"Public Attitudes Toward Siting a High Level Nuclear Waste Repository in Nevada"

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Howard Kunreuther, Douglas Easterling, William Desvousges and Paul Slovic

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Public Attitudes Toward Siting a High-Level Nuclear Waste Repository in Nevada

Howard Kunreuther,1 Douglas Easterling,1 William Desvousges,2 and Paul Slovic3

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This paper examines the sources of public opposition to a high-level nuclear waste repository among samples of 1001 residents of Nevada and a national sample of 1201 residents. Two models of choice are contrasted: A benefit–cost model and a risk–perception model of individual choice. The data suggest that the willingness of Nevada residents to accept a repository at Yucca Mountain depends upon subjective risk factors, especially the perceived seriousness of risk to future generations. Perceived risk depends in part on level of trust placed in the Department of Energy to manage a repository safely. Opposition to a local repository did not decrease significantly if compensation in the form of annual rebates, either ($1000, $3000, or $5000 per year for 20 years) were offered to residents. The public needs to be convinced before compensation is considered, that the repository will possess minimal risks to themselves as well as to future generations, and that the site currently targeted is suitable. One way to do this is through adoption of mitigation and control procedures such as strict federal standards and local control over the operation of the repository. The federal government should also consider returning to the fair procedure for selection between candidate sites specified in the initial Nuclear Waste Policy Act of 1982.

KEY WORDS: Nuclear waste; perceived risk; compensation; mitigation.

1. INTRODUCTION

The decision as to where a high-level nuclear waste (HLNW) repository should be sited has generated a great deal of public concern regarding safety and equity. The repository, to be constructed 2000 feet below ground, will permanently store spent nuclear fuel rods shipped from commercial reactors throughout the United States. Although the repository is intended to reduce radiation risks relative to the temporary storage methods that currently exist, it has proven difficult to find a site that is universally acceptable.

The controversy on where to locate the repository came to a head in December 1987, when Congress amended the Nuclear Waste Policy Act of 1982 (NWPA) to narrow the search to a single site — Yucca Mountain in Nevada. Political leaders in Nevada generally oppose the repository and have taken a number of steps to block its construction at Yucca Mountain. For example, the state legislature passed Assembly Bill 222 in June 1989 making it illegal to dispose of high-level nuclear waste within Nevada. This legislation has been interpreted to allow state agencies to deny permits that the Department of Energy (DOE) requires for its characterization of the Yucca Mountain site.1

In addition, the U.S. Congressional delegation from Nevada has become increasingly polarized against the repository; indeed, ex-governor Richard Bryan was able to defeat Senator Chic Hecht for the U.S. Senate in 1988 largely as a result of Hecht’s equivocal stand on the repository. In taking this antirepository position, elected officials feel that storage and transportation of nuclear wastes within the state pose unacceptable risks to the
state's population and may create an image of Nevada as a nuclear wasteland (the proposed site is adjacent to the existing nuclear weapons testing site). Further, these risks are viewed by the state as inherently noncompensable.

The controversy surrounding the siting of a HLNN repository in Nevada can be traced to basic discrepancies between state and federal officials in the importance they attach to various consequences of the repository. This paper provides a perspective on these differences by contrasting two models of individual choice that describe the different stakeholders. First, we develop a benefit-cost model that appears to reflect the view that DOE has of the repository. We contrast this approach with a risk perception model of individual choice which incorporates additional factors reflecting social concerns. This second model appears to reflect the Nevada state officials’ position.

We then examine which of these models best describes the attitudes of the public by analyzing data from two telephone surveys: a national survey of 1201 U.S. households and a survey of 1001 residents of Nevada. The results of the surveys suggest that it is necessary to employ a siting process that instills trust and public confidence, so that the repository will be perceived as safe to residents and to future generations. Further, compensation packages will not allay public concerns with respect to the repository.

2. SETTING THE SCENE

2.1. Original Legislation

Many of the concerns raised by the State of Nevada had been explicitly addressed by Congress with the passage of the original Nuclear Waste Policy Act (NWPA) of 1982. The framers of the act recognized that a repository would not be politically acceptable to a host state unless that state had itself undertaken actions that assured citizens of the safety of the facility and the suitability of the local site. To promote this public confidence, NWPA provided potential host states with a substantive role in overseeing the siting process, including Federal funding for independent scientific studies of the site’s suitability. Host states were also granted the ultimate power of review with the right to file a “notice of disapproval,” which can block the construction of the repository subsequent to the President’s recommendation (if both houses fail to override the veto within 90 days). In addition to these provisions designed to ensure that only suitable sites would be selected, NWPA also addressed issues of regional equity by calling for the construction of two repositories, one in the East and one in the West.

2.2. Implementation

The actual process of selecting candidate sites has failed to meet the high standards embodied in the NWPA Act of 1982. First, DOE appeared to rely on political criteria to select Yucca Mountain in Nevada; Deaf Smith County, Texas; and the Hanford Reservation in Washington, as the three sites for characterization.

A second compromise to the principles of NWPA involved the abandonment of the regional equity provision. At the same time that the President confirmed the three sites to be characterized for the Western repository, he also suspended all activity leading to the construction of a repository in the East.

Third, the 1987 amendments to NWPA altered the fundamental process by which the repository site would be chosen. Rather than simultaneously characterizing three potential facilities, a sequential process was invoked wherein only the Yucca Mountain site is currently scheduled for further study. The 1987 amendments also authorized federal grants to Nevada in the amount of $10 million per year during site characterization and licensing, and $20 million per year once the repository begins receiving waste. This offer of compensation has achieved little in the way of defusing state opposition.

In November 1989, Department of Energy Secretary James Watkins acknowledged widespread dissatisfaction with the siting effort by calling for a fresh start to the study of the Nevada site. Initial studies of Yucca Mountain had taken 2 years and had cost $500 million, but scientific disputes regarding the integrity of the data caused substantial public opposition. The decision to begin anew means that there is great uncertainty as to whether the HLNN repository will eventually be located at Yucca Mountain or whether an alternative plan for storing these wastes will resurface.

3. CONTRASTING MODELS OF CHOICE FOR SITTING FACILITIES

An important step in attempting to develop a mutually acceptable agreement between the various interested parties is to understand how the public perceives the repository. In this section, we present two alternative models that might be used to explain individuals' preferences for or against a nearby repository. These models differ primarily in their conceptualization of risk: In the benefit–cost model, risk is captured by probabilities and possible consequences, while the risk–perception model employs a broader set of concerns.

3.1. A Benefit–Cost Model

The model of choice underlying benefit–cost comparisons assumes that a Nevada resident's preference for a repository at Yucca Mountain depends upon a comparison of his or her overall utility under the two alternatives:

- No repository at Yucca Mountain (the status quo)
- Repository at Yucca Mountain

Assume that an individual $i$ compares the two alternatives over a time horizon that spans the current period to period $T$. Then $i$'s utility of the no repository option is simply:

$$U_i(\text{No Repository}) = U_i \left[ \sum_{t=0}^{T} W_t \left( \frac{1}{1+r^t} \right) \right]$$

where $U_i$ is a function describing the utility or well-being of individual $i$, $W_t$ is the level of $i$'s wealth in period $t$, and $r$ is the market discount rate.\(^6\)

The consequences under the repository option are much less certain than under the status quo. Therefore, the calculation of an overall utility requires that the utilities of the possible outcome states be weighted by their respective probabilities. In particular, we assume that the individual considers a number of alternative repository scenarios, $S$, each of which describes a possible sequence of events (e.g., accidents at the repository, groundwater contamination, changes in the economic structure of the area) occurring from $t=0$ until $t=T$. For each scenario, net wealth, $N_i(S)$, is computed as follows:

$$N_i(S) = \sum_{t=0}^{T} \left[ \frac{1}{(1+r)^t} \right] \left[ W_t + B_u(S) - L_u(S) \right]$$

In this equation, $B_u(S)$ is the perceived benefit of the repository to individual $i$ in period $t$ under scenario $S$. Benefits might include outcomes, such as new employment opportunities, lower state and local taxes, new roads and other public facilities. The term $L_u(S)$ refers to the magnitude of the loss to individual $i$ in period $t$ under scenario $S$. Losses might include the economic and health effects of repository accidents, along with a decline in property values. The evaluation of net benefits is thus both individualized and time-discounted. Based on the net wealth figures under each scenario, an expected utility for the repository option would be computed as:

$$E[U_i(\text{Repository})] = \sum_{S} p_i(S) U_i[N_i(S)]$$

where $p_i(S)$ is $i$'s perceived probability of scenario $S$ occurring. Within this model, perceived risk increases (and expected utility decreases) as the individual assigns higher probabilities and/or a higher loss of wealth to those scenarios involving repository accidents or contamination.

The benefit–cost model makes an important assumption regarding the relative weighting of short-run vs. long-run risks. Specifically, the presence of a positive discount rate, $r$, implies that losses occurring far into the future (i.e., risks to future generations) will have little impact on net wealth, and consequently will not influence the individual's appraisal of the utility of a repository.

Once utilities have been computed for the possible outcome states, individual $i$'s decision to vote for or against a repository is determined by the relative magnitudes of Eqs. (1) and (3). Because the repository is a novel technology, the values of $p_i(S)$, $L_i(S)$, and $B_u(S)$ are surrounded by a great deal of uncertainty. Thus, any attempt to explain an individual's preferences using the benefit–cost model will require an assessment of that individual's perceptions of probabilities, loss magnitudes, and benefits.\(^7\)

The benefit–cost model suggests that an individual's willingness to vote in favor of the repository will vary as a function of the perceived likelihood of adverse events, the perceived consequences of such events, and

\(^6\) In this simplified version of the model, $W$ is assumed to be known to $i$ with certainty.

\(^7\) A more formal two-period model of choice based on expected utility analysis for analyzing the siting decision in Nevada is developed in Kuzmiker and Easterling.\(^{10}\)
the level of economic benefits. In addition, the perceived impact of a repository accident upon oneself \( (L_u) \) should vary inversely with the individual's distance from the repository. Distance may also determine whether the economic benefits of the facility (e.g., new jobs and a larger tax base) will extend to oneself. Table I specifies the variables utilized in the telephone survey that would be hypothesized to be important in explaining voting behavior if residents of Nevada utilized a benefit-cost model to make their choices.

3.2. A Risk Perception Model

While the benefit–cost model allows a high degree of specificity in the representation of an individual's utility, it is limited in its ability to explain the public's decision process and, hence, may not be very helpful in guiding policy. The model relies on accident probabilities and the magnitude of loss to oneself in describing the repository risk, but the public is likely to evaluate the seriousness of risk in other ways.

First, repository risks are unlikely to be assessed solely in terms of their personal impact, but rather are considered in terms of their consequences to a wider population. The prospect of storing wastes for 10,000 years may, in particular, invite concern for future generations. This regard for societal impacts is consistent with William Freudenberg's view that the public acts as a conscientious "board of directors" in overseeing the appropriateness of risky technologies.

Second, empirical studies of risk perception suggest that the risk associated with a technology is not evaluated solely in terms of probabilities and loss magnitudes, but according to more subjective factors, such as the involuntary nature of exposure, unfamiliarity, and dread.

Finally, in assessing the acceptability of locating a repository nearby, residents may focus on indirect indicators of risk, such as trust in the federal government and the presence of appropriate monitoring and control procedures. Indeed, in choosing whether or not to vote for a repository, the individual may find it unnecessary to estimate probabilities and loss magnitudes, instead conducting a simple examination of whether the requisite safety features are in place. Probabilities may seem uninformative for catastrophic risks where there is limited, if any, historical data.

The risk perception literature suggests that the risk indicators used in the benefit–cost model (i.e., the first six variables in Table I) will not sufficiently explain an individual’s willingness to vote for a nearby repository. In place of these predictors, the risk perception model relies on the five risk indicators shown in Table II. The question of whether economic benefits adds explanatory

| Table I. Variables Used to Explain Voting Behavior in the Benefit–Cost Model |
|------------------|------------------|------------------|
| **Variable**     | **Range**        | **Description**  |
| PR_ACCID         | 1-5              | Probability of an accident at the repository\(^{a}\) |
| PR_TRANS         | 1-5              | Probability of radiation released during the transport of nuclear waste to the repository\(^{a}\) |
| PR_WATER         | 1-5              | Probability that repository wastes will leak into groundwater\(^{a}\) |
| PR_SABOTG        | 1-5              | Probability of terrorist sabotage at the repository\(^{a}\) |
| CONS_DEATH       | 1-5              | A repository accident would involve certain death\(^{a}\) |
| KILLMANY         | 1-5              | A repository accident could kill many people at one time\(^{a}\) |
| BENEFITS         | 1-5              | A repository would stimulate economic growth in nearby communities\(^{a}\) |
| DISTANCE         | 16-383           | Distance from respondent’s home to Yucca Mountain (measured in air miles) |

\(^{a}\)Scale ranges from “Very Unlikely” to “Very Likely.”

| Table II. Variables Used to Explain Voting Behavior in the Risk Perception Model |
|------------------|------------------|------------------|
| **Variable**     | **Range**        | **Description**  |
| RISK SELF        | 0-10             | Perceived seriousness of the risk to oneself from a repository at Yucca Mountain\(^{a}\) |
| RISK FUTUR       | 1-5              | A repository at Yucca Mountain poses serious risks to future generations\(^{a}\) |
| CONTROL RISK     | 1-5              | Persons living near a repository would be able to control the risks\(^{a}\) |
| DREAD            | 1-5              | A repository would be dreaded by nearby residents\(^{a}\) |
| TRUST            | 0-10             | Trust the federal government to make the repository as safe as possible\(^{a}\) |

\(^{a}\)Scale ranges from “Not at All Serious” to “Very Serious.”

\(^{a}\)Scale ranges from “Strongly Disagree” to “Strongly Agree.”

\(^{a}\)Scale ranges from “No Trust at All” to “Complete Trust.”

\(^{a}\) Even if \( p \) and \( L \) are estimated, it is unclear as to whether they will be combined in a multiplicative fashion as is assumed under the benefit–cost model.
power to risk perception variables can be assessed empirically.

The risk perception model may surpass the benefit-cost model not only in its ability to explain behavior, but also in suggesting remedial policy actions. For example, if factors such as trust in government are found to be the major determinants of an individual’s willingness to vote for the repository, this would suggest that actions be explored to instill public confidence in the siting process. Fewer such policy implications are readily apparent from a finding that \( p \) and \( L \) are important determinants of voting behavior.

4. TELEPHONE-SURVEY METHODOLOGY

4.1. Sampling Plan

The factors that influence individuals’ willingness to tolerate a nearby repository can be gleaned from an analysis of a survey of Nevada households undertaken in the spring of 1987, at a time when there were still three candidates for the Western repository. The sample was drawn using standard random digit-dialing techniques. The two counties closest to the proposed Yucca Mountain site, Lincoln and Nye, were intentionally oversampled in order to allow a more accurate comparison between these residents and the rest of the State. Residents of these two counties tended to view the repository more favorably (e.g., lower risk of an accident, greater benefits) than did the rest of the sample. This result appears to reflect a more general trend for rural residents to be less averse to the repository than urban residents from Las Vegas and Reno.\(^9\)

Of the 2676 households in which an eligible respondent was reached, 1001 (37.4\%) provided complete interviews. Because of the modest response rate, the findings may not generalize to the entire population of Nevada. We do feel, however, that the results provide considerable insight into the factors influencing attitudes toward the repository.

A parallel survey was conducted using a national sample (excluding Nevada). For this survey, 1201 of 3419 individuals contacted (35.1\%) yielded completed interviews. This survey is used here only to confirm our conclusions concerning the impact of compensation on tolerance of a local repository.

\(^9\) Lincoln and Nye Counties contain about 2\% of Nevada’s population, but comprise 20\% of the sample. See Ref. 15, Section 3, for the rationale and details of the sampling plan.

4.2. Descriptive Statistics

Table III presents univariate statistics for the variables used in the comparison of the benefit-cost and risk perception models for the Nevada sample.\(^10\) The outcome measure, willingness to vote for Yucca Mountain, is formed from a partitioning of the item, “If a vote were held today on building a permanent repository, where would you vote to locate the repository?” For our purposes, the three responses other than Yucca Mountain (i.e., Hanford, Deaf Smith, and none of the above) were pooled to form a “not at Yucca Mountain” response.\(^11\)

5. TESTS OF MODELS OF PREFERENCE

5.1. Benefit-Cost Model

The benefit-cost model is evaluated by assessing the ability of the variables introduced in Table I to predict willingness to vote for Yucca Mountain among Nevada residents. As a first step, we consider each variable’s zero-order relation with the outcome measure (i.e., ignoring the effect of all other variables) based on a series of univariate logistic analyses. As shown in the first column of Table IV, each indicator of risk and benefit is by itself significant at \( p < 0.001 \) using a chi-square (\( \chi^2 \)) test. Willingness to vote for Yucca Mountain is negatively related to the probability and consequence measures, while positively related to perceived benefits. Further, these relationships are essentially linear; controlling for the linear contrast, none of the residual effects attains significance at \( p < 0.01 \).\(^12\)

The coefficient for DISTANCE is negative, indicating that support for a repository at Yucca Mountain decreases as one moves further from the proposed site. While the relation between DISTANCE and VOTE is

\(^{10}\) Descriptive statistics for the National sample can be found in Kunreuther et al.\(^{13}\)

\(^{11}\) In the analyses which follow, the 90 individuals with a “Don’t Know” response on the VOTE variable are omitted since we cannot determine why they responded in this manner.

\(^{12}\) In converting the categorical item into a linear scale, we assumed that a “Don’t Know” response reflects an intermediate opinion, so this category was always assigned the middle value. The propriety of this scaling was borne out by the lack of significance in the residuals; had the “Don’t Know” responders actually had extreme attitudes toward the repository, the linear contrast would have failed to capture fully the explanatory power of the variable. A significance level of 0.01 was employed for these tests of nonlinearity due to the large number of independent tests (12 over the two models). For the benefit-cost model, none of the tests for nonlinearity were significant at \( p < 0.05 \).
<table>
<thead>
<tr>
<th>Variable</th>
<th>Yucca Mtn., Nevada</th>
<th>Hanford, Wash.</th>
<th>Deaf Smith, Texas</th>
<th>None of above</th>
<th>Don't know</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOTE</td>
<td>24.3</td>
<td>4.2%</td>
<td>18.6%</td>
<td>44.0%</td>
<td>9.0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>66.8%</td>
</tr>
</tbody>
</table>

- **Very unlikely** (1)
- **Somewhat unlikely** (2)
- **Don't know** (3)
- **Somewhat likely** (4)
- **Very likely** (5)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Strongly disagree (1)</th>
<th>Disagree (2)</th>
<th>Don't know (3)</th>
<th>Agree (4)</th>
<th>Strongly agree (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONS DEATH</td>
<td>3.0%</td>
<td>20.5%</td>
<td>2.8%</td>
<td>50.1%</td>
<td>23.6%</td>
</tr>
<tr>
<td>KILLMANY</td>
<td>2.7%</td>
<td>15.7%</td>
<td>3.0%</td>
<td>52.6%</td>
<td>26.0%</td>
</tr>
<tr>
<td>BENEFITS</td>
<td>6.7%</td>
<td>40.3%</td>
<td>7.7%</td>
<td>39.3%</td>
<td>6.1%</td>
</tr>
<tr>
<td>RISK FUTUR</td>
<td>3.1%</td>
<td>24.6%</td>
<td>5.5%</td>
<td>40.8%</td>
<td>26.1%</td>
</tr>
<tr>
<td>CONTRO RISK</td>
<td>20.9%</td>
<td>64.8%</td>
<td>1.5%</td>
<td>11.8%</td>
<td>1.0%</td>
</tr>
<tr>
<td>DREAD</td>
<td>1.5%</td>
<td>19.6%</td>
<td>4.6%</td>
<td>54.1%</td>
<td>20.2%</td>
</tr>
</tbody>
</table>

**Univariate statistics**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Range</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISTANCE</td>
<td>16-683</td>
<td>149.6</td>
<td>83.0</td>
</tr>
<tr>
<td>RISK SELF</td>
<td>0-10</td>
<td>5.17</td>
<td>3.71</td>
</tr>
<tr>
<td>TRUST</td>
<td>0-10</td>
<td>4.08</td>
<td>3.14</td>
</tr>
</tbody>
</table>

---

significant, this effect has much less statistical power than do the probability and consequence measures.\(^{13}\)

To eliminate redundancies in the effects of the various benefit-cost predictors, we performed multiple logistic regression analysis. In the first analysis (Model 1 in Table IV), all predictors were entered into the model. Two variables (PR SABOTG and DISTANCE) failed to account for unique variance and were omitted, yielding the final benefit-cost model shown in the last column (Model 2).

These analyses reveal that acceptance of a local repository is highly sensitive to the perceived likelihood of adverse events — accidents at the repository, accidents in transporting waste to the repository, and waste leaching into the groundwater. The variables reflecting perceived losses also account for major portions of the variance in willingness to vote for Yucca Mountain. Those who feel a repository accident will result in certain death or will kill many people are more likely to oppose the repository than are those who view an accident as less serious. BENEFITS achieves the highest level of statistical significance in Model 2, largely because this variable is the only indicator of the positive consequences of a repository. Perceived risk, on the other hand, was assessed with many indicators.

To illustrate the cumulative impact of the benefit-cost factors on voting behavior, we used Model 2 to estimate willingness to vote for Yucca Mountain for two extreme individuals. Person A has a positive evaluation of the repository along all the included factors (i.e., assigns the lowest possible values to the likelihood and consequence items, while assigning the highest value to the benefits measure). In contrast, Person B views all repository risks as very likely, an accident as involving certain death and potentially killing many persons, and the repository as offering no economic benefits. Based on the parameter estimates in Model 2, the probability...
### Table IV. Predictive Ability of Benefit–Cost Model in Explaining Willingness to Vote for Repository at Yucca Mountain

<table>
<thead>
<tr>
<th>Factor</th>
<th>$\chi^2$ test of linear effect</th>
<th>Logistic regression equation (coefficient and standard error)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
</tr>
<tr>
<td>PR — ACCID</td>
<td>154.68***</td>
<td>$-2.12^*$</td>
</tr>
<tr>
<td></td>
<td>(.085)</td>
<td>(.084)</td>
</tr>
<tr>
<td>PR — TRANS</td>
<td>120.31***</td>
<td>$-2.29^*$</td>
</tr>
<tr>
<td></td>
<td>(.087)</td>
<td>(.086)</td>
</tr>
<tr>
<td>PR — WATER</td>
<td>167.97***</td>
<td>$-3.17^*$</td>
</tr>
<tr>
<td></td>
<td>(.086)</td>
<td>(.085)</td>
</tr>
<tr>
<td>PR — SABOTG</td>
<td>66.12***</td>
<td>$-1.19$</td>
</tr>
<tr>
<td></td>
<td>(.075)</td>
<td></td>
</tr>
<tr>
<td>CONS — DEATH</td>
<td>115.22***</td>
<td>$-2.83^*$</td>
</tr>
<tr>
<td></td>
<td>(.093)</td>
<td>(.092)</td>
</tr>
<tr>
<td>KILLMANY</td>
<td>114.49***</td>
<td>$-3.22^*$</td>
</tr>
<tr>
<td></td>
<td>(.097)</td>
<td>(.096)</td>
</tr>
<tr>
<td>BENEFITS</td>
<td>96.13***</td>
<td>$.639</td>
</tr>
<tr>
<td></td>
<td>(.091)</td>
<td>(.089)</td>
</tr>
<tr>
<td>DISTANCE</td>
<td>7.28**</td>
<td>$-0.013</td>
</tr>
<tr>
<td></td>
<td>(.0011)</td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>—</td>
<td>$2.36^*$</td>
</tr>
<tr>
<td></td>
<td>(.59)</td>
<td>(.525)</td>
</tr>
<tr>
<td>Fit of the Model (C statistic)</td>
<td>—</td>
<td>$.863</td>
</tr>
</tbody>
</table>

*This test ignores the effect of all other factors. Each test statistic has 1 degree of freedom. No factor showed statistical evidence ($p<0.05$) of a nonlinear effect.

$p<0.05$, $**p<0.01$, $***p<0.001$.

that Person A will vote for Yucca Mountain is 0.978, while the probability that Person B will vote for the repository is 0.010.

### 5.2. Risk Perception Model

In the risk perception model, perceived risk is assessed not by explicit measures of probability and consequences, but by global evaluations of risk severity (RISK — SELF and RISK — FUTUR), as well as by subjective factors that might influence these evaluations (CONTROL — RISK, DREAD, and TRUST). The first column of Table V shows that each of these five factors is by itself a significant predictor of willingness to vote for Yucca Mountain. Willingness to vote for Yucca Mountain is lower for those who perceive the repository as imposing high levels of risk to self, risk to future generations, and dread. Similarly, those who view the risks as controllable and those who have confidence in the federal government’s ability to manage the repository safely are more willing to vote in favor of the local site. Again, the relations are largely linear, with no factors showing a significant ($p<0.01$) residual effect controlling for the linear contrast.\(^{14}\)

In combining the risk perception model predictors into a single model, we find that CONTROL — RISK and DREAD fail to explain unique portions of the variance in willingness to vote for Yucca Mountain (see Model 3 in Table V). Controlling for the other three indicators of risk, neither of these two predictors is significant at $p<0.05$. Model 4 omits these two factors and constitutes the final equation for the behavioral model. This model also includes the BENEFITS measure, as the perception of economic growth is a significant predictor of VOTE, controlling for the perceived risk measures.

Table V shows that the four factors in Model 4 are clearly significant in explaining willingness to vote for Yucca Mountain, but the regression coefficients provide only a limited sense of the size of the effects. This ambiguity is inherent in logistic regression because the

\(^{14}\) For one factor, RISK — SELF, the residual effect was significant at $p<0.05$ ($\chi^2(9) = 17.39, p = 0.043$). This effect was largely due to the fact that those who responded “Don’t Know” to RISK — SELF were more extreme than expected in their unwillingness to vote for Yucca Mountain. Still, this effect is minor compared to the linear trend ($\chi^2(1) = 169.75$) and will be ignored in subsequent models.
Table V. Predictive Ability of Behavioral Model in Explaining Willingness to Vote for Repository at Yucca Mountain

<table>
<thead>
<tr>
<th>Factor</th>
<th>$\chi^2$ test of linear effect*</th>
<th>Logistic regression equation (coefficient and standard error) Model 3</th>
<th>Logistic regression equation (coefficient and standard error) Model 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK SELF</td>
<td>169.75***</td>
<td>-0.215*** (.035)</td>
<td>-0.221*** (.035)</td>
</tr>
<tr>
<td>RISK FUTUR</td>
<td>224.75***</td>
<td>-0.716*** (.099)</td>
<td>-0.761*** (.095)</td>
</tr>
<tr>
<td>CONTROL RISK</td>
<td>60.68***</td>
<td>0.096 (.111)</td>
<td>-</td>
</tr>
<tr>
<td>DREAD</td>
<td>90.15***</td>
<td>-0.123 (.101)</td>
<td>-</td>
</tr>
<tr>
<td>TRUST</td>
<td>108.41***</td>
<td>0.172*** (.034)</td>
<td>0.178*** (.033)</td>
</tr>
<tr>
<td>BENEFITS</td>
<td>96.11***</td>
<td>0.533*** (.097)</td>
<td>0.552*** (.097)</td>
</tr>
<tr>
<td>Intercept</td>
<td>-</td>
<td>-0.071 (.631)</td>
<td>-0.221 (.481)</td>
</tr>
<tr>
<td>Fit of the Model (C statistic)</td>
<td>-</td>
<td>0.901</td>
<td>.900</td>
</tr>
</tbody>
</table>

*This test ignores the effect of all other factors. Each test statistic has 1 degree of freedom. The nonlinear residual effect did not attain the 0.01 significance level for any of these factors.

**p < 0.001.

analysis explains variance in the logit [i.e., $\log(p/(1-p))$] where $p$ is the probability of voting yes], rather than variance in the probability directly. Thus, the effect of a particular change in perception will depend upon the values taken by the other factors in the model.

Using the coefficients from Model 4, we can determine the total range in willingness to vote for Yucca Mountain. An individual who holds extreme negative views on all four measures of risk and benefit will have an estimated probability of 0.003, whereas an individual with the opposite pattern will have an estimated probability of 0.972 of voting for a repository at Yucca Mountain.

To provide a more explicit indication of each factor's effect, we have constructed Table VI, in which the estimated probability of voting for Yucca Mountain is computed for selected combinations of predictor values. The first three rows of Table VI demonstrate the impact of moving from a RISK SELF score of 10 to a RISK SELF score of 0. The table indicates that such a shift in perceived risk to self will have its greatest impact on willingness to vote for Yucca Mountain if the person holds nonextreme opinions on the other three factors. For example, if RISK FUTUR, TRUST, and BENEFITS all take on their middle values (i.e., 3, 5, and 3, respectively), then moving from RISK SELF = 10 to RISK SELF = 0 will increase the estimated probability of voting for Yucca Mountain by 0.408 (i.e., 0.511–0.103).

From Table VI, it is clear that risk to future generations is critical in determining one's willingness to support a local repository. For example, if RISK SELF, TRUST, and BENEFITS take on their middle values, the RISK FUTUR variable has more than a 54 percentage point effect on the outcome probability. The impact of RISK FUTUR would not have been predicted by a standard benefit–cost model with a positive discount rate. This model does not capture individual's concerns for the welfare of individuals whose consumption stream begins at large values of t (i.e., for persons who come into the world after the country has committed itself to an irreversible decision). An individual who attaches importance to the impact upon future generations could be guided by either: (a) a moral concern for persons who do not have a voice in the decision-making process or (b) a fundamental psychological motivation, "generativity," defined as the need of the self to establish and guide the next generation.

Concern for future generations appears to be an especially strong determinant of preference in the realm of nuclear technology. The world's experience with nuclear weapons has imbued nuclear technology in general with an "infinite" power capable of exterminating the species, which poses a special threat to generativity.
Table VI. Effect of Individual Predictors on Willingness to Vote for Yucca Mountain (Risk Perception Model)

<table>
<thead>
<tr>
<th>Variable tested</th>
<th>Worst value</th>
<th>Middle value</th>
<th>Best value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK SELF = 10</td>
<td>0.03</td>
<td>0.10</td>
<td>0.79</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>0.01</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0.03</td>
<td>0.11</td>
</tr>
<tr>
<td>RISK FUTUR = 5</td>
<td>0.03</td>
<td>0.07</td>
<td>0.62</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0.15</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0.67</td>
<td>0.61</td>
</tr>
<tr>
<td>TRUST = 0</td>
<td>0.03</td>
<td>0.12</td>
<td>0.85</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>0.08</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>0.20</td>
<td>0.45</td>
</tr>
<tr>
<td>BENEFITS = 1</td>
<td>0.03</td>
<td>0.10</td>
<td>0.79</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0.10</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>0.30</td>
<td>0.51</td>
</tr>
</tbody>
</table>

*The estimated probability of voting for Yucca Mountain for the given combination of predictors is based on the coefficients in Model 4. It is true coincidence that RISK SELF has the same size effect as BENEFITS.

Example, residents of Harrisburg, Pennsylvania, who were interviewed following the nuclear reactor accident at Three Mile Island showed "a common concern with future generations, their children, and their genetic future."20

5.3. Comparison of the Two Models

The benefit-cost model is the standard approach for analyzing behavior. Its usefulness in the current case is supported by the significance of factors that serve as proxies for expected cost and benefits in Model 2. Yet considerable literature on the siting of hazardous facilities suggests that the risk variables considered in the risk perception model also play a role in the decision process.

To test whether the alternative indicators of perceived risk enhance our understanding of voting behavior, we assess the impact of adding RISK SELF, RISK FUTUR, and TRUST (one at a time) to the benefit-cost model. The first column of Table VII shows the significance of each of these three risk indicators when it is added to Model 2. All three are significant at \( p < 0.001 \), and thus have unique explanatory power over and above that captured by the benefit-cost model. In contrast, the risk indicators used in the benefit-cost model provide only limited explanatory power when controlling for the risk perception model. As shown in the second column of Table VII, only one of the five measures of probability and consequences (KILLMANY) is significant at \( p < 0.01 \). Finally, in the last column of Table VII, we present the significance tests of each predictor within a single combined model that consolidates Models 2 and 4. Again, the risk perception model predictors (with the inclusion of BENEFITS) clearly have the more impressive effects.

6. FACTORS TO IMPROVE PERCEPTIONS OF REPOSITORY

The ability of the risk perception model to explain variation in willingness to vote for Yucca Mountain suggests that "acceptance" of a local repository would be more forthcoming if the perceived risks (especially to future generations) were lessened and if the federal government instilled more confidence in its ability to manage the facility. Further support might be elicited if the benefits associated with the facility were increased. We tested these implications in two distinct ways. First and most straightforwardly, respondents were asked to judge the importance of a number of mitigation and compensation measures in gaining the acceptance of local residents. Second, we tested whether willingness to vote for a local repository was enhanced by the introduction of monetary payments.
6.1. Judged Importance of Mitigation and Compensation Measures

Table VIII presents data indicating the relative importance of various policy tools in enhancing the acceptability of a repository. These tools are designed either (a) to mitigate the risk of a repository (either perceived or actual), (b) to compensate nearby residents for the noxious effects of the repository, or (c) to reward residents for agreeing to host a facility designed to solve a pressing national need. Each respondent was asked to rate the importance (either very, somewhat, or not at all) of the different measures in making a repository "more acceptable" to nearby residents. Table VIII shows the percentage of Nevada residents rating each measure as "very important." Because it is especially crucial to address the concerns of those currently opposed to a local repository, results are presented separately for those who voted for Yucca Mountain and those who voted against Yucca Mountain.

Among those Nevadans currently opposed to Yucca Mountain, risk mitigation is clearly deemed more important than compensation. The majority of this group calls not only for strict federal standards, but also for local control over the operation of the repository (via a committee with the authority to shut down the facility). Carnes et al. have also found that conferring shut down power on local residents is important in eliciting support for nuclear waste facilities. It is interesting to note that in the current study the group already in favor of Yucca Mountain attached much less importance to this measure. For both groups, the most important of the compensation/reward incentives is the protection of property values, reflecting widespread concern that the repository may attach a stigma to surrounding communities.

6.2. Effect of Ex Ante Compensation in Changing Support

6.2.1. Background

The significance of the BENEFITS variable in predicting willingness to vote for Yucca Mountain suggests that a repository would be more acceptable to residents of the host state if the benefits were increased. Sweetening the pie with compensation and/or rewards is one way to do this. Funds might be delivered in the form of direct payments to each resident or grants to communities close to the proposed repository for improving facilities such as schools, parks, or hospitals. According to this line of thinking, it would just be a matter of how much would have to be provided to induce a positive vote.

On the other hand, evidence from the siting of other nuclear waste facilities suggests that compensation will not increase the utility of the repository as long as the risks are perceived to be serious. When the local task force in Oak Ridge, Tennessee evaluated the feasibility of a proposed monitored retrievable storage (MRS) facility in its community, it wanted assurance that the facility was safe before it would consider the possibility of receiving compensation. Governor Bryan of Nevada captured this feeling toward nuclear waste when he noted that:

The framers of NWPA realized that, in order for any state to ever be able to accept a repository, a situation must be created whereby the leaders and citizens in that state are able to see and believe that the site selected was the product of an impeccable, scientifically objective screening process. No amount
of compensation or federal "incentives" can ever substitute for safety and technical suitability in the site selection effort.\textsuperscript{16}

In order to determine the impact of compensation on attitudes toward the repository, respondents in both the Nevada and national surveys were asked to consider the siting decision under a scenario where they would receive direct monetary payments in the form of tax credits or rebates. Respondents were asked what their attitude toward the repository would be if compensation were provided in the form of a grant to their community.

6.2.2. Rebates

In Fig. 1 the percentage of Nevada respondents who would vote for a repository at Yucca Mountain when no compensation was offered is compared to the approval rate when a federal tax credit of either $1000, $3000 or $5000 was provided each year for the next 20 years.\textsuperscript{17} For each of the three rebate levels, willingness to vote

\textsuperscript{16} For the national survey, the question was phrased in terms of a nearby repository (either 50 miles away or 100 miles away, depending upon the experimental condition). Only half of each sample was asked about the impact of compensation. The remainder were asked questions related to their willingness to pay additional taxes in return for moving a proposed repository to a distant state.

\textsuperscript{17} Respondents were randomly assigned to one of these three dollar amounts.
for Yucca did not change significantly in moving from the no-compensation condition to the with-compensation condition ($\chi^2(3) = 5.25, p > 0.1$), using a test of change for correlated proportions.\(^{24}\) Further, contrary to the predictions of the benefit-cost model, the magnitude of the rebate had no perceptible influence on the percentage who would support the repository; change in willingness to vote for Yucca Mountain did not vary significantly across the three rebate levels ($\chi^2(4) = 4.16, p > 0.3$).\(^{18}\)

Given the importance of perceived risk on a person’s attitude toward the repository, we considered whether this factor might influence individuals’ response to a rebate. Figure 2 contrasts the percentage of Nevadans who would vote in favor of a repository at Yucca Mountain with and without a rebate as a function of their perceived risk to self. We already know from our previous analysis that the vast majority of individuals who perceived a nonexistent risk from the repository would vote in favor of its construction at Yucca Mountain when no rebate is provided. When a rebate is offered to these residents, there is actually a decrease in the percentage who would vote for the repository. A slight increase in willingness to vote for Yucca Mountain is observed in the groups with medium and high perceptions of risk to self, although the predominant attitude is still opposed to the repository. The hypothesis that a rebate has the same impact across risk categories was rejected using a chi-square test of independence ($\chi^2(6) = 29.12, p < 0.001$).

There are at least two ways to interpret this somewhat surprising finding regarding the negative impact of rebates on the low-risk group. The introduction of compensation may be viewed as a signal that the repository imposes a risk where before they thought it was nonexistent. Indeed, the phenomenon is the principal reason why the developer of a liquified natural-gas terminal in California did not propose any monetary payment in return for the hosting of the facility. The developer felt that such compensation would “imply some serious or unacceptable risk” from the terminal.\(^{25}\)

Another possible reason that rebates may lead to a deterioration of support for Yucca Mountain is suggested by Morell and Magorian,\(^{20}\) who point out that compensation that is unrelated to a facility’s direct impacts (e.g., monetary payments when the impacts are on health) is likely to be interpreted by the recipient community as a bribe, and thus may backfire. Some respondents in our survey may have perceived the rebate as a form of bribery, which altered the siting process from one of finding the best location to one of finding the community easiest to buy off. Voting against Yucca Mountain under the rebate condition would thus represent a means of rejecting the entire siting procedure.

6.2.3. Grants

The provision of a grant to the community appears to be a more acceptable form of compensation to residents of Nevada than a direct rebate. As shown in Fig. 3, willingness to vote for Yucca Mountain increased from 24.3–33.5% with the introduction of community grants. This change was highly significant based on a test of correlated proportions ($\chi^2(3) = 39.97, p < 0.001$).\(^{19}\)

Compared to rebates, grants are less likely to be perceived as a bribe and can be used to reduce other risks faced by individuals if the funds are allocated to improving health services. The relative advantage held by grants is apparent from Fig. 4, which compares willingness to vote for Yucca Mountain under the two compensation scenarios.\(^{20}\) The hypothesis that grants lead to more willingness to vote for Yucca Mountain than do rebates was supported by a chi-square test for correlated proportions ($\chi^2(3) = 8.26, p < 0.05$). There was no statistical evidence that the effect varied as a function of the rebate size.

A comparable analysis can be performed with the national sample. Respondents in the national survey were asked the same compensation questions as the Nevada respondents except that the repository was now placed within 50 or 100 miles from the respondent’s home.\(^{21}\) Figure 4 depicts the percentage who favored a local repository under rebates and under grants (based on only the 606 respondents who were given both questions). As with the Nevada sample, there was no evidence that willingness to vote for the nearby repository with rebates differed by the size of the rebate ($\chi^2(4) = 0.391, p > 0.9$).

The distributions of the compensation questions are re-

\(^{18}\) For this test, respondents were classified into one of these categories: (a) rebate had no effect on voting response; (b) rebate made repository more acceptable; or (c) rebate made repository less acceptable. The effect of rebate level was then assessed by testing whether the distribution of this “change” variable differed across the three dollar amounts. A similar test was used below to test whether the effect of rebate varies by level of perceived risk.

\(^{19}\) The grant question was asked of all respondents, so this test was based on a sample of 1001.

\(^{20}\) This analysis includes only those respondents who were presented with the rebate question.

\(^{21}\) The effect of distance was marginally significant for the two vote items. When a rebate was offered, a repository 50 miles away was supported by 25.6%, compared to 22.0% for a repository 100 miles away ($\chi^2(2) = 5.035, p = 0.08$, based on 606 respondents). When grants were offered, the respective rates were 25.6% and 31.5% ($\chi^2(2) = 5.652, p = 0.06$, based on 1201 respondents).
markably similar across the two samples. As with the Nevada respondents, grants tended to produce slightly greater acceptance than did rebates in the national sample, although this difference did not attain significance ($\chi^2(3) = 6.08, p > 0.1$).

### 7. CONCLUSIONS

Our data indicate that the siting of a high-level nuclear waste repository will be extraordinarily difficult under the current institutional arrangements. Nevada residents support a repository at Yucca Mountain only if they are convinced that the facility does not impose serious risks to themselves and to future generations. In addition, trust in the federal government’s ability to manage the repository is crucial to producing these perceptions of safety. The importance of these risk factors in explaining Nevadans’ support for the repository reveals the need for policy measures that clearly demonstrate to the public the structural soundness of the facility and the competence of DOE. Until such faith is instilled in the public, compensation (especially in the form of direct payments to individuals) will do nothing to soften opposition to the repository.

The critical question raised by the analyses is what type of siting procedure can accomplish the formidable task of convincing residents of the host state that a repository will be safe. Based on the responses reported in Table VIII, the imposition of strict safety standards...
by the federal government is clearly a crucial starting point. However, standards by themselves appear insufficient; a complex licensing procedure is already an integral part of the guiding legislation, but this has failed to assure the vast majority of our sample. Either the existing standards are not strict enough or the public is unconvinced that DOE will fully adhere to the standards. To produce confidence in the safety of the repository, it seems crucial to introduce an ancillary measure, such as a local committee with authority to shut down the facility.

Any attempt to make the repository appear safe to the public must counteract a number of recent incidents that have compromised the integrity of the siting process and the reputation of DOE. Although the original NWPA granted potential host states considerable oversight authority in conducting independent tests of DOE's conclusions, Congress has failed to authorize sufficient funding for these analyses and has imposed restrictions on the type of study that will be funded.\(^{27}\)

At the same time, DOE's credibility has been seriously damaged by reports indicating that the Department has based its analyses on incomplete and ambiguous data, and in fact has suppressed data that call into question the suitability of the Yucca Mountain site.\(^{28-30}\) These criticisms of DOE's implementation of NWPA come on top of evidence indicating a widespread lack of concern with safety in the oversight of nuclear weapons facilities, at least prior to the current administration of James Watkins (e.g., bonuses were paid to operators based on production, not safety; former DOE Secretary Edwards rejected a 1981 review of safety and cut back on the number of safety personnel in the Department\(^{31-33}\)).

Together, these reports have engendered extreme mistrust of DOE by many of those with a stake in the repository, especially political leaders and public-interest groups in potential host states. For example, Kraft and Clay\(^{34}\) found that among individuals speaking at public hearings held under NWPA, 58% raised questions regarding the credibility of DOE and 35% criticized the Department's technical competence. The Nuclear Waste Technical Review Board has recently provided a number of recommendations to assist DOE in improving the technical work at Yucca Mountain as well as its interaction with the state of Nevada.\(^{35}\)

In designing policy tools to gain the support of residents of the host state, the federal government will not only need to lower the perceived risk of the repository, but will also need to return to a fair procedure for choosing between candidate sites. According to results presented in a companion report,\(^{36}\) Nevada residents will be more accepting of the Yucca Mountain repository if they view the proposed technology as the best way to store high-level nuclear wastes and if they view Nevada as the safest place in the U.S. for the site. In contrast, recent events in Congress strongly indicate that Nevada is being singled out due to its meager political clout.\(^{37}\) In fact, many Nevadans feel that they have been "dumped on" by the rest of the country, and are concerned that the siting process will further stigmatize Nevada if the state ultimately hosts the repository, threatening economic development and the tourism industry.\(^{38}\)

Given the public's current attitude toward an underground nuclear waste repository, we can expect considerable dissatisfaction both in Nevada and nationally if the facility is constructed according to the currently unfolding siting process. On the other hand, much of this opposition could be defused by policies that explicitly recognize public concerns and introduce mitigation and control measures to enhance the long-run safety of the facility.

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REFERENCES


