the number of UNF repositories is broad, three options appear to capture the plausible range for consideration; (a) continued dispersed, on-site storage, chiefly at operating nuclear reactors; (b) a number of regional repositories, perhaps designed to optimize UNF transport routing; and (c) one or two centralized repositories. What do we know about Americans' preferences across these options?

A number of studies of public opinion have included measures of pieces of this issue. As noted earlier, an MIT study concluded that, if there were effective waste storage, public support for nuclear energy would substantially increase (Ansolabehere, 2007: 10). Ann Bisconti has posed questions about where UNF should be stored to both national samples of the adult population and residents living within 10 miles of nuclear power plants (Bisconti 2010). Both samples were asked to agree or disagree with the following statement about the safety of on-site storage:

Nuclear waste can be safely stored at the plant site.

Sixty-three percent of the national sample agreed that on-site storage was safe, compared with 56% of those who lived near the reactors. Bisconti notes that, in the prior year, 71% of the survey participants near the reactors had agreed with this statement (Bisconti 2010: 47).

Bisconti's surveys have also asked respondents to agree or disagree with the following statement:

¹⁵ Of course, design variations would have been quite feasible, with appropriate changes in policy, at the Yucca Mountain site as well.

It is appropriate that nuclear waste be stored at 1 or 2 volunteer sites where it can be stored more securely and efficiently.

Among participants in the national survey, 80% agreed. Agreement was even stronger – at 91% -- among respondents who lived within 10 miles of a nuclear power plant (World Nuclear News 2009). Overall Bisconti interprets these findings as indicating that while citizens remained confident that UNF can be temporarily stored on-site, “...plant neighbors expressed more clearly than ever that they don’t want uranium fuel to stay at the plant sites. Their preference: centralized storage options.” (Bisconti 2010: 47).

Asking for more direct comparisons of options does not provide the same results. The 2010 NSNP questionnaire measured the relative public preference for continued on-site, distributed regional sites, and one or two national sites for long term storage on UNF. Respondents were asked to consider the preferred number of repositories as follows:

While nuclear power plants will continue to store some spent fuel in their cooling pools, much of the radioactive materials currently at temporary storage sites in 39 states might be consolidated at a smaller number of regional or central facilities. Once it is consolidated, the spent nuclear fuel can more easily be secured and protected from attack. The fewer the number of regional or central storage facilities, the less complex are the political and legal obstacles for finding communities willing and able to host the facilities. At the same time, a larger number of regional storage facilities would reduce the distances radioactive materials must be transported by train or truck, and would also reduce the number of communities through which the transport routes would pass.

Respondents were asked to rate their preferences for each of three options on a scale from one to seven, where one means strongly oppose and seven means strongly support. They were also asked to rank the following three options from most to least preferred. The options were presented in random order:

After spent nuclear fuel is removed from the cooling pools, continue the current practice of temporarily storing it above ground at designated nuclear power plants. This option does not require additional transportation of radioactive materials by train or truck, and it presents few additional political or legal obstacles.

Construct six to eight regional storage sites that can be more easily secured and can provide longer-term storage. This option requires transporting spent nuclear fuel by

train or truck over moderate distances and is likely to generate political and legal opposition.

Construct two large centralized storage sites (one in the west and one in the east) that can be most secure and provide permanent storage. This option requires transporting spent nuclear fuel by train or truck over longer distances and is likely to generate political and legal opposition.

The average respondent level of support on the 1-7 scale for (a) continued on-site, (b) 6-8 regional sites, or (c) 2 centralized repositories were 4.15, 4.18, and 3.91, respectively. Mean preferences for continued on-site storage and the multiple regional repositories are statistically indistinguishable; both are preferred over the two centralized repositories option.

Several points are evident from the NSNP survey results. When provided with more extensive background information, it is apparent that strong preferences for the number of repositories have yet to develop. This, in turn, suggests that there remains considerable latitude for determining an acceptable option. For each of the options considered, the most frequent (modal) response was the scale mid-point, indicating uncertainty or lack of preference; strongly held positions (either in support or opposition) remained near or below 20% for all three options. At the same time, support for a larger number of sites – whether regional or continued at reactors – was greater than support for 2 centralized sites.¹⁶ This suggests that the public would not rule out multiple repositories, in concept. The prospective difficulties with obtaining acceptance from prospective host communities, via NIMBY-type reactions, are discussed later.

9. At What Depth?

Another critical design issue concerns the depth of storage, which can plausibly range from ground level to miles below the surface in “deep borehole” repository designs. This matter has received attention only in the NSNP surveys. Survey participants in 2010 were asked to consider their preferences across three possible designs; surface storage, deep geologic mine repositories, and deep borehole repositories. The question was posed as follows:

Next we want you to consider the issue of storage depth. There are three general options. [The ordering of the options was randomized]

¹⁶ The mean difference in preferences for these two options was statistically significant at $p < 0.01$.

One option is to store spent nuclear fuel at or near the surface in hardened structures of concrete and steel. This allows monitoring and retrieval, but it is considered to provide a safe means to manage the material for only about a hundred years.

One option is to build mine-like storage facilities that are thousands of feet underground. These can be constructed to allow materials to be retrieved, or they can be designed to permanently block access in the future. They are suitable for storage over thousands of years.

One option involves drilling multiple boreholes of about 1.5 feet in diameter and up to three miles deep. Spent nuclear fuel would be stored in the deepest parts of the boreholes that are in bedrock. There is almost no chance that the materials could migrate into the surface environment over thousands of years, and they would be extremely difficult to retrieve.

NSNP survey respondents indicated their support for each option on a scale from one to seven, where one meant strongly oppose and seven meant strongly support. Support for the mine-like geologic storage scored highest (4.92 on the 1-7 scale). Support for the ground-level and deep-borehole options was statistically tied (4.16 and 4.08, respectively). When asked to rank the options, the deep geologic storage option was the first choice of 49% of the respondents; the ground-level and deep-borehole options were the preferred choice of 27% and 25%, respectively.

Among the NSNP respondents the mine-like repository option is the clear preference for depth. However the characterization of the options placed emphasis on the implications of each choice for retrievability and suitability for long-duration of storage. The survey respondents' preference for the mine-like repository may well reflect the characterization of that option as affording both retrievability and the option to seal the materials for "thousands of years". This is consistent with the more general preference for retrievability discussed above.

10. Repository Combined with other Facilities?

The selection of the design features of a repository may have large implications for the acceptance of the facility by prospective host communities. The Yucca Mountain repository, for example, was designed (and presented to the public) exclusively as a disposal facility, to be permanently sealed after a monitoring period. It was to have minimal long-term

scientific research activity, and was not designed to include non-disposal functions for nuclear waste management (e.g., an MRS, research, or reprocessing). The combination of features of the proposed facility (including those absent) shapes the way an observer understands the combination of risk and benefits of the facility. For that reason the combination of design features of a facility may have large implications for public acceptance when siting UNF facilities.

Given the large number of permutations of possible facility design features, the NSNP survey focused on the effects of two variations in design features: combining the repository with a research laboratory and/or with a UNF reprocessing facility. To evaluate the effect of these options, two variations on a “base” repository were considered: one option was for two centralized mine-like repositories, the other was for seven regional repositories employing deep-borehole disposal. Respondents were randomly assigned to consider only one base option.¹⁷ The description of the base repositories for one half of the respondents was as follows:

For the next few questions, assume that construction of two underground mine-like storage facilities is being considered for the storage of spent nuclear fuel. One would be in the eastern U.S., and the other in the west. Each of these sites would include secure surface storage buildings and a mine several thousand feet deep where radioactive materials could be isolated from people and the environment and could be designed to allow retrieval or to permanently seal away the materials. The facilities and the mines would be designed to meet all technical and safety requirements set by the U.S. Nuclear Regulatory commission, the U.S. Environmental Protection Agency, and applicable state regulatory agencies. Using a scale from one to seven where one means strongly oppose and seven means strongly support, how do you feel about this option?

The other half of the respondents received this alternative base option:

For the next few questions, assume that construction of about seven regional sites across the U.S. are being considered for the storage of spent nuclear fuel. Each of these sites will include secure surface storage buildings and a number of deep boreholes drilled up to three miles deep into bedrock where the radioactive materials could be isolated permanently from people and the environment. The facilities and boreholes would be designed to meet all technical and safety requirements set by the U.S. Nuclear Regulatory

¹⁷ The random split resulted in 1,177 survey participants receiving the deep-borehole repository option, and 1,228 receiving the mine-like deep geologic repository option.

Commission, the U.S. Environmental Protection Agency, and applicable state regulatory agencies. Using a scale from one to seven, where one means strongly oppose and seven means strongly support, how do you feel about this option?

Note that both of the alternative base cases stipulated that the repository would have secure surface storage, and would be in compliance with relevant regulatory safety requirements.

The inclusion of the more complete descriptions resulted in moderate public support for both options. The deep-geologic mine option received an average initial support of 4.82 on the one (“strongly oppose”) to seven (“strongly support”) scale. Fifty-eight percent of the respondents expressed support for this option, while 16% were opposed (26% were neutral). The other half of the sample gave the deep-borehole option a mean support score of 4.49. Fifty-one percent of the respondents supported it, while 21% were opposed (28% were neutral). Given these starting points, what happens to support for the facility if the repository function is combined with the laboratory and/or reprocessing function?

To evaluate the effects of a combination of facilities, respondents were asked the following questions:

Now we want you to consider how your support would be affected by more specific information. Please respond to each of the following questions on a scale from one to seven, where one means the information would greatly decrease your support and seven means it would greatly increase your support.

The following two questions were posed in random order:

What would happen to your level of support if you learned that each of the sites also would contain a national research laboratory for studying ways to more safely and efficiently manage and dispose of nuclear materials?

What would happen to your level of support if you learned that each of the sites also would include facilities for reprocessing spent nuclear fuel for reuse in generating electricity?

The effect on support for a base repository when combined with a hypothetical national research laboratory is shown in Table 2. Changes in support due to addition of the

laboratory are shown for those who initially supported, were neutral, or opposed the base facility (as described above).

TABLE 2: CHANGE IN SUPPORT FOR REPOSITORY WHEN COMBINED WITH RESEARCH LABORATORY

Initial Preference	2 Mine-Like Geologic Repositories			7 Deep Borehole Repositories		
	Support (58%)	Neutral (26%)	Oppose (16%)	Support (51%)	Neutral (28%)	Oppose (21%)
Support Increased	70%	55%	48%	72%	61%	50%
Support Unchanged	20%	37%	21%	19%	33%	23%
Support Decreased	10%	8%	31%	9%	6%	26%

Of greatest policy relevance are those who initially opposed or were neutral to siting the facility. Among those initially opposed, approximately half (48-50%) said their support for the repository would increase if the facility was combined with the national research laboratory. The numbers are larger (55-61%) for those who were initially neutral. This is consistent with the findings of earlier studies of public support for facility siting, in which it was found that modifying the function of a facility in a manner that addresses the initial risks – both reducing the risks and providing benefits germane to those risks – will do the most to increase acceptance of the facility (Jenkins-Smith and Kunreuther 2005). In this case, co-locating a UNF repository with a national research laboratory that would study “ways to more safely and efficiently manage and dispose of nuclear materials” both serves to reduce the relevant risks and provides high-prestige employment and other economic development benefits. Based on the broad increases in levels of support, such a facility may be less susceptible to the kind of stigmatizing imagery that adheres to a stand-alone repository.

As noted above, systematic surveys of the American public have consistently shown that substantial majorities support the concept of reprocessing UNF (Ansolabehere 2007; World Nuclear News 2009). Given the broad support for reprocessing UNF, what would be the implications of co-locating a reprocessing facility with a repository? The effects are shown in Table 3. Again, the changes in support are shown for those who initially opposed, were neutral, or supported each of the base repository options.

TABLE 3: CHANGE IN SUPPORT FOR REPOSITORY WHEN COMBINED WITH REPROCESSING FACILITY

Initial Preference	2 Mine-Like Geologic Repositories			7 Deep Borehole Repositories		
	Support (58%)	Neutral (26%)	Oppose (16%)	Support (51%)	Neutral (28%)	Oppose (21%)
Support Increased	66%	47%	48%	66%	56%	50%
Support Unchanged	21%	43%	16%	21%	35%	25%
Support Decreased	13%	10%	36%	12%	9%	26%

As with the co-locating a repository with a national research laboratory, combining a repository with reprocessing facilities increases support. Among those who either initially opposed the repository or were neutral, about half said the addition of the reprocessing capability would increase support for the repository. Relatively modest percentages said that the combination would reduce support. Given the consistent and generally supportive view that most Americans have toward reprocessing, this increase in support for the repositories when combined with reprocessing is not surprising, and could be policy-relevant.

The broader implications are that public acceptance of a UNF repository will be sensitive to the overall design attributes of the facility. When the facility is exclusively for disposal, the perceived risks and associated negative imagery will tend to dominate perceptions (especially when UNF has been designated a “waste”). When the facility is more heterogeneous, including design elements that address offsetting risk/benefit activities (such as a laboratory or reprocessing facilities), prospects for public acceptance are increased.

11. Compensation and Public Acceptance

Studies of hazardous facility siting have shown that providing compensation to host communities can increase public support, but may only be effective if the overall balance of risks and benefits attributed to the facility is within acceptable ranges (Kunreuther and Easterling 1998; Jenkins-Smith and Kunreuther 2001, 2005). To what extent does compensation play a role in acceptance? The NSNP survey posed the following question in 2010:

What would happen to your level of support if you learned that each of the states hosting the sites would receive several billion dollars a year, paid for by revenues from nuclear energy, that could be used for hospitals, roads, and schools in that state?

The pattern of changes in expressed support is shown in Table 4, which again shows changes within the groups of those who supported, were neutral, or opposed the repository siting prior to introducing the compensation option.

TABLE 4: CHANGE IN SUPPORT FOR BASE REPOSITORY DESIGNS WITH STATE COMPENSATION

Initial Preference	2 Mine-Like Geologic Repositories			7 Deep Borehole Repositories		
	Support (58%)	Neutral (26%)	Oppose (16%)	Support (51%)	Neutral (28%)	Oppose (21%)
Support Increased	62%	42%	39%	59%	52%	41%
Support Unchanged	20%	43%	23%	24%	30%	22%
Support Decreased	18%	15%	37%	17%	18%	37%

Although overall increases in support in response to compensation are evident, the changes are more modest than was the case for bundling positive attributes into the facility design. Among those who initially opposed the siting, the fraction for which compensation decreases support is nearly as large as that for which it increases support. Among those initially neutral however the effect of compensation on increasing support is substantial; between 42% and 52% of those neutral to the repository expressed increased support when compensation was added to the mix. The conclusion is that compensation is likely to have the effect of increasing support only among those for whom the facility design does not generate strong opposition. For that reason it appears that primary emphasis should be on specification of other facility attributes that generate initial public acceptance. Compensation should be considered as a means to maintain and broaden approval only after the facility attains sufficient public support.

12. Proximity of Nuclear Facilities and Public Acceptance

Used nuclear fuel disposal repositories long have been viewed to be one of the most difficult-to-site facilities (Slovic, Flynn and Layman 1991).¹⁸ The Department of Energy's recent motion to withdraw the license application for the Yucca Mountain facility would seem to confirm this judgment. What are the lessons about proximity in the US case?¹⁹ Two kinds of evidence seem relevant. The first consists of systematic measures of the sensitivity of the US public's level of support for repository siting to the distance of the prospective repository from the respondent's residence. These data can be used to reveal initial preferences, prior to the onset of policy debates over a specific repository proposal. A number of recent studies have explored the relationship between proximity and siting nuclear power plants²⁰, but in recent years only the NSNP has used surveys to experimentally measure the variation in public support for a UNF repository based on distance of the facility from the survey participants' residences. The second kind of evidence comes from cases in which measures of public acceptance for an actual repository can be related to distance from the facility. While no permanent UNF repositories have been sited in the US, and no systematic data are available on public support for repository siting outside Nevada,²¹ measures of public support for the Waste Isolation Pilot Plant (WIPP) in southern New Mexico provide an important case for evaluating the effect of proximity on support for repository siting over the course of an extended and ultimately

¹⁸ See the relative level of opposition to the potentially hazardous facilities analyzed in Jenkins-Smith and Kunreuther (2001).

¹⁹ The lesson according to some officials is grim. Edward Sproat, former director of the DOE's Office of Civilian Radioactive Waste Management, characterized gaining local support as "a noble objective." But he added "if you set your program up so that local acceptance is an absolute necessity to site your repository, I'm not going to say you will fail, but you should be prepared to fail." (Kanter 2007).

²⁰ A 2007 MIT study asked respondents "how would you feel if a new nuclear power plant were built within 25 miles of your home?" (Ansolabehere 2007: 27). Seventy-five percent of respondents said they opposed such a siting. Ann Bisconti, on the other hand, finds that among survey respondents already residing within 10 miles of an operating nuclear power plant, 75% would favor adding a new reactor to the nearest plant (Bisconti 2010). And Greenberg (2009) measured support for concentrating nuclear facilities (reactors, laboratories and repositories) in localities already hosting one or more of such facilities, and found significant variation in support across sites.

²¹ The Nevada case, which was singled-out as the nation's only HLNW repository site to be evaluated over the strong and persistent objections of most Nevada elected officials, provides evidence of the difficulties for siting under "worst case" conditions for garnering public support.

successful repository siting campaign. The data from both the NSNP and the study of WIPP are therefore used to draw lessons about proximity and public acceptance for nuclear materials facility siting.

The NSNP data collected in 2010 permit analysis of the change in support for two broad repository designs (Mine-like Deep Geologic and Deep Borehole) as the stipulated distance of the repository site is increasingly close to the respondent. All respondents were asked the following question:

What would happen to your level of support if you learned that one of these sites is to be located in your state?

Responses were coded on a one to seven scale, where one means the information would greatly decrease support for siting the repository and seven means greatly increase support. Respondents were then were asked:

What would happen to your level of support if you learned that one of these sites is to be located (randomly assigned: 50, 300) miles from your principal residence?

For this analysis, the percentages of respondents who support, are neutral, or oppose the repository are shown for each of three categories of distance: (a) within the respondent's state of residence, (b) within 300 miles of the respondent's principal residence, or (c) within 50 miles of the respondent's principal residence.²² Results are shown in Table 5.

TABLE 5: CHANGE IN SUPPORT FOR REPOSITORY BY PROXIMITY

Repository is within...	Mine-Like Geologic Repository			Deep-Borehole Repository		
	Increased Support	No Change	Increased Opposition	Increased Support	No Change	Increased Opposition
Respondent's State	44%	30%	26%	45%	27%	28%
300 miles of residence	42%	27%	31%	40%	27%	33%
50 miles of residence	30%	31%	39%	40%	20%	40%

The results from the NSNP analysis appear to support the broader finding, consistent with the not-in-my-backyard (NIMBY) proposition, that closer proximity will

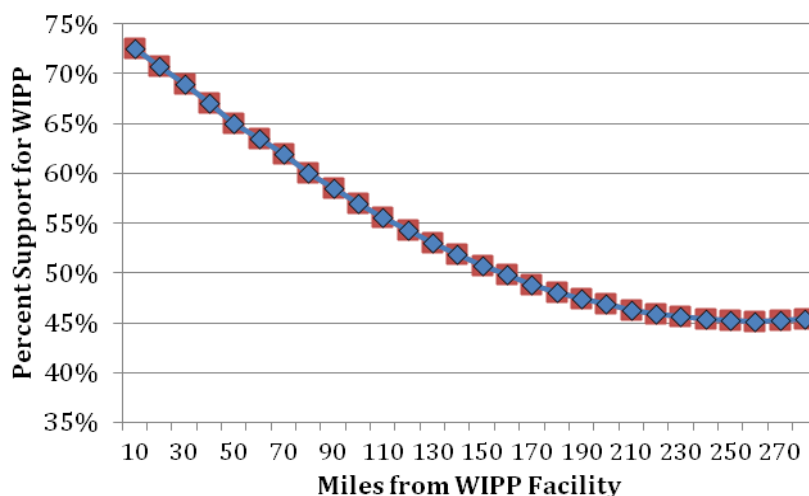
²² The number of respondents randomly assigned to each subgroup was 857 for the 50-mile group, and 900 for the 300-mile group.

increase the fraction of the public who oppose the siting of a repository. But note that substantial proportions of survey participants indicated that their support for the facility is *increased* by closer proximity. Even at the closest (50-mile) distance, 30% of those respondents considering the mine-like repository, and 40% of those considering the deep-borehole repository, indicate that the location will increase support. At the same time, the overall percentage of respondents who oppose the facility increases at closer proximities, which is consistent with the findings of other survey research (Ansolabehere 2007). What is of interest for policy purposes, however, is the finding that significant fractions of the public appear to increase as well as decrease support for a repository as the prospective site is moved closer to their place of residence.

In the context of an actual siting debate, then, we would expect to see some fraction of the respondents closest to the proposed site increase their level of support. In the case of WIPP, data collected in New Mexico by the University of New Mexico permit analysis of the effect of proximity on support for opening the WIPP facility. These data measured New Mexicans' views on WIPP, including support for opening the facility, using statewide random telephone surveys conducted in the spring and fall of each year over the 1990 to 2010 period (Jenkins-Smith, Silva, Nowlin and deLozier 2010). Analysis of these data shows that support for opening the facility increased significantly, on average, the closer the respondent's residence (as mapped by residential zip codes) was to the WIPP facility. Figure 4 illustrates the estimated level of support for WIPP, based on distance of the population from the facility.²³

²³ The effects of proximity were estimated using time series regression models with polynomial expressions for distance (Jenkins-Smith, Silva, Nowlin and deLozier 2011).

FIGURE 4: ESTIMATED SUPPORT FOR WIPP BY DISTANCE FROM FACILITY



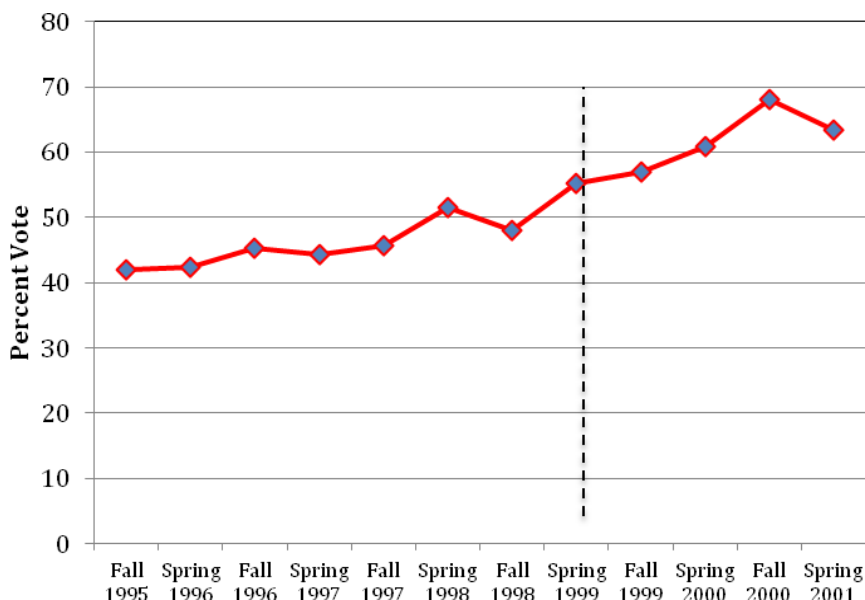
As shown in Figure 4, the sample of New Mexico citizens indicates that over 60% of those living within 40 miles of the WIPP facility supported the facility, whereas support dropped to 50% or less for residents more than 160 miles distant.

The New Mexico data confirm that, in the context of a long-term debate over repository siting, the actual relationship between proximity and policy acceptance can be positive. The WIPP case is not analogous to prospective UNF repository siting in several respects; the materials range from low-level waste to highly radioactive remote contact-handled materials, and all of the materials at WIPP are deemed wastes without provision for retrieval. Given that the materials at WIPP are identified solely as a waste, and that the facility is nearly exclusively designed for disposal,²⁴ the WIPP would seem to pose a difficult case for which to obtain public support. Indeed, in the early years of the policy debate over WIPP, New Mexicans by a 2 to 1 margin opposed opening the facility (McCutcheon 2008). Support grew over time but was still did not reach a majority six months before the repository was approved in May of 1998. Only after EPA approval and WIPP began receiving waste in 1999 did a majority of New Mexicans consistently express support for

²⁴There is a research program based at New Mexico State University in Las Cruces, New Mexico, focused on monitoring the environment around the WIPP facility. The extent to which association with this program increases support for WIPP has not been systematically measured.

the operation of WIPP. Fig. 9-5 illustrates that trend over the 1995 to 2001 period, in which the vertical dashed line indicates the date WIPP opened.

FIGURE 5: PERCENT OF NEW MEXICANS WHO WOULD VOTE TO OPEN WIPP



The WIPP case demonstrates that the initial opposition to a proposed repository can be reduced significantly over the course of a sustained repository siting initiative. These results should temper conclusions reached on the basis of surveys measuring public responses for hypothetical repositories; the latter provide initial indications of support and opposition, but cannot capture the learning and preference changes that result from the kind of sustained policy discourse that occurred over the course of the WIPP debate.

13. Summary of Public Opinion Findings

The evidence regarding public opinion concerning UNF and HLRW management presented in this paper indicates that, despite being relatively uninformed about aspects of radioactive materials and nuclear materials management policies, the public hold coherent and informative preferences about what to do with UNF and (by implication) HLRW. These preferences can be summarized as follows:

Most Americans favor continued or increased reliance on nuclear energy, and believe the benefits of nuclear power exceed the risks. The public appears to have a gradually growing awareness of current UNF dispositions. The evidence indicates that a resolution of the UNF storage/disposal issues will further increase public support for reliance in nuclear energy.

Support for a repository is substantially affected by whether the materials could, in principle, be retrieved for resource use or to improve safety by future generations. The public supports retrievability in repository designs by a 2-to-1 ratio.

Multiple studies indicate that the public prefers reprocessing UNF to a once-through UNF disposal strategy. This finding holds across different survey modes, research teams, and question wording, and is therefore quite robust.

Given current levels of awareness, the public tends to prefer geologic mine-type repositories to deep-borehole or hardened surface storage facilities. None of these options are decisively rejected by the public, however.

Ceteris paribus, the public expressed greater support for multiple (6-8) regional repositories over 1-2 centralized repositories. Note that the differences in levels of support, while statistically significant, were modest.

Public support for a repository (either mine-type or deep borehole) increases significantly if the facility is bundled with a nuclear safety research laboratory or the capacity for reprocessing. Approximately half of those who initially expressed opposition to a repository increase their levels of support once the laboratory or reprocessing are included in the design description.

Support for a repository increases modestly if compensation is provided ("several billion dollars per year") to the host state(s). The increase in support is large among those who were initially neutral about the repository; among those initially opposed, adding the compensation is as likely to increase levels of opposition as support.

The overall effects of having a proposed repository nearby are generally to increase opposition and are consistent with the not-in-my-backyard (NIMBY) phenomenon. However, a significant fraction (30-40%) of survey participants say their support for a repository would increase in the repository were located within 50 miles of their home (another 39-40% said that would increase opposition). Measures of levels of support for the Waste Isolation Pilot Plant (WIPP) show that support was greatest among those closest to the facility. Thus proximity has mixed effects, and – depending on policy design and facility attributes – can be expected to evolve significantly over the course of a facility siting initiative.

14. New Research to Inform Policy

As noted at the outset of this paper, the number of recent and systematic studies of public beliefs, perceptions and preferences regarding UNF and HLRW management has been few. The scope of such studies has also been limited, with very few studies measuring public beliefs and preferences beyond very general opinion items. Moreover, in public opinion research as with other large-scale empirical scientific undertakings, it is important that cumulative research findings benefit from challenge and verification across multiple and heterogeneous research teams. For these reasons, there is ample and pressing need for more social science research on public belief systems across the spectrum of research questions.

For purposes of this paper, however, I limit my recommendations to those research initiatives that I judge to be of greatest relevance and use to policy makers who are working to develop successful and sustainable UNF and HLRW management policies. Here I summarize five distinct kinds of research questions, many of which could be combined as components of larger projects, that would advance understanding of public opinion and preferences in ways that would assist policy makers.

1. Public beliefs, perceptions and preferences concerning nuclear policy and siting issues have been shown to change significantly over time. In the case of the WIPP, public preferences about opening the facility shifted from a sizable majority in opposition to a sizable majority in support over the quarter century long policy debate. For policy makers to understand and respond to salient public concerns, and to monitor responses to policy developments or modifications, it will be essential to undertake systematic, nation-wide tracking surveys of public belief systems concerning UNF and HLRW management policies over time.

2. Survey research has shown that current public opinion on UNF and HLRW policy is based on relatively modest public understanding of the issues. Yet public acceptance and policy preferences are and will remain important – if not decisive – conditions shaping nuclear materials management policies. Public views can be expected to develop and change, possibly in dramatic ways, in response to ongoing public policy deliberations on the issue as well as to events bearing on energy and nuclear safety. For that reason it is important that future research identify the structure of public opinion; we need to better understand *why* the public holds preferences as well as *what*

those preferences may be at a given point in time. What aspects of public preferences concerning UNF and HLRW are resilient to new events and policy counter-arguments, and which aspects are more labile and subject to significant variation over time? To undertake such studies, survey research must be designed to measure the overall belief systems of which nuclear policy beliefs are a part, extending well beyond the kinds of specific policy preferences that are typically measured.

3. Much greater research focus should be given to local community siting concerns and preferences. Should indications of possible regional or local interest in siting nuclear fuel cycle facilities become evident, those areas should be (a) assessed for initial beliefs, concerns and preferences and (b) monitored over time for evolution of local policy preferences.

4. Systematic survey research should be coupled with qualitative and quantitative narrative analysis to better develop our understanding of the manner in which UNF and HLRW policy and facility design variations condition the persuasiveness of competing policy arguments (or narratives). As noted above, nationwide surveys indicate that there are very strong connections between design features of both policies and UNF management facilities. In a policy debate grounded on specific proposed facilities, the arguments (or structured narratives) concerning the proposed policy are likely to be shaped by these design features (e.g., the success of opponents' characterization of the proposed Yucca Mountain facility as a "nuclear waste dump" may have been facilitated by designation of the UNF as waste and by designing the repository to have no function other than permanent disposal). Understanding the manner in which policy and facility design affect the effectiveness of competing policy narratives and public preferences can offer ways to both design more acceptable policies and more effectively engage with affected publics about those policies.

5. The substantive scope of studies of public opinion concerning UNF and HLRW issues needs to be expanded to include (a) process issues about the appropriateness and fairness of methods for evaluating, choosing and compensating host communities and states, and (b) managing the social and perception impacts of UNF and HLRW transportation and temporary storage.

References

- Ansolabehere, Stephen. 2007. *Public Attitudes Toward America's Energy Options: Insights for Nuclear Energy*. Cambridge, MA: MIT Center for Advanced Nuclear Energy Systems, MIT-NES-TR-08.
- Bassett, Gilbert, Hank Jenkins-Smith, Robert O'Connor and Carol Silva. 1998. "What Have We Learned". Unpublished Research Summary. Available from the authors (hjsmith@ou.edu).
- Bassett, Gilbert and Hank Jenkins-Smith. 1994. "Perceived Risk and Uncertainty of Nuclear Waste: Differences Among Science, Business, and Environmental Group Members," *Risk Analysis*. 14: 851-856.
- Bassett, Gilbert, Hank Jenkins-Smith, and Carol Silva. 1996. "On-Site Storage of High Level Nuclear Waste: Attitudes and Perceptions of Local Residents," *Risk Analysis*. 16 :301-312.
- Bisconti Research, Inc. 2006. *Recent National Opinion Surveys about New Nuclear Power Plants: October 2006*. Washington, DC: Bisconti Research Inc.
- Bisconti, Ann. 2010. "Nuclear YIMBY: Local Communities Welcome New reactor Projects." *Public Utilities Fortnightly*, July 2010.
- Flynn, James, C.K. Mertz, and Paul Slovic. 1991. *The 1991 Nevada State Telephone Survey: Key Findings*. Eugene, OR: Decision Research. Available online at: <http://www.state.nv.us/nucwaste/library/>
- Flynn, James, Paul Slovic, and C.K. Mertz. . 1993. *The Spring 1993 Nevada State Telephone Survey: Key Findings*. Eugene, OR: Decision Research. Available online at: <http://www.state.nv.us/nucwaste/library/>
- Flynn, James, Paul Slovic, and C.K. Mertz. 1994. *The Autumn 1993 Nevada State Telephone Survey: Key Findings*. Eugene, OR: Decision Research. Available online at: <http://www.state.nv.us/nucwaste/library/>
- Greenberg, Michael. 2009. "NIMBY, CLAMP, and the Location of New Nuclear-Related Facilities: U.S. National and 11 Site-Specific Surveys." *Risk Analysis*, Vol. 29, No. 9, 2009: DOI: 10.1111/j.1539-6924.2009.01262.x
- Herron, Kerry and Hank Jenkins-Smith. 2006. *Critical Masses and Critical Choices: Evolving Public Opinion on Nuclear Weapons, Terrorism and Security*. Pittsburgh University Press. Pittsburgh, PA. 2006.
- Hokkanen, P. and M. Kojo. 2003. *Ympäristövaikutusten arviointimenettelyn vaikutus päätöksentekoon* (Influence of EIA on decision-making). Suomen ympäristö (*Finnish Environment*) 612 Helsinki, Ministry of the Environment.
- Jenkins-Smith, Hank and Carol Silva. 1998. "The Role of Risk Perception and Technical Information in Scientific Debates Over Nuclear Waste Storage," *Journal of Reliability Engineering and System Safety*. 59: 107-122.

- Jenkins-Smith, Hank and Howard Kunreuther. 2001. "Mitigation and Benefits Measures as Policy Tools for Siting Potentially Hazardous Facilities: Determinants of Effectiveness and Appropriateness," *Risk Analysis*, 21: 371-382.
- Jenkins-Smith, Hank and Howard Kunreuther. 2005. "Mitigation and Benefits Measures as Policy Tools for Siting Potentially Hazardous Facilities: Determinants of Effectiveness and Appropriateness" in S. Lesbirel and D. Shaw (eds.), *Facility Siting and the Management of Legitimate Claims*. Northampton, MA: Edward Elgar Press.
- Jenkins-Smith, Hank and Kerry Herron. 2007. *American Views on Energy and Environmental Security: Comparing Phone and Internet Surveys: 2006*. Albuquerque, NM: Sandia National Laboratories – SAND2007-7733.
- Jenkins-Smith, Hank and Kerry Herron. 2008. *American Security Perspectives: Public Views on Energy, Environment, Nuclear Weapons and Terrorism: 2008*. Albuquerque, NM: Sandia National Laboratories - SAND2008-8027.
- Jenkins-Smith, Hank, Amy Goodin, Carol Silva, Rick Waterman and Scott Hughes. 1999. *Nuclear Reactions: A Synthesis of Survey Research Findings on Public Perceptions of Nuclear Materials Management Programs*. Albuquerque, NM: University of New Mexico Institute for Public Policy.
- Jenkins-Smith, Hank, and Howard Kunreuther. 2001. Mitigation and benefits measures as policy tools for siting potentially hazardous facilities: Determinants of effectiveness and appropriateness. *Risk Analysis*, 2001: 21(2); 371-382.
- Jenkins-Smith, Hank, Carol Silva, Kerry Herron and Robert Rechar. 2011, Forthcoming. "Enhancing Acceptability and Credibility of UNF Repository Development." Paper to be presented at the International High Level Nuclear Waste Management annual meeting, April 11-14, 2011, in Albuquerque, NM.
- Jenkins-Smith, Hank, Carol Silva, Matthew Nowlin and Grfant deLozier. 2011. "Reversing Nuclear Opposition: Evolving Public Acceptance of a Permanent Nuclear Waste Disposal Facility." *Risk Analysis*: DOI: 10.1111/j.1539-6924.2010.01543.x
- Jenkins-Smith, Hank, Kerry Herron and Carol Silva. 2011, Forthcoming. *Perspectives on Energy, the Environment, Nuclear Weapons, and Terrorism: 2010 National Security Surveys*. Forthcoming Sandia Report, Albuquerque, NM: Sandia National Laboratories.
- Jones, Jeffrey. 2009. "Support for Nuclear Energy Inches Up to New High." Washington, DC: Gallup Opinion.. Available online at: <http://www.gallup.com/poll/117025/support-nuclear-energy-inches-new-high.aspx>
- Kanter, James. 2007. "Radioactive NIMBY: No One Wants Nuclear Waste." *New York Times*, published November 7, 2007.
- Kunreuther, Howard, and Douglas Easterling. 1998. "The Role of Compensation in Hazardous Facility Siting." *Journal of Policy Analysis and Management* 15(4): 601-622.
- Lupia, A. and M. McCubbins. 1998. *The Democratic Dilemma: Can Democratic Citizens Learn what they Need to Know?* Cambridge MA: Cambridge University Press.

McCutcheon, C. *Nuclear Reactions: The Politics of Opening a Radioactive Waste Disposal Site*. University of New Mexico Press, 2002.

Mountain West Research. 1989. *Yucca Mountain Socioeconomic Project Preliminary Findings: 1989 Nevada State Telephone Survey*. (June 1989). Available online at: <http://www.state.nv.us/nucwaste/library/>

Nuclear Energy Institute. 2009. "Nuclear Plant Neighbor Survey Shows Strong Support for Current and New Power Plants". Washington DC: Nuclear Energy Institute. Available online at: <http://www.nei.org/newsandevents/newsreleases/nuclear-plant-neighbor-survey-shows-strong-support-for-current-and-new-power-plants>

Nuclear Energy Institute. 2010. "Nuclear Energy Support Hits Record-High Levels Among Americans, New Survey Shows." Washington DC: Nuclear Energy Institute. Available online at: <http://www.nei.org/newsandevents/newsreleases/nuclear-energy-support-hits-record-high-levels-among-americans-new-survey-shows/>

OECD-NEA. 2001. *Reversibility and Retrievability in Geologic Disposal of Radioactive Waste: Reflections at the International Level*. OECD; Paris.

OECD-NEA. 2009. *RWMC Reversibility and Retrievability Project: Phase-2 report*. NEA/RWM(2009)3/REV1. OECD. Paris. 5 March 2009.

PEW Research Center for the People and the Press. 2010. "Wide Partisan Divide Over Global Warming." Washington, DC: Pew Research Center Publications. Accessed online at: <http://pewresearch.org/pubs/1780/poll-global-warming-scientists-energy-policies-offshore-drilling-tea-party>

Slovic, Paul, M. Layman and J. Flynn 1991 "Risk Perception, Trust and Nuclear Waste: Lessons from Yucca Mountain." *Environment* 33: 6-11, 28-30.

Solomon, Barry D.; Andr en, Mats; and Strandberg, Urban (2010) "Three Decades of Social Science Research on High-Level Nuclear Waste: Achievements and Future Challenges," *Risk, Hazards & Crisis in Public Policy*: 1(2). DOI: 10.2202/1944-4079.1036

World Nuclear News. 2009. "Support for Reprocessing and Action on Waste". Published March 26, 2009. Available online at: <http://www.world-nuclear-news.org/print.aspx?id=24933>

Yankelovich, D. 1991. *Coming to Public Judgment: Making Democracy Work in a Complex World*. Syracuse, NY: Syracuse University Press.