In the Village Square: Risk Misperception and Decisionmaking in the Regulation of Low-Level Radioactive Waste

Jorge Contreras

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In the Village Square: Risk Misperception and Decisionmaking in the Regulation of Low-Level Radioactive Waste

Jorge Contreras*

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The future of nuclear energy in this country will be decided in the village square. There are those who would exclude all but the experts from decision making on nuclear power, and particularly on nuclear waste. I say our American citizens have the right and duty to participate in governmental decision making in this area as in every other.

Albert Einstein

Perception is reality.

Representative Edward Markey

INTRODUCTION

According to the United States Supreme Court, "[w]e live in a world full of low level radioactive waste." Every year, commercial and government sources in the United States generate approximately 1.4 million cubic feet of "low-level" radioactive waste (LLRW) — slightly contaminated material discarded by a variety of institutional, medical, utility, and government users of radiation. For a number of reasons, public perceptions of radioactive waste disposal have become increasingly negative. As a result, the public now perceives the risks associated with LLRW and its disposal to be far greater than current estimates of the actual risk. Thus, the disposal of LLRW in the United States has become a significant problem. The regulatory structure that governs LLRW disposal and, in particular, the central federal statute, the Low-Level Radioactive Waste Policy Act of 1980 (LLRWPA) and its 1985 Amendments, aggravate the difficulty. This statute is, in part, a product of risk misperception at the local, state, and federal levels and has the potential to worsen significantly the LLRW disposal situation by permitting existing disposal facilities to refuse waste from other regions of the country.


4. See infra table 1.


6. LLRW is regulated by various state and federal agencies including the Environmental Protection Agency, Department of Transportation, and the Nuclear Regulatory Commission. See infra part III.A.2.

7. The Supreme Court scrutinized the LLRWPA this year in New York v. United
This comment summarizes the policies and regulatory mechanisms governing the disposal of LLRW in the United States and proposes statutory changes that might improve the process. Section I describes the technical properties and sources of LLRW. Section II briefly analyzes the risks associated with LLRW disposal and places them in the context of other public risks. Section III outlines the development and current state of the statutory and regulatory framework governing LLRW disposal. Section IV identifies some of the problems inherent in that structure. Section V proposes an approach to siting LLRW disposal facilities that takes into account the considerations of the preceding four sections. Most importantly, the proposed approach strives toward "comprehensive rationality" by balancing not only technical but also political, social, and economic factors in the siting process. The proposed approach includes a voluntary, auction-based compensation system for host communities and retains a combination of federal licenses and state authority over disposal facilities. The approach seeks to distribute widely the economic burden of LLRW disposal.

I

TECHNICAL AND SCIENTIFIC BACKGROUND

The LLRWPA broadly defines LLRW as any radioactive waste which has not otherwise been classified as high-level waste (HLW), special radioactive by-product material, or spent reactor fuel. The section describes the characteristics, sources, and risks of LLRW.

A. Low-Level Radioactive Waste

1. Radiation and Radioactivity

Radiation is caused by the emission of particles from materials called radioisotopes. Radiation causes injury to living organisms when

---

9. The “activity” of a radionuclide is based on the number of emissions per minute. The basic unit of radioactivity, one Curie (Ci), corresponds to $2.22 \times 10^{12}$ emissions per minute. Most particles emitted by radionuclides fall into three categories: alpha particles (consisting of two protons and two neutrons); beta particles (consisting of a single electron); and gamma photons (massless wave-like particles). See generally JACOB SHAPIRO, RADIATION PROTECTION: A GUIDE FOR SCIENTISTS AND PHYSICIANS, Part II (3d ed. 1990) [hereinafter RADIATION PROTECTION].

Each time an atom emits a particle, that atom undergoes a transformation, often into a non-radioactive isotope. Thus, for a given sample of radioactive material, the rate of its radioactive emissions decreases as the sample decays or is transformed. The average time for half of a sample of a radioactive isotope to decay is called the “half-life” of the isotope. The half-lives of radionuclides in LLRW range from 6 hours to 4.5 billion years. Generally, a radionuclide sample is considered non-radioactive after ten to twenty half-lives have elapsed. OFFICE OF
these emitted particles collide with and damage biological tissue. The amount of radiation imparted to matter is measured in units called the Radiation Absorbed Dose (rad). The amount of damage to human tissue from a dose of radiation is measured in units of "rem," which are calculated by multiplying the rads by a quality factor (QF) which describes the relative energy of the type of particle comprising the radiation.

2. Properties of LLRW

As shown in Table 1, LLRW is far less radioactive than other classes of radioactive waste. The radiation emitted by LLRW is typically beta or gamma radiation. Beta radiation from LLRW can generally be stopped by a layer of clothing or a thin plastic or glass shield. Gamma radiation is more energetic and generally requires three feet of concrete or two inches of lead to be 90% shielded.

<table>
<thead>
<tr>
<th>Waste</th>
<th>Avg. Radioactivity (Ci/ft³)</th>
<th>Volume in 1989 (10³ft³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LLRW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class A</td>
<td>0.02</td>
<td>1,388</td>
</tr>
<tr>
<td>Class B</td>
<td>1.72</td>
<td>39.</td>
</tr>
<tr>
<td>Class C</td>
<td>14.75</td>
<td>12.</td>
</tr>
<tr>
<td>HLW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial</td>
<td>375.</td>
<td>n/a</td>
</tr>
<tr>
<td>Defense</td>
<td>87.</td>
<td>n/a</td>
</tr>
<tr>
<td>Spent Fuel</td>
<td>75,600.</td>
<td>n/a</td>
</tr>
</tbody>
</table>

10. Typical levels of human exposure to radiation are measured in millirad ("mrad") and millirem ("mrem"), representing, respectively, 0.001 rad and 0.001 rem.

11. For example, for typical beta and gamma radiation, QF = 1; for heavy alpha particles, QF = 20; and for other particles QF varies from 2 to 40. See RADIATION PROTECTION, supra note 9, at 46-47. The QF was formerly called the Relative Biological Effectiveness (RBE). Id.

12. See OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 91; RADIATION PROTECTION, supra note 9, at 13 (listing ranges in air of typical LLRW beta-emitting isotope, i.e., hydrogen-3 =0.02 feet, carbon-14 = 1 foot, strontium-90 = 29 feet). Gamma particles will travel for virtually infinite distances unless stopped by matter. RADIATION PROTECTION, supra note 9, at 21.

13. OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 88. The figures expressing each class' average radioactivity were derived by dividing the total national volume by the total national radioactivity for that class. See also RONALD L. FUCHS & KIMBERLY CULBERTSON-ARENDS, 1989 STATE-BY-STATE ASSESSMENT OF LOW-LEVEL RADIOACTIVE WASTES RECEIVED AT COMMERCIAL DISPOSAL SITES A2 (1990) (providing more recent figures).
3. **Sources of LLRW**

**a. Utilities**

Nuclear power plants generate the majority of LLRW in the United States.\(^{14}\) Their waste includes wet LLRW, such as sludge and filters containing radioactive particles removed from reactor cooling water, and dry LLRW in the form of mildly contaminated items such as gloves, clothing, and other supplies used at power plants.\(^{15}\) Eighty percent of the LLRW volume generated at a typical plant is such dry waste.\(^{16}\)

Decommissioned nuclear power plants will soon be another source of utility LLRW. After nuclear plants outlive their useful lives of approximately forty years, they will be closed down and either decontaminated or entombed. These procedures will generate significant amounts of LLRW.\(^{17}\)

**b. Industrial**

There are over 4000 industrial LLRW generators in the United States.\(^{18}\) Industrial users generate LLRW in connection with the production of radioactive chemicals for agricultural, environmental, pharmaceutical, and biomedical uses; the production of materials for nuclear power generation; and the manufacture of consumer products such as smoke detectors, enamel glazes, fabrics, illuminated signs, luminous watch dials, and measurement devices.\(^{19}\)

**c. Government**

Most LLRW generated by federal weapons and energy research is stored at fourteen federal disposal facilities.\(^{20}\) Approximately two percent of government LLRW, however, is disposed of at commercial LLRW facilities. This includes waste generated by the Department of Veterans Affairs hospitals, Department of Agriculture activities, reme-

\(^{14}\) See infra Table 2.

\(^{15}\) See EDWARD L. GERSHEY ET AL., LOW-LEVEL RADIOACTIVE WASTE — FROM CRADLE TO GRAVE 86 (1990); MASSACHUSETTS SPECIAL LEGISLATIVE COMMISSION ON LOW-LEVEL RADIOACTIVE WASTE, LOW-LEVEL RADIOACTIVE WASTE MANAGEMENT: MOVING TOWARD A SOLUTION 99-102 (1985) [hereinafter MASSACHUSETTS 1985].

\(^{16}\) MASSACHUSETTS 1985, supra note 15, at 101.

\(^{17}\) For example, the Boston Edison Company estimated that the decommissioning of the Pilgrim Nuclear Power Plant in Massachusetts would generate roughly 275,000 cubic feet of LLRW over a one to four year period. Id. at 103.

\(^{18}\) GERSHEY ET AL., supra note 15, at 22.

\(^{19}\) Id.; TEXAS LOW-LEVEL RADIOACTIVE WASTE DISPOSAL AUTHORITY, LOW-LEVEL RADIOACTIVE WASTE DISPOSAL IN TEXAS: USES OF RADIOACTIVE MATERIALS (pamphlet on file with author).

\(^{20}\) MASSACHUSETTS 1985, supra note 15, at 104-05.
dial cleanup programs, and contractors producing fuel for nuclear submarines.\textsuperscript{21}

\textit{d. Academia}

Universities and hospitals conducting biomedical research also generate small amounts of LLRW.\textsuperscript{22} Biomedical research depends on radionuclides because of the precision with which they can be measured.\textsuperscript{23} Radionuclides assist in the tagging of genes in genetic sequencing research and in the identification of cell-destroying agents in immunological research.\textsuperscript{24} Some large universities also operate nuclear reactors or accelerators which generate LLRW.\textsuperscript{25}

e. \textit{Medical}\textsuperscript{26}

Over one hundred million medical procedures using radioactive materials are conducted in the United States each year.\textsuperscript{27} Three of the more common procedures are described here.

Diagnostic radiology involves the injection of a radionuclide into a patient. The radionuclide concentrates in an area to be diagnosed, typically an organ or bone, and allows detailed images of the area to be taken with radiation detectors. This procedure permits the diagnosis of numerous organ disorders and cancers without surgery.\textsuperscript{28}

Radioimmunoassays are common tests in which blood samples are reacted with radioactive chemicals to measure the levels of hormones, drugs, or enzymes in the blood.\textsuperscript{29}

Radiotherapy involves the exposure of cancer cells to direct radiation. This exposure can be effected either by implanting a sealed source of radiation in a patient, or by directing a beam of radiation at a cancerous area.\textsuperscript{30}

\begin{itemize}
\item \textsuperscript{21} \textit{Id.} at 105-06.
\item \textsuperscript{22} \textit{Id.} at 88.
\item \textsuperscript{23} \textit{Id.}
\item \textsuperscript{24} \textit{Id.}
\item \textsuperscript{25} \textit{Id.} at 92-93.
\item \textsuperscript{26} \textit{See generally id.} at 82-88 (describing use of radioactive materials in diagnostic radiology, radioimmunoassay, and radiotherapy); \textit{ERIC J. HALL, RADIATION AND LIFE} 83-143 (2d ed. 1984) (detailing three different applications of radiation: x-ray diagnosis, nuclear medicine, and radiation therapy/oncology.)
\item \textsuperscript{27} \textit{GERSEY ET AL., supra} note 15, at 25.
\item \textsuperscript{28} \textit{MASSACHUSETTS 1985, supra} note 15, at 82-84.
\item \textsuperscript{29} \textit{Id.} at 84-85.
\item \textsuperscript{30} \textit{Id.} at 85-87.
\end{itemize}
### Table 2

<table>
<thead>
<tr>
<th>Source/Isotope</th>
<th>% Volume</th>
<th>% Activity</th>
<th>Half-life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utility</td>
<td>52.1</td>
<td>83.7</td>
<td></td>
</tr>
<tr>
<td>Cesium-134</td>
<td>18.0</td>
<td></td>
<td>2.1 years</td>
</tr>
<tr>
<td>Cobalt-60</td>
<td>16.0</td>
<td></td>
<td>5.3 years</td>
</tr>
<tr>
<td>Cesium-137</td>
<td>36.0</td>
<td></td>
<td>30.0 years</td>
</tr>
<tr>
<td>Industry</td>
<td>34.0</td>
<td>14.7</td>
<td></td>
</tr>
<tr>
<td>Iridium-192</td>
<td>7.0</td>
<td></td>
<td>74.2 days</td>
</tr>
<tr>
<td>Hydrogen-3</td>
<td>88.0</td>
<td></td>
<td>12.3 years</td>
</tr>
<tr>
<td>Government</td>
<td>7.0</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>Hydrogen-3</td>
<td>55.0</td>
<td></td>
<td>12.3 years</td>
</tr>
<tr>
<td>Carbon-14</td>
<td>10.0</td>
<td></td>
<td>5730.0 years</td>
</tr>
<tr>
<td>Academic</td>
<td>4.1</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>Phosphorus-32</td>
<td>22.0</td>
<td></td>
<td>14.3 days</td>
</tr>
<tr>
<td>Sulfur-35</td>
<td>22.0</td>
<td></td>
<td>88.0 days</td>
</tr>
<tr>
<td>Hydrogen-3</td>
<td>29.0</td>
<td></td>
<td>12.3 years</td>
</tr>
<tr>
<td>Medical</td>
<td>2.1</td>
<td>&lt;1.0</td>
<td></td>
</tr>
<tr>
<td>Technecium-90</td>
<td>96.0</td>
<td></td>
<td>6.0 hours</td>
</tr>
</tbody>
</table>

4. **LLRW Volumes**

The commercial LLRW generated through 1988 in the United States accounts for 29.3% of the total radioactive waste volume, but only 0.02% of the total radioactivity from waste.\(^{32}\) As of 1988, there were approximately forty-six million cubic feet of this waste stored in the United States.

---


32. **Office of Technology Assessment, supra** note 9, at 88. Non-commercial defense LLRW accounted for another 55.5% of the volume and 0.06% of the radioactivity, bringing the total volume of radioactive waste which can be considered "low level" in the United States to 84.8%; this comprises only 0.08% of the overall radioactivity from waste. *Id.*
LLRW is divided into three hazard classes. The relatively innocuous Class A LLRW is by far the most commonly produced, representing 96.8% of the LLRW stream by volume as of 1989.

Due to the escalating cost of LLRW disposal, producers of LLRW have begun to reduce the volume of LLRW they generate. There are three ways in which this waste minimization can be accomplished: volume reduction of LLRW before disposal, substitution of non-radioactive materials for radioactive isotopes in LLRW-generating processes, and elimination of certain LLRW-generating processes. In recent years, a combination of the first two of these three options has led to a significant decline in the amount of LLRW generated each year. Between 1980 and 1988, the annual volume of commercial LLRW shipped for disposal dropped from approximately 3.25 million cubic feet to 1.6 million cubic feet. The Office of Technology Assessment estimates that, with continued volume reduction efforts, this volume could potentially be reduced by about fifty percent.

5. Disposal of LLRW

Most isotopes used in clinics and laboratories have relatively short half-lives. They often can be stored at the site where they are produced for the requisite ten to twenty half-lives until they reach safe levels. This method of disposal is referred to as "storage-for-decay." The best example of an isotope suited for decay storage is Technecium-99m, which is used in over eight million medical procedures each year. Having a

---

33. The categories are Class A, Class B, and Class C. The classifications are based on the wastes' concentration, energy level, half-life, and source. GERSHEY ET AL., supra note 15, at 13, 16. See also 10 C.F.R. § 61.55 (1991) (discussion of classifications). A fourth category of LLRW, called "Greater than Class C Waste" or "GTCC," is the responsibility of the federal government and is thus excluded from most discussions of LLRW. OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 84-85. Another category of LLRW is "mixed" waste. It contains radioactive components as well as other hazardous chemicals. It constitutes three to ten percent of all commercial LLRW. Id. at 85-86.

34. See supra Table 1.

35. See infra part IV.D.1.

36. Current LLRW volume reduction techniques include concentration by evaporation, ion-exchange, filtration, precipitation, centrifuging, and distillation; sorting of solid waste; decontamination rather than disposal of large pieces of contaminated equipment; compaction and shredding; incineration; and better waste management. See OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 102-12.

37. See id. at 101-02.

38. Id. at 102.

39. Id. at 88.

40. These reductions could occur if currently available waste minimization techniques were more widely applied and if disposal fees were based on volume. Id. at 89.

41. Id. at 104; see supra Table 2.

42. OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 105.

half-life of only six hours, its radioactivity will decrease to 0.1% of its original level in two and one half days.

Longer-lived and more active waste has generally been stored at centralized storage facilities. Existing commercial LLRW disposal facilities in the United States have all used a disposal technique called shallow land burial (SLB); containers of waste are deposited in excavated trenches between twenty and sixty feet wide, twenty and forty feet deep, and several hundred feet long. Once a trench is filled, it is "capped" with a layer of soil three to ten feet thick. As a result of new NRC safety requirements, the three currently operating LLRW facilities at Beatty, Nevada, Barnwell, South Carolina, and Richland, Washington use "improved SLB" technologies. These sites segregate Class A, B, and C waste, and stabilize Class B and C waste by solidifying it in a stabilizing agent such as cement or by packaging it in a "high-integrity container."

Despite these new precautions, eighty percent of the states and regional disposal compacts have banned shallow land burial for commercial LLRW disposal. There are, however, a number of alternative technologies available including earth or clay-covered concrete pads or "tumulus," currently used at the Oak Ridge National Laboratory; earth-mounded concrete bunkers, successfully used in France for the past two decades; and deep geologic repositories hundreds of feet below the ground, which have been planned in several European countries. These technologies are more expensive than SLB disposal.

44. Id.
45. OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 135-36.
46. Id. at 135-36. See generally id. at 109-11 (discussing waste stabilization).
47. OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 135-36. The U.S. Department of Energy maintains that these prohibitions stem from a series of drainage accidents at the now closed Maxey Flats, Kentucky, and West Valley, New York SLB facilities. See infra notes 69-74 and accompanying text.
48. See generally OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 99-147.
49. Id. at 136. G.D. BURHOLT & A. MARTIN, THE REGULATORY FRAMEWORK FOR STORAGE AND DISPOSAL OF RADIOACTIVE WASTE IN THE MEMBER STATES OF THE EUROPEAN COMMUNITY 11-12 (1988). The European countries vary dramatically in the methods they use to contain LLRW. For example, in the United Kingdom landfill disposal is used, though a deep disposal facility is being considered. France currently uses the SLB method, and Spain and Belgium are also planning SLB disposal sites. Switzerland employs underground facilities and has proposed the construction of a rock cavern repository. Such a repository is under construction in Sweden. Germany plans to store LLRW in deep underground mines and, possibly, salt domes. In the Netherlands, LLRW was dumped into the Atlantic until 1982; it is presently stored above-ground pending the construction of a permanent above-ground facility. Id. at 11-12. See also GERSHEY ET AL., supra note 15, at 98.
50. See OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 145.
1. Health Risks from Radiation Exposure

Radiation causes two types of damage to human tissue: "somatic" damage, typically manifested as cancer, and genetic damage. The exact relationship between radiation exposure, particularly low-level radiation exposure, and these types of injury is not conclusively known. As is discussed below, data charting the effects of radiation on human tissue is scarce. However, the Nuclear Regulatory Commission (NRC) estimates that each rem of radiation to which the population is annually exposed causes approximately $5 \times 10^{-4}$ additional annual cancer fatalities. There are no official estimates of genetic risk from radiation. Because data on genetic defects in human populations accrue extremely slowly (often taking several generations to accumulate), no authoritative studies have yet been concluded.

51. HALL, supra note 26, at 22, 43-44.
52. See infra Part I.B.2. One recent study conducted by researchers at Johns Hopkins University over thirteen years on a sample of more than 70,000 U.S. naval shipyard workers exposed to low levels of radiation found no significant correlation between leukemia and low dosages of radiation. Keith Schneider, Study Sees Minimal Risk From Low Radiation, N.Y. TIMES, NATIONAL SUNDAY, Nov. 3, 1991, at L29.


These figures are broad estimates of the incidence of all cancers. Different cancers, however, have different rates of incidence. See NCRP LIMITS, supra, at 17, (providing factors for weighing exposure of different body parts to radiation). Cf. John D. Boice, Jr., et al., Diagnostic X-ray Procedures and Risk of Leukemia, Lymphoma, and Multiple Myeloma, 265 JAMA 1290, 1291-94 (1991) (finding that the risk of multiple myeloma was increased among patients undergoing frequent x-ray examinations, but that the risks of leukemia and non-Hodgkin's lymphoma were not significantly increased).

54. See MERRIL EISENBUD, ENVIRONMENTAL RADIOACTIVITY: FROM NATURAL, INDUSTRIAL, AND MILITARY SOURCES 28 (3d ed. 1987) [hereinafter ENVIRONMENTAL RADIOACTIVITY] (because most radiation-induced genetic mutations appear to be recessive, they most likely will not be expressed in offspring; however, cumulative effects of mutations from successive generations may increase the probability of offspring mutation). One study suggests that the first generation of children born to survivors of the atomic bomb explosions at Hiroshima and Nagasaki has not exhibited an excess of genetic defects. Bernard L. Cohen, Exaggerating the Risks, in NUCLEAR POWER: BOTH SIDES 69, 73 (Michio Kaku & Jennifer Trainer, eds., 1982) [hereinafter BOTH SIDES] (citing James V. Neel et al., Mortality of Children of Atomic Bomb Survivors and Controls, 76 GENETICS 311 (1974)); RADIATION PROTECTION, supra note 9, at 362 (citing ADVISORY COMMITTEE ON BIOLOGICAL EFFECTS OF IONIZING RADIATIONS, NAS-NRC, THE EFFECTS ON POPULATIONS OF EXPOSURE TO LOW LEVELS OF IONIZING RADIATION (1980)).
2. Difficulties with Risk Estimation for Low-Level Radiation

Some critics of the NRC radiogenic cancer risk estimates believe that the NRC figures understate the risk. Many others claim that the figures overstate the risk. Much of this disagreement arises from the NRC's use of a "linear, no-threshold" model for estimating risks from low-level radiation. This model assumes that there is a simple proportional (linear) relationship between radiation dosage and health risk. Thus, an exposure of 100 rems would create 1000 times the risk of an exposure of 0.1 rem. The model assumes that there is no "risk-free" level of radiation exposure. Critics claim that the linear model is unrealistic, but because they disagree as to the fundamental relationship between radiation dosage and health effects, they are not in agreement as to an alternate model.

Beyond the choice of an appropriate dosage-effect model, numerous other areas of uncertainty make precise determination of the risk from low-level radiation difficult. For example, some researchers have suggested that effects from long-term chronic exposures to radiation may be less severe than those from acute exposures. Secondly, the long latency periods of most health effects from radiation make it difficult to trace particular instances of disease to specific exposures. The latency period for many cancers can be up to thirty years, and genetic damage may not manifest itself for many generations. Thirdly, much data on radiation effects is derived from animal studies, which may be of limited value in predicting effects on humans. Finally, critics find fault with the conservative method of basing exposure projections on hypothetical "maximally exposed individuals" who "are born and die at the point of

57. See NRC BRC, supra note 53, at 5. This assumption is made because most of the data on large-scale human exposure to radiation comes from studies of radiogenic leukemia experienced by Hiroshima survivors, many of whom received radiation doses on the order of 200 rems. From these figures, the NRC can simply extrapolate downward to arrive at risk figures for much lower exposures. See GERSHEY ET AL., supra note 15, at 148-50.
58. NRC BRC, supra note 53, at 5.
59. For example, some scientists favor a "linear-quadratic" model, in which the response, health effects per unit dose of radiation, increases quadratically in the upper range and linearly in the lower range. This theory suggests that the NRC figures are overstated. See GERSHEY ET AL., supra note 15, at 149; ENVIRONMENTAL RADIOACTIVITY, supra note 54, at 17; Cohen, supra note 54, at 71-72 (critical of the linear model). Others favor a "supralinear" model, in which the risk per rem at low doses is higher than at high doses. See Gofman, supra note 55, at 66.
60. OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 93.
61. RADIATION PROTECTION, supra note 9, at 356; HALL, supra note 26, at 43-44.
62. OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 94; RADIATION PROTECTION, supra note 9, at 362-64.
maximum pollution concentration and never leave the spot, even to go to school or work . . . .”63

The reader should bear in mind that the risk estimates used in the following sections are confined to cancer fatalities and do not include non-fatal cancers, other health effects, and genetic damage.

3. Public Exposure from LLRW Facilities

The primary pathway for public exposure to radiation from LLRW disposal facilities at humid sites is through groundwater contamination.64 Other potential pathways include ingestion of contaminated vegetation and livestock, inhalation of contaminated air, and direct irradiation.65

Estimates of maximum radiation exposures from properly operating LLRW facilities range from 0.003 mrem/year66 to 10 mrem/year.67 Current NRC regulations limit the acceptable annual steady-state dose to 100 mrem per person.68

The documented leakage of radiation from commercial LLRW disposal facilities in the United States has been well below these limits. For example, at the now defunct Maxey Flats, Kentucky site, rainwater tended to collect in the disposal trenches and overflow into the surrounding area. In 1974, plutonium was detected beyond the boundaries of the site; three years later the State of Kentucky closed the site.69 Yet it was estimated that this groundwater contamination caused an individual dose of less than 1 mrem to a few people in the immediate area,70 yielding a collective population dose of 4 rem.71 The impact of contamination at

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64. OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 94.
65. Id.
67. OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 94 (citing DEPARTMENT OF ENERGY, LOW-LEVEL RADIOACTIVE WASTE DISPOSAL FACILITY CONCEPTUAL DESIGNS (1987)).
68. Id. at 96 (citing 10 C.F.R. § 61). The NRC has followed the recommendations of the NCRP in developing its regulations. Current NCRP recommended annual whole body doses for the following groups are as follows:

<table>
<thead>
<tr>
<th>Type of Exposure</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupational (single event)</td>
<td>10 rem</td>
</tr>
<tr>
<td>Occupational (continual)</td>
<td>5 rem</td>
</tr>
<tr>
<td>Public (infrequent exposure)</td>
<td>500 mrem</td>
</tr>
<tr>
<td>Public (continual)</td>
<td>100 mrem</td>
</tr>
</tbody>
</table>

NCRP LIMITS, supra note 53, at 35, 48.
70. Eisenbud, supra note 66, at 76.
the West Valley, New York site was even less, with an average dose of 0.02 mrem to the two million users of the contaminated water supply. Using the risk figures developed earlier, such an exposure would increase the number of annual cancer fatalities in this population from approximately 4,000 to 4,000.025. Computer simulations of European sites have yielded similarly low long-term dosage expectations for LLRW facilities.

A major failure of an LLRW facility could result in acute radiation exposure to the population near the site. Though no such failure has yet occurred, one study has estimated that a member of the public near such a failure could be exposed to radiation at a rate of 500 mrem/year. Yet, it is highly unlikely that an LLRW facility failure of this magnitude would be allowed to continue for a full year. Thus, the amount of radiation actually received by the public would be substantially less. European computer simulations have estimated that doses received by the public, even from relatively major accidents, will be significantly lower than 500 mrem.

NCRP POPULATION].

72. John M. Matuszek, Safer Than Sleeping With Your Spouse-The West Valley Experience, in SCIENCE, POLITICS, AND FEAR, supra note 2, at 270. The maximum collective population dose from the water supply was less than 50 rem. Id. An additional LLRW “accident” occurred at the Beatty, Nevada site in 1976. Over the years, workers had pilfered contaminated tools (shovels, hammers, and lumber) from the dump site for their own use. In March, 1976, state investigators discovered the contaminated items and ordered the dump site closed for investigation. See RALPH NADER & JOHN ABBOTTS, THE MENACE OF ATOMIC ENERGY 351 (1977).

73. See supra note 53 and accompanying text.

74. A recent computer simulation of shallow land burial and tunnel LLRW disposal sites in Yugoslavia yielded population dosage rates from groundwater seepage and other scenarios well below the International Commission on Radiological Protection (ICRP) limit of 1 mrem per year. The greatest steady-state exposure was from overflow of accumulated water in trenches in the shallow land burial model, the same problem that existed at Maxey Flats, which resulted in a dose of 2.63% of the ICRP limit to the nearby population. V. Jelavic et al., Safety Assessment of Intermediate and Low Level Radioactive Waste Disposal in Yugoslavia, in SAFETY ASSESSMENT OF RADIOACTIVE WASTE REPOSITORYS 852, 859 (Organization for Economic Cooperation and Development ed. 1989); GERSHEY ET AL., supra note 15, at 142. See also T.G. Parker et al., Development of Radiological Impact Assessments for the Drigg Low-Level Radioactive Waste Disposal Site, in SAFETY ASSESSMENT OF RADIOACTIVE WASTE REPOSITORYS, supra, at 129, 130-35 (reviewing long-term dosage expectations at the Drigg LLRW site in England).

75. OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 94 (citing ILLINOIS DEPARTMENT OF NUCLEAR SAFETY, DRAFT — RISKS FROM LOW-LEVEL RADIOACTIVE WASTE DISPOSAL (1987)).

76. The Yugoslav simulation showed that even in the case of a waste fire, the maximum exposure to the human population near the site would be only 135 mrem. Jelavic et al., supra note 74, at 859.
II
LLRW AND RISK ANALYSIS

A. Risk Analysis Methods

To discuss the risks and perceived risks of LLRW disposal one must identify the most appropriate analytic framework. Two prevalent risk analysis methods are cost-benefit analysis and comparative risk analysis. Both frameworks require that certain assumptions be made. For the reasons discussed below, comparative risk analysis may be better suited for working with the existing data and assumptions about LLRW. Several difficulties would arise in attempting to conduct a detailed cost-benefit analysis of the LLRW disposal question. First, some commentators question whether such an analysis is, in principle, appropriate to determinations concerning human deaths. Second, decisions about the costs and benefits to be taken into consideration must be made subjectively and are thus suspect. Third, the analysis must be conducted using a common value denominator, such as dollar-equivalents. As yet, there is no generally accepted method for valuing the non-monetary costs of LLRW disposal (e.g. increased chance of human fatality) in terms of dollar equivalents. Fourth, even if all costs could be reduced to common units, it would be an enormous task (far beyond the scope of this comment) to evaluate the benefits of the diverse activities that generate LLRW. An accurate cost-benefit analysis would correlate the costs imposed by each LLRW-generating activity to the benefits, and take into account the disproportionate allocation of costs and benefits among the

78. Nonetheless, such an analysis has been performed for the Carlsbad, New Mexico, Waste Isolation Pilot Plant (WIPP) project. Allen V. Kneese et al., Economic Issues in the Legacy Problem, in Equity Issues in Radioactive Waste Management 203, 210-26 (Roger E. Kaspren ed., 1983) [hereinafter Equity Issues].
80. With respect to which costs to consider in waste disposal issues, in particular, one physicist argues:

In discussing adequate protection from nuclear waste, the proper yardstick, in my opinion, is not how many people will be killed by it on a statistical basis . . . . Rather, the point is whether we want to impose on future generations the need to live permanently with radiation monitors . . . . In my opinion we should make every effort to avoid subjecting our descendants to this additional concern.

82. See Gershey et al., supra note 15, at 19-27; see also supra notes 14-31 and accompanying text. Further, it is unclear how to value the benefit, if any, derived from a source like nuclear power generation. The literature debating the advantages and disadvantages of nuclear power over other sources of energy is vast. See, e.g., Vince Taylor, Living Without Nuclear Energy, in Both Sides, supra note 54, at 155; Nader & Abbotts, supra note 72; Anna Gyorgy et al., No Nukes: Everyone's Guide to Nuclear Power (1979).
Finally, cost-benefit analysis becomes quite unrealistic when used to extrapolate nonmonetary costs and benefits to future generations, as must be contemplated with the disposal of radioactive waste.83

Comparative risk analysis limits the measurement of risk to a single factor and compares that factor with other activities in society. For environmental risks, the standard factor is generally "excess cancer fatalities per maximum exposure."84 This approach also relies on certain important assumptions. For LLRW, the most important assumption is that the NRC figure relating cancer fatality to radiation exposure ($5 \times 10^{-4}$ additional cancer fatalities per year per rem) is reasonably accurate.85 A second, related, assumption, is that the population exposure from a LLRW disposal facility will not exceed the NRC's 100 mrem per year maximum.86 Although both of these assumptions may prove to be inaccurate, they best reflect the evidence available at this time.

Since a meaningful cost-benefit analysis is too unwieldy for assessing LLRW risk, this comment contrasts the risk of fatality from LLRW disposal with other fatality risks. It compares expenditures made to avoid the LLRW risk with expenditures made to avoid risks of similar magnitude.87

**B. Comparing the LLRW Risk with Other Risks**

1. **Background Radiation**

One informative risk comparison is between the predicted radiation exposure from LLRW disposal and radiation exposure from natural background sources. The average annual radiation dose per person from all sources in the United States is approximately 363 mrem.88 Of this dose, 55% is from naturally occurring radon gas, 8% from cosmic rays, 8% from terrestrial gamma radiation, and 11% from radionuclides natu-

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83. See Douglas MacLean, *Radioactive Wastes: A Problem of Morality Between Generations, in EQUITY ISSUES*, supra note 78, at 175 ("Discounting the value of future consequences at an annual rate of 5 percent, for example, would make one death today equivalent to 1,738 deaths in 200 years and 3 billion deaths in 450 years, assuming the value of human life remains constant."). *Id.* at 180.

84. This factor is typically expressed as excess cancer fatalities either over a 70 year life-span or per year. *See, e.g., JOHN D. GRAHAM ET AL., IN SEARCH OF SAFETY: CHEMICALS AND CANCER RISK* (1988).

85. NRC BRC, *supra* note 53, and accompanying text.

86. See NCRP LIMITS, *supra* note 53, at 35, 48. *See also supra* note 68 and accompanying text.

87. This approach is that used by Bernard Cohen to analyze the radioactive waste problem. Bernard L. Cohen, *Society's Valuation of Life Saving in Radiation Protection and Other Contexts*, 38 HEALTH PHYSICS 33 (1980); *see also CROUCH & WILSON, supra* note 81, at 76-78 (1982) (describing the Cohen approach). This analysis, however, has also been criticized. *Cf.* FISCHHOFF ET AL., *supra* note 81, at 80 (referring to analysis as a bootstrapping approach that unduly relies on past behavior).

rally found within the human body. Thus, almost 300 mrem per year arise from "natural" radiation exposure. An additional 53 mrem per year are, on average, administered to patients in the form of nuclear medicine and x-rays; while consumer products such as tobacco, televisions, computer terminals, luminous watch dials, smoke detectors, and combustible fuels contribute another 5 to 13 mrem/year. Less than one percent, or 3 mrem, of the average annual exposure is contributed by a combination of occupational exposure, fallout from nuclear weapons testing, and nuclear power generation.

In addition to these exposures, many ordinary activities can increase individual exposure to radiation. For example, a round-trip flight between Los Angeles and Paris exposes its passengers to approximately 4.8 mrem from cosmic radiation. Airline crews are known to receive annual doses of nearly 1 rem. Even under ordinary circumstances, some locales receive more radiation than others. Residents of Denver, Colorado, for example, consistently receive annual cosmic ray doses twice that received by residents of Washington, D.C.

The risk of fatal cancer from the 300 mrem of naturally occurring background radiation is approximately thirty-six higher than the risk from continual exposure to a properly operating LLRW facility (see Table 3).

2. Other Risks of Fatality

Table 3 demonstrates that the risk of death from a properly operating LLRW facility is small in comparison with other risks.

89. NCRP POPULATION, supra note 71, at 55. See generally ENVIRONMENTAL RADIOACTIVITY, supra note 54, at 121-72 (discussing sources of naturally occurring radioactivity).
90. NCRP POPULATION, supra note 71, at 53. 
91. Id.
92. Although the population average for occupational radiation exposure is quite low, it comprises a larger percentage of exposure for individuals in certain occupations, such as nuclear power plant maintenance. Eisenbud, supra note 66, at 78.
93. NCRP POPULATION, supra note 71, at 52.
94. ENVIRONMENTAL RADIOACTIVITY, supra note 54, at 164 (assuming an average flying time of 11 hours each way).
95. Airline crews receive between 910 and 990 mrem each year. U.S. COUNCIL ON ENERGY AWARENESS, INFO NO. 251, AIRLINE CREWS' EXPOSURE TO RADIATION EXAMINED (March, 1990) (citing DEPARTMENT OF TRANSPORTATION, AIRLINER CABIN ENVIRONMENT: CONTAINMENT MEASURES, HEALTH RISKS, AND MITIGATION OPTIONS (1989)).
96. OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 90. This disparity is caused by Denver's elevation and the consequent increased doses of cosmic radiation.
97. See supra notes 66-67 and accompanying text. This estimate is based on the maximum exposure estimate of 10 mrem/year. Using the lower end estimate of .003 mrem/year, natural radiation would present a risk $10^3$ times greater than a properly operating LLRW facility.
98. The absolute number of deaths from LLRW-related cancer may appear overstated in this table because only the people in the immediate vicinity of the LLRW facility are subject to the risk, whereas with the other listed events most of the population is exposed to the risk.
TABLE 3

ANNUAL INDIVIDUAL RISKS OF FATALITY IN THE UNITED STATES.

<table>
<thead>
<tr>
<th>Event</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cancer (total)</td>
<td>$2000.0 \times 10^{-6}$</td>
</tr>
<tr>
<td>Automobile Accident</td>
<td>$250.0 \times 10^{-6}$</td>
</tr>
<tr>
<td>Pollution</td>
<td>$200.0 \times 10^{-6}$</td>
</tr>
<tr>
<td>Cancer (caused by background radiation)</td>
<td>$180.0 \times 10^{-6}$</td>
</tr>
<tr>
<td>Falling</td>
<td>$100.0 \times 10^{-6}$</td>
</tr>
<tr>
<td>Drowning</td>
<td>$33.0 \times 10^{-6}$</td>
</tr>
<tr>
<td>Air Travel</td>
<td>$10.0 \times 10^{-6}$</td>
</tr>
<tr>
<td>Cancer from a properly operating LLRW facility</td>
<td>$5.0 \times 10^{-6}$</td>
</tr>
<tr>
<td>Accidental Electrocution</td>
<td>$6.3 \times 10^{-6}$</td>
</tr>
<tr>
<td>Lighting</td>
<td>$0.83 \times 10^{-6}$</td>
</tr>
</tbody>
</table>

3. Comparative Costs of Risk Avoidance

A final useful comparison involves the relative costs of avoiding the LLRW risk and other risks. High costs are not undesirable if they are incurred in undertaking worthwhile endeavors. It is thus instructive to examine how much additional public safety is purchased for the high price of LLRW facility siting. As discussed below, releases such as those that occurred at Maxey Flats and West Valley have led to the construction of new and safer LLRW facilities. The safety features have helped drive the cost of the facilities from approximately $10 million to $60 million. Since the collective dosage from the West Valley facility translates into a risk of .025 additional fatal cancers, the cost per fatal cancer avoided by implementing these design changes is approximately two billion dollars.

In comparison, there are many less expensive means to save one life. Introducing measles immunizations to Gambia and Cameroon would cost $50 per life saved. Improving traffic signs in the United States would cost $31,000 per life saved. Finally, screening for breast cancer and lung cancer in the United States would cost $160,000 and $140,000

99. See Hall, supra note 26, at 223; Gershey et al., supra note 15, at 151-53; Lutzker, supra note 2, at 184; Crouch & Wilson, supra note 81, at 165-91 (providing a "catalogue of risks" calculated in various ways).

100. See supra notes 69-74 and accompanying text.

101. See infra Tables 5 and 6. The numbers in these tables are not adjusted for inflation.

102. See supra note 73 and accompanying text.


104. Id. at 9 (citing Department of Transportation, 1984 Annual Report on Highway Safety Improvement Programs).
per life saved respectively. In light of these figures, the cost of preventing LLRW-induced cancer appears to be inordinately high.

In summary, the fatality risk of LLRW disposal, though present, is small when compared to other risks, including those imposed by background radiation. The LLRW radiation threat adds a small risk to a much larger pre-existing cancer risk. In contrast, the measures taken to avoid the LLRW risk cost more than the measures taken to avoid other risks of similar and greater magnitude. This disproportionality results from the public's general misperception and overestimation of the LLRW risk. The next section will discuss the reasons for this misperception.

C. Public Misperception of the LLRW Risk

Radioactive waste instills a special type of fear in the public, a perception that it is "somehow unique, more dreadful than other industrial dangers." Behind the inadequacies of LLRW legislation and its failure in practice lurks one powerful factor: what Spencer Weart calls "nuclear fear," an exaggerated public terror of radiation and nuclear hazards, "single-minded and insatiable, stretching from ordinary citizens to the highest authorities."


Though public concern about radiation has existed since 1945, in the early years of the "nuclear age" such concern focused on atomic weapons and nuclear power plants. During the 1940's, 1950's, and early 1960's, the public was little concerned with, or even aware of, nuclear waste. 1960 survey found fifty-seven percent of Americans confident that radioactive waste isolation was "safe." Only in the late 1960's did the public's generalized fear of radiation begin to extend into the area of nuclear waste.

105. Id. at 8.
107. Id. at 373.
110. See id. at 18-19.
a. Institutional Distrust

Several factors contributed to this growing fear of radioactive waste. One was an increasing public distrust of government oversight of this waste.\textsuperscript{111} Public confidence in the Atomic Energy Commission was shaken after it appeared that the agency had covered up the dangers of fallout from nuclear weapons testing.\textsuperscript{112} Ralph Nader and John Abbotts list further misdeeds:

The fallout "incident" would be followed by others, resulting in further damage to the AEC's credibility: . . . the exposure of miners to lung cancer; the discovery of radioactive mill tailings in streams, in drinking water, and under homes; the harassment of [two scientists] when they attempted to release scientific evidence developed in the AEC's own laboratory. . . . Rather than deal with these issues the AEC preferred to play a role of nuclear apologist, apparently inspired by former Chairman Glenn T. Seaborg's vision of a plutonium future.\textsuperscript{113}

The AEC's loss of credibility was, in the view of some commentators, only one example of the "general decline in public trust" which occurred during this era.\textsuperscript{114} The public increasingly perceived government officials as "dangerous men not unlike mad scientists," and viewed their decisions in all fields with increasing hostility.\textsuperscript{115}

b. The Media

Media coverage has significantly fostered the public's fear of nuclear accidents and nuclear waste, including LLRW. Two interrelated factors are at work: extensive media coverage of radiation-related news and the constant focus of that coverage on possible risks to public health. The media pays little attention to the exact extent of those risks or to the benefits generated by radiation related activities.\textsuperscript{116}

One study of national newspapers found a disproportionately high number of news stories about accidents involving radiation.\textsuperscript{117} High
levels of television coverage make radiation accidents seem more commonplace and threatening. Two Swedish researchers note that “[o]n television, the entire world is our accident risk arena. Therefore, our fear of potential accidents has grown and become more pronounced.” This amount of coverage is further exaggerated by the sensational language used to sell stories. Spencer Weart’s description of the Three Mile Island coverage is telling:

Journalists sought out the most worried people for interviews, while on national television Walter Cronkite philosophized about Frankenstein and man’s “tampering with natural forces.” The world press made numerous references to monsters, robots, and the Devil, as well as to Hiroshima, nuclear war, and the end of humanity. . . . For a solid week Three Mile Island dominated evening television news and crowded the front pages of newspapers, not only in the United States but around the world.

c. Waste-Related Accidents

Public concern about nuclear waste also derives from a series of accidents at waste storage facilities. The most publicized of these occurred at the Hanford plutonium works in Washington. On June 8, 1973, workers at the site discovered that 115,000 gallons of high-level radioactive waste had leaked from a storage tank into the surrounding soil. The leak of approximately two thousand gallons per day had gone unnoticed for fifty-one days.

Another highly publicized incident involved the discovery in 1979 that the Idaho National Engineering Laboratory had been discharging accidents involving radiation as opposed to 120 entries per year related to motor vehicle accidents and only 25 entries per year related to industrial accidents. However in the same period there were no fatalities from radiation accidents whereas there were 50,000 motor vehicle caused fatalities and 4500 industrial accident caused fatalities. Id.


119. Weart, supra note 106, at 371-72; but see Doris Graber, Mass Media and American Politics 295 (1984) (“In the Three Mile Island accident, conjectures about possible effects of a nuclear explosion were avoided. Local media even rejected advertisements by merchants for ‘evacuation sales’ and radiation detectors.”).

Congressman John Wyler of New York envisioned the following scenario:

[Suppose you took some of this extremely low level material from the hospital and you put that in the garbage dump. Then channel 7 would be down there tomorrow morning taking pictures of it saying, do you know low level radioactive material is being dumped in the middle of New York City? I can just see it. They would have a field day and have everybody screaming and yelling and climbing the walls wondering when they are going to die of radiation.

That is what many of us here in the Congress are up against when we get out on the floor to try to explain to some of our colleagues what we are talking about. Low-Level Nuclear Waste Burial Grounds: Hearing Before the Subcomm. on Energy Research and Production of the House Comm. on Science and Technology, 96th Cong., 1st Sess. 54 (1979) (statement of Rep. John Wyler) [hereinafter House Hearing, Nov. 7, 1979].

120. See Carter, supra note 69, at 71-72; Nader & Abbotts, supra note 72, at 154-56.
small quantities of radioactive plutonium and iodine into the Snake River since 1952. Despite the small amounts of radiation released,\textsuperscript{121} the press heavily covered the incident.\textsuperscript{122} The LLRW accidents at West Valley and Maxey Flats also received significant press attention.\textsuperscript{123}

Although no human health effects have been tied to these accidents, and the exposure risks were purely local, news coverage of the events brought them to national prominence. In this way, small localized risks were given a much broader effect than warranted by their actual danger.

d. Non-distinction Between LLRW and HLW

Though the Three Mile Island accident, the leaks at Hanford, and the proliferation of nuclear weapons are substantially unrelated to the issue of LLRW disposal, the public fear they generate transfers readily to LLRW. Thus, fear of nuclear weapons, fear of nuclear reactors, fear of high-level waste, and fear of low-level waste are linked.\textsuperscript{124} As one commentator notes, "[t]he nuclear waste issue is part and parcel of the nuclear power debate; whether the waste issue can be resolved without resolving the nuclear power controversy as a whole is unclear."\textsuperscript{125}

This public non-distinction has been recognized by members of Congress. As Representative Mike McCormick observed at the House hearings on nuclear waste, "[n]o matter how sophisticated a discussion we may achieve here, the general public will look at all things radioactive the same way."\textsuperscript{126} Representative John Wydler observed about the public perception of radioactive waste, "[t]hey don't like any of it. They don't want any of it."\textsuperscript{127}

\begin{itemize}
\item \textsuperscript{121} Subcomm. on Energy and the Environment of the House Comm. on Interior and Insular Affairs, 96th Cong., 2d Sess., Report on Discharge of Low-Level Radioactive Waste to the Snake River Plain Aquifer 4 (1980) (stating that the releases of radioactive iodine were less than one tenth the regulatory limit and that the plutonium releases were 200 million times lower than federal and state concentration guidelines).
\item \textsuperscript{122} Idaho Lieutenant Governor Philip E. Batt eventually admitted that "the matter has become emotional to the point that it is difficult to generate objective and unbiased scientific data. I regret that public statements, including my own — expressing concern, and widespread press coverage have overdramatized the situation." Id. at 13 (letter from Idaho Lt. Gov. Philip E. Batt to Rep. Symms).
\item \textsuperscript{124} Cf. NAS Social and Economic, supra note 108, at 30 (linking fear of nuclear weapons to fear of nuclear power); Richard J. Bord, The Low-Level Radioactive Waste Crisis: Is More Citizen Participation the Answer?, in Science, Politics, and Fear, supra note 2, at 195 (suggesting that risks from radioactive waste and nuclear power are not differentiated by the public).
\item \textsuperscript{125} Kasperson, supra note 111, at 56.
\item \textsuperscript{126} House Hearing, Nov. 7, 1979, supra note 119, at 56-57 (statement of Rep. McCormack (WA)).
\item \textsuperscript{127} Id. at 56 (statement of Rep. Wydler (NY)).
\end{itemize}
2. Psychological Influences on Public Misperception of LLRW

With these catalysts at work, public attitudes toward radioactive waste rapidly deteriorated in the late 1960's and 1970's. By 1974, fifty-two percent of survey respondents considered radioactive waste management a "serious problem."¹²⁸

This negative perception extends to LLRW management as well. Five distinct factors appear to contribute to this perception.¹²⁹

First, the harms that radiation can cause are particularly frightening ones: cancer and genetic mutation. Radiation threatens the integrity of the human body in ways which the public does not generally understand.¹³⁰ One commentator argues that "these fears cannot be eliminated by rational-probabilistic assessments of risk . . . because it may be the mode rather than the number of deaths that is critical."¹³¹

Second, radiation is often associated with nuclear war and disasters of immense proportions.¹³² Nuclear waste conjures up terrible images of "nuclear objects buried in the earth — what people had associated for decades with wicked violations and dreadful dooms."¹³³ Catastrophic deaths are often viewed as more frightening than individual deaths, hence the things that could cause them are viewed as inordinately risky.¹³⁴

Third, Paul Slovic's "availability" heuristic proposes that an event is viewed as likely or frequent if it is easy to imagine or recall similar incidents. Thus, the mind systematically exaggerates the likelihood of vivid and sensational events, such as homicide, tornadoes, fires, automobile accidents, and nuclear catastrophes, while it underestimates the risk of less vivid fatalities.¹³⁵ Since the public does not distinguish the risks of LLRW from the imagery of nuclear catastrophes, the LLRW risks are

¹²⁸. NAS SOCIAL AND ECONOMIC, supra note 108, at 19 (citing a 1974 survey by Opinion Research Corp). See also Kasperson, supra note 111, at 56 ("A succession of recent Harris Polls has revealed that radioactive waste disposal heads the list of major public concerns about nuclear energy.").

¹²⁹. These factors can be categorized as various "hazard characteristics" applicable to the radiation hazard. For a discussion of hazard characteristics in general, see Alan Hedge, Major Hazards and Behavior, in RISK AND DECISIONS, supra note 118, at 142-45.


¹³¹. Id. (quoting R.J. Lifton). See also A.R. Hale, Subjective Risk, in RISK AND DECISIONS, supra note 118, at 78 ("[S]ome injuries (quadriplegia and brain damage) . . . were consistently rated as worse than death. Similar scales have been developed for diseases.").

¹³². See NAS SOCIAL AND ECONOMIC, supra note 108, at 33. For many, anxiety about nuclear war is "displaced" or "extended" to commercial uses of nuclear power. Kasperson, supra note 111, at 57.

¹³³. Id. at 318.

¹³⁴. Paul Slovic & Baruch Fischhoff, How Safe is Safe Enough? Determinants of Perceived and Acceptable Risk, in TOO HOT TO HANDLE? 112, 143 (C. Walker et al. eds., 1983). One study argued that the cost of n lives lost at once should be valued at n² due to the greater cost to the community of simultaneously lost lives and the horrific nature of catastrophes. Id.

¹³⁵. Id. at 115-16.
easily recalled.\textsuperscript{136} Furthermore, people are overly confident of the judgments they form based on such heuristics and consistently overestimate the accuracy of these judgments.\textsuperscript{137}

Fourth, any waste disposal facility involves the imposition of a new "public risk." According to Peter Huber, public risks include "threats to human health or safety that are centrally or mass-produced, broadly distributed, and largely outside the individual risk bearer's direct understanding and control."\textsuperscript{138} In contrast, "private risks" are "discretely produced, localized, personally controlled, or of natural origin."\textsuperscript{139} In practice, "[p]anic, protest, and organized resistance thus greet almost every venture that entails new public risk . . . efforts to restrain private risk-taking are denounced as grave attacks on personal freedom."\textsuperscript{140} For example, though the fatality risk of riding in an automobile is far greater than the risk from LLRW, people usually incur the automobile risk voluntarily, whereas the LLRW risk is imposed by forces beyond the individual's control. Thus, the risk of automobile fatality is accepted more readily than that of radiogenic cancer from a LLRW facility.\textsuperscript{141}

Fifth, radioactive waste is feared because many of its effects are still unknown. Uncertainty about risks increases public anxiety and often results in excessive precautions.\textsuperscript{142} The knowledge that radiation is invisible and that its victims must often wait for years before they manifest symptoms of exposure contributes to this fear.\textsuperscript{143}

Additionally, Weart argues that "nuclear fear" has a unique quality not shared even by more common hazards such as toxic chemical wastes.\textsuperscript{144} This fear arises from images we have come to associate with things nuclear: mushroom clouds, cooling towers, mad scientists, and apocalypse. The popular conception of radiation's risks, though often

\begin{thebibliography}
\bibitem{136} For instance, in a 1980 survey, 52\% of respondents erroneously believed that "nuclear power plants could explode and cause a mushroom shaped cloud like the one at Hiroshima." NAS SOCIAL AND ECONOMIC, supra note 108, at 30. Moreover, holders of such beliefs tend to interpret subsequent data to support their existing beliefs. "New evidence appears reliable and informative if it is consistent with one's initial belief; contradictory evidence is dismissed as unreliable, erroneous, or unrepresentative." Slovic & Fischhoff, supra note 134, at 119-20.

\bibitem{137} Slovic & Fischhoff, supra note 134, at 117.


\bibitem{139} Id. at 278.

\bibitem{140} Id. at 281.


\bibitem{142} Slovic & Fischhoff, supra note 134, at 118-19. See Nichols & Zeckhauser, supra note 63, at 19 ("highly uncertain risks, such as environmental carcinogens, are the ones most likely to be overcontrolled."); A.R. Hale, Subjective Risk, in RISK AND DECISIONS, supra note 118, at 77 (discussing the effect of uncertainty on public anxiety).

\bibitem{143} Kasperson, supra note 111, at 57.

\bibitem{144} WEART, supra note 106, at 372-73 (comparing the fear caused by the Three Mile Island accident to the fear caused by a chemical waste dump accident).
\end{thebibliography}
inconsistent with scientific evidence, is very real to the public and to Congress. As will be discussed in the following sections, political reality often deviates from technical reality; and in the political arena, "perception is reality."

III
THE STRUCTURE AND DEVELOPMENT OF THE LOW-LEVEL RADIOACTIVE WASTE POLICY ACT

A. The LLRWPA

1. The 1980 LLRWPA

In December of 1980, Congress passed the Low Level Radioactive Waste Policy Act (LLRWPA). The Act gave the states the responsibility for providing disposal capacity for the non-federal LLRW generated within their borders. It also encouraged states to dispose of LLRW on a regional basis.

To facilitate these policies, the LLRWPA permitted the states to "enter into such compacts as may be necessary to provide for the establishment and operation of regional disposal facilities for low-level radioactive waste." To encourage the formation of compacts, Congress provided that "[a]fter January 1, 1986, any such compact may restrict the use of the regional disposal facilities under the compact to the disposal of low-level radioactive waste generated within the region." Thus, any regional compact could bar extra-regional waste from its facilities after the 1986 deadline, meaning that each region had to have a disposal facility operating before that date.

2. Federal Regulatory Control

Under the LLRWPA, the NRC retains its authority to regulate and license LLRW disposal facilities. Through the "Agreement State Program," however, the NRC could grant state agencies regulatory authority...
ity over certain aspects of waste disposal. To date, twenty-nine states have obtained Agreement State status. Their regulations, however, must be at least as stringent as NRC regulations.

The NRC guidelines for “Licensing Requirements for the Land Disposal of Radioactive Waste” were issued in 1983. They provide four general performance objectives and a series of technical requirements for disposal sites. The first three performance objectives seek to protect workers, the public, and the environment from the radioactive materials. The fourth objective calls for assurances that sites will remain stable for extended periods of time. The technical regulations relate to site characterization; facility design; waste form, classification, packaging; and care of sites after shutdown.

A number of other federal statutes and regulations affect the disposal of LLRW. The Resource Conservation and Recovery Act of 1976 (RCRA), administered by the EPA, applies to the disposal of “mixed” waste containing both radioactive and other hazardous materials. Radionuclides are treated as hazardous substances under CERCLA and the Clean Air Act as well. Certain regulations issued by the Department of Transportation affect the transportation and packaging of radioactive waste.

3. 1985 Amendments to LLRWPA

The 1980 LLRWPA permitted regional compacts having LLRW disposal facilities to exclude extra-regional LLRW from those facilities beginning on January 1, 1986. As this date approached, however, it became clear to Congress that many states would not be able to ratify compact agreements by the 1986 date, nor would any new disposal facili-

152. See infra Section III.B for a brief history of federal authority over LLRW.
153. See OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 151-52.
156. OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 60-61.
158. See OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 62-77. RCRA regulates hazardous, rather than radioactive, substances. However, a substance may be both a radioactive and a hazardous substance. Martin v. Kansas Bd. of Regents, 32 Env’t Rep. Cas. (BNA) 1944, 1951 (D. Kan. 1991).
160. 42 U.S.C §§ 7401-7671q (1988); 40 C.F.R. § 61.01(a) (1989) (listing radionuclides as a hazardous air pollutant).
ties be operating before that date. Thus, as the end of 1985 approached, Congress sought to provide continued access to the existing disposal facilities while at the same time continuing to encourage regions without compacts to develop LLRW sites.

The solution finally reached on December 19, 1985, only hours before adjournment of the 99th Congress, became the 1985 LLRWPA Amendments. Most importantly, the amendments extended by seven years the period during which the three existing disposal facilities at Beatty, Nevada, Barnwell, South Carolina, and Richland, Washington had to accept extra-regional waste. However, rather than granting a simple time extension, Congress established a series of "milestones," minimum indications of progress toward siting disposal facilities, for nonsited states and compacts.

The milestones were intended to spur the non-sited states' progress toward siting and constructing their own disposal facilities. For example, by January 1, 1988, each non-sited state was required to develop a detailed siting plan for its own facility. If a state failed to meet this deadline, it could be denied access to the three existing facilities beginning in 1989.

A state could suffer two consequences for failing to meet the Amendments' milestones. First, there was potential shut-out from existing disposal facilities. Second, there was a series of sharply increasing surcharges to waste generators for waste produced in non-sited states and shipped to other disposal facilities.

**B. The Take Title Provision**

The most drastic penalty for states failing to meet the final statutory milestone requirement was the so-called "take title" provision of the

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164. *Id. at 2.*


166. *Id. § 2021e(e)(1)(B)(ii).*

167. *Id. § 2021e(e)(2)(B)(ii).*

168. *Id. § 2021e(e)(2)(A-D). The Supreme Court recently upheld this portion of the LLRWPA in New York v. United States, 112 S. Ct. 2408, 2427 (1992). Justice O'Conner wrote for the majority of the court that: As a simple regulation, this provision would be within the power of Congress to authorize the States to discriminate against interstate commerce. The affected states are not compelled by Congress to regulate, because any burden caused by a State's refusal to regulate will fall on those who generate waste and find no outlet for its disposal, rather than on the State as a sovereign. Id. (citations omitted).*

LLRWPA Amendments. Essentially, if a state failed to develop a LLRW disposal facility, either individually, or as a member of a regional compact by January 1, 1996, the state, shall take title to the waste, shall be obligated to take possession of the waste, and shall be liable for all damages directly or indirectly incurred ... as a consequence of the failure of the state to take possession of the waste ....

This provision threatened states that did not have operational disposal facilities by 1996 with potentially huge liability. In response, the state of New York challenged the LLRWPA on several constitutional grounds. The Supreme Court struck down the take title provision of the LLRWPA in New York v. United States. Justice O’Conner, writing for the majority, observed that with the take title provision, “Congress has crossed the line distinguishing encouragement from coercion.” She reasoned that the provision violated the Tenth Amendment, which reserves to the states all powers not delegated to the federal government:

In this provision, Congress has not held out the threat of exercising its spending power or its commerce power; it has instead held out the threat, should the States not regulate according to one federal instruction, of simply forcing the States to submit to another federal instruction. A

<table>
<thead>
<tr>
<th>Year</th>
<th>Ordinary Surcharge (per cubic foot)</th>
<th>Surcharge for Milestone Failure (per cubic foot)</th>
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<tbody>
<tr>
<td>1986</td>
<td>$10</td>
<td>$20</td>
</tr>
<tr>
<td>1987</td>
<td>10</td>
<td>shutout</td>
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<td>1988</td>
<td>20</td>
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<td>1989</td>
<td>20</td>
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<td>1990</td>
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<td>1991</td>
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<td>1992</td>
<td>40</td>
<td>$120</td>
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<td>1993</td>
<td>shutout</td>
<td>shutout</td>
</tr>
</tbody>
</table>

Twenty-five percent of the surcharges collected by a receiving state were to be held in escrow by the Secretary of Energy. Id. § 2021e(d)(2)(A). If the milestones were met, this money was to be transferred to the non-sited state in which the waste originated. The rebate would be used to fund the siting process in that state. Id. § 2021e(d)(2)(A)(ii). If the state did not meet the milestones, the money would be kept by the state receiving the waste. Id. § 2021e(d)(2)(A)-(E).

The Supreme Court examined and upheld the surcharge provisions in New York v. United States, 112 S. Ct. at 2425-27. Justice O’Conner called the imposition of surcharges “an unexceptional exercise of Congress’ power to authorize the states to burden interstate commerce.” Id. at 2425. The Secretary’s collection of a percentage of the surcharge was “no more than a federal tax on interstate commerce,” and the refund of collected surcharges to generating states was “a conditional exercise of Congress’ authority under the Spending Clause” providing access to federal funds. Id. at 2426.

171. Id.
172. 112 S. Ct. at 2427-29. New York’s suit was consolidated with similar suits brought by two New York counties. An independent challenge to the take title provision, which was not part of this suit, was mounted by the state of Michigan. Michigan v. United States, 773 F. Supp. 997 (W.D. Mich. 1991). The district court, like the courts below in New York, held the Act constitutional.
173. 112 S. Ct. at 2428.
choice between two unconstitutionally coercive techniques is no choice at all. Either way, "the Act commandeers the legislative process of the States by directly compelling them to enact and enforce a federal regulatory program."\(^{174}\)

Rather than invalidating the entire Act, however, the Court held that the unconstitutional take title provision was severable from the other provisions of the LLRWPA Amendments.\(^ {175}\)

The Act is still operative and it still serves Congress' objective of encouraging the States to attain local or regional self-sufficiency in the disposal of low level radioactive waste. It still includes two incentives that coax the States along this road. A state whose radioactive waste generators are unable to gain access to disposal sites in other States may encounter considerable internal pressure to provide for the disposal of waste, even without the prospect of taking title.\(^ {176}\)

C. The Political Process Responsible for the LLRWPA

Three key political concerns surrounded the passage of the LLRWPA. The first was for the safety of LLRW storage. Legitimate concerns about transportation and packaging were sharply heightened by the general fear of radioactive waste. Second, states intended to keep control of LLRW in their own hands and away from the federal government. Finally, the three sited states were determined to spread the responsibility for LLRW storage among the other states.

The issues of state sovereignty and interstate parity that permeated the LLRWPA debate had their origins years earlier in the first radioactive waste disposal legislation. Briefly reviewing the history of nuclear regulatory authority in the United States will help explain the genesis of the 1980 LLRWPA and its amendments.

1. Legislative Background

a. Early Regulation

In 1946, Congress passed the Atomic Energy Act (AEA)\(^ {177}\) which gave sole responsibility for all United States nuclear energy activities to

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\(^{174}\) Id. (quoting Hodel v. Virginia Surface Mining & Reclamation Assn., Inc., 452 U.S. 264 (1981)). Justice White, joined by Justices Blackmun and Stevens, argued that the take title provision was a reasonable sanction for noncompliance with the terms of the Act. Id. at 2435. The Act, they reasoned, was a "delicate compromise between the three overburdened states... and the rest of the States," Id. at 2440, that comprised "the product of cooperative federalism." Id. at 2438. Justice White argued that the court should have based its reasoning on Garcia v. San Antonio Metropolitan Transit Authority, 469 U.S. 528 (1985), rather than Hodel and its line of cases. Id. at 2443. Following Garcia, Justice White would have held that state input into the Congressional lawmaking process afforded the states adequate procedural protections in this case. Id. at 2444.

\(^{175}\) Id. at 2434.

\(^{176}\) Id.

the AEC. By that time, most nuclear research was related to the Manhattan Project and other military applications; any waste generated was stored at government facilities.

By 1954, Congress amended the Act to expand the AEC's role to civilian atomic energy activities. Two government disposal facilities, Oak Ridge, Kentucky and Idaho Falls, Idaho, were principally responsible for handling commercial LLRW in addition to government waste.

Between 1945 and 1955, the amount of radioactive waste produced in the United States tripled. In response, Congress amended the AEA in 1959 to allow states to control the disposal of certain non-military radioactive wastes within their borders, so long as they met minimum federal standards. However, the AEC refused to give states full authority over LLRW disposal. The AEC reasoned that individual states might not be qualified to manage LLRW sites and that federal control of LLRW sites would be most efficient.


178. See Michael E. Burns & William H. Briner, Setting the Stage, in SCIENCE, POLITICS, AND FEAR, supra note 2, at 22-23.


Were the states allowed to impose stricter standards on the level of radioactive waste releases discharged from nuclear power plants, they might conceivably be so overprotective in the area of health and safety as to unnecessarily stultify the industrial development and use of atomic energy for the production of electric power.

447 F.2d at 1154. This restrictive approach, however, was eventually eroded by the Supreme Court. In Pacific Gas & Electric Co. v. State Energy Resources Conservation Development Comm., 461 U.S. 190 (1983), the Court upheld a California statute prohibiting the operation of nuclear power plants until the federal government developed a plan for permanent disposal of radioactive waste. The Court held that the states could regulate the nuclear industry so long as their regulations were directed at economic rather than safety concerns (safety still being the exclusive province of the federal government). The Supreme Court reaffirmed the federal role in radioactive waste disposal in New York, 112 S. Ct. at 2420, when it acknowledged in dicta that "under the Supremacy Clause, Congress could, if it wished, preempt state radioactive waste regulation." This power, however, did not authorize Congress to enact the "take title" provision of the LLRWPA. Id. at 2427-28.


181. Burns & Briner, supra note 178, at 38. The Oak Ridge facility, which received waste from twenty-five different institutions, was soon unable to handle this large waste volume. Id.


This restriction on state authority over LLRW attracted criticism from both the states and private industry, who anticipated a lucrative market in LLRW disposal.\textsuperscript{184} By 1962, these pressures persuaded the AEC to allow private firms to acquire licenses for LLRW disposal sites.\textsuperscript{185} The only authority the federal government retained over LLRW related to waste produced by federal programs.\textsuperscript{186} Civilian power, research, and medical LLRW were controlled by the states. Six commercial LLRW disposal facilities opened between 1962 and 1971.\textsuperscript{187} These facilities were owned by the states, but operated by private companies.

In 1974, Congress dissolved the AEC and replaced it with the Nuclear Regulatory Commission (NRC) and the Energy Research and Development Administration (ERDA).\textsuperscript{188} The NRC had primary responsibility for nuclear power regulation and licensing of civilian nuclear facilities, while ERDA was responsible for the research, promotion, and military aspects of nuclear energy.\textsuperscript{189}

\textit{b. Closure of LLRW Sites}

The nuclear waste related incidents of the 1970's drastically changed the national outlook for LLRW disposal.\textsuperscript{190} In 1977, the State of Kentucky closed its Maxey Flats site when contamination was discovered in the nearby groundwater.\textsuperscript{191} The West Valley, New York site was closed

\begin{tabular}{|l|c|c|c|}
\hline
Site & Opened & Closed & 1989 LLRW volume (million cubic ft.) \\
\hline
Beatty, NV & 1962 & — & 4.0 \\
Maxey Flats, KY & 1963 & 1977 & 4.8 \\
West Valley, NY & 1963 & 1975 & 2.5 \\
Richland, WA & 1965 & — & 10.8 \\
Sheffield, IL & 1967 & 1978 & 3.1 \\
Barnwell, SC & 1971 & — & 20.6 \\
\hline
\end{tabular}

\textsuperscript{184} See id.
\textsuperscript{185} Id.
\textsuperscript{186} Cf. 42 U.S.C. 2021c(b) (1988). The government's handling of its own LLRW has attracted considerable criticism. See generally RADWASTE, supra note 180, at 119-39. For example, until 1970, the government permitted disposal of its LLRW by ocean dumping. Dumping site locations included areas 50 miles off San Francisco, 120 miles off New Jersey, and 12 miles off Boston, directly in Massachusetts Bay. Protests by local and international groups eventually helped to persuade the government to end its ocean dumping policy. Id. at 122-24.

\textsuperscript{187} 1989 LLRW volume


\textsuperscript{190} See generally supra notes 116-23 and accompanying text (discussing highly publicized nuclear waste-related accidents).

\textsuperscript{191} See CARTER, supra note 69, at 73; supra notes 69-74 and accompanying text (describing the extent of the Maxey Flats and West Valley accidents).
in 1975 for similar reasons, and in 1978, Illinois closed the Sheffield site when it ran out of storage capacity.

Thus, by 1978, only the Beatty, Nevada, Barnwell, South Carolina, and Richland, Washington sites continued to accept LLRW. The situation worsened the following year, when the receipt of three defective LLRW shipments at the Richland site caused Washington governor Dixie Lee Ray to close temporarily Richland to commercial waste on October 4, 1979. Similar safety concerns at the Beatty site caused Nevada governor Robert List to close his state's facility. Finally, South Carolina governor Richard Riley announced that the Barnwell site, which by then was receiving eighty percent of the nation's LLRW, would reduce by half the amount of LLRW it accepted. Clearly, the LLRW disposal situation in the United States was moving toward a crisis.

2. Fear Affecting Legislation

Members of Congress and state governments were not immune to the widespread public fear of nuclear waste that swept the country in the 1970's. The atmosphere of impending crisis surrounding political discussions of LLRW revealed this fear.

a. State Officials

State governors and legislators were particularly attuned to public fear of radioactive waste entering their states. They had much to lose by

192. Carter, supra note 69, at 73; Radwaste, supra note 180, at 148.
193. See Radwaste, supra note 180, at 146. By April, 1978, Sheffield's five disposal trenches were filled with approximately three million cubic feet of LLRW. The site operator's efforts to expand Sheffield's disposal capacity, however, were successfully blocked by Illinois officials. Id.
194. See Radwaste, supra note 180, at 155. Governor Ray was formerly chairman of the AEC. The defects included three boxes of radioactive scrap iron and gravel that had broken open in transit, a leaking barrel of cobalt-57, and a shipment of depleted uranium that was 20,000 pounds overweight and was being transported in a truck with numerous equipment defects. Id.
195. Condon, supra note 151, at 72-73. In one incident a truck carrying radioactive materials caught fire at the Nevada site and exposed ten people to radiation. Later, another truck arrived at the site leaking contaminated liquids. Radwaste, supra note 180, at 156-57.
196. Radwaste, supra note 180, at 153.
197. Radwaste, supra note 180, at 157.
becoming too closely associated with the seemingly dangerous technology of radioactive waste disposal.\textsuperscript{199}

The concern they repeatedly emphasized, sometimes with great flourish, was for the health and safety of their citizens. Richard Riley, Governor of South Carolina, complained that "[t]he health of our citizens . . . is endangered by slipshod packaging and negligent transportation of radioactive materials."\textsuperscript{200} Even more strongly, former Governor Mike O'Callaghan of Nevada told a Senate Subcommittee "that it is going to be very difficult to convince people that they can go to bed at night and a truck hauling liquid waste can't destroy their neighborhood when they are asleep."\textsuperscript{201}

Congress understood the political pressures causing state officials to oppose LLRW disposal sites in their states. As Senator Henry Bellmon admitted:

[I]t is hard for me to understand how any Governor, any State legislature will ever be able to openly endorse the establishment of a radioactive waste disposal area inside their own state. . . . It is looked on as a potential danger, a threat."\textsuperscript{202}

\textbf{b. Congress}

In many cases, members of Congress echoed the fears of their state-government counterparts. Congressional representatives have resolutely defended the political decisions of their state officials opposing in-state LLRW facilities, as in this exchange on the issue of interstate parity between Governor Ray of Washington and Representative Roth of Wisconsin:

\textsuperscript{199} See, e.g., CARTER, supra note 69, at 150 ("[The Ohio candidates for governor and lieutenant governor in 1978] were not going to be left politically exposed on an issue so volatile as the disposal of radioactive waste, which already had led to the formation of several citizens' coalitions in opposition."); Timothy L. Peckinpaugh, The Politics of Low-Level Radioactive Waste Disposal, in SCIENCE, POLITICS, AND FEAR, supra note 2, at 58 (" Few governors or state legislative officials care to be party to the politically messy task of deciding where a new low-level radioactive waste disposal facility should be sited.").

\textsuperscript{200} House Hearing, Nov. 7, 1979, supra note 119, at 7.


\textsuperscript{202} Nuclear Waste and Facility Siting Policy: Hearings on S. 594, S. 685, S. 701, and S. 797 Before the Senate Comm. on Energy and Natural Resources, 96th Cong., 1st Sess., pt. 1, at 74 (1979). See also Nuclear Waste and Facility Siting Policy: Hearings on S. 594, S. 685, S. 701, S. 797, and S. 1443 Before the Subcomm. on Energy Regulation of the Senate Comm. on Energy and Natural Resources, 96th Cong., 1st Sess., pt. 2, at 381 (1979) [hereinafter Senate Hearing, July 19, 1979] (statement of Steven V. Sklar, Chairman, NCSL Subcommittee on Nuclear Energy) ("I have felt the pressures that can be brought to bear on elected officials, and I am convinced that if a state is permitted by a siting process to absolutely disapprove a proposed facility, its elected officials will have little choice politically but to say no.").
Mr. Roth: It would be politically impossible for our Governor to accept wastes from Michigan, Illinois, and Minnesota. At the same time, I am sure they will not accept ours.

Gov. Ray: If it is politically impossible for . . . Wisconsin to accept waste from other states, why would it be politically impossible for Wisconsin to take care of its own waste?

Mr. Roth: Are you asking me why? I don’t know. I am supposed to be asking the questions.

Gov. Ray: Let’s make that just a rhetorical question.

Mr. Roth: I know what subject to stay away from.203

Some members of Congress spoke of LLRW in terms more colorful than true. Representative Udall spoke in 1985 of the “painful realization that there is no place to put an unwanted dangerous substance that does not turn out to be in someone else’s backyard.”204 Representative Markey of Massachusetts warned that Congress could not “afford to repeat the disastrous history of low-level waste facilities such as West Valley, Sheffield, and Maxey Flats which closed because of serious environmental problems.”205

Despite the general misunderstanding of LLRW, others in Congress became quite well-informed about the technical aspects of LLRW management. Congressman John Wyler of New York expressed his frustration at the general level of Congressional misunderstanding and dependence on popular opinion as follows:

[M]isunderstanding results in decisions on an idiotic basis. Decisions are being made . . . in low-level waste radiation that have no real sense to them. Yet those charged with the responsibility can’t really do anything about it. . . . This is not a serious danger. This is not a problem that is insoluble. We can do it if we will just get away from the fear angle for a few minutes and think about the facts involved.206

3. The Demand for State Sovereignty

A recurring and contentious topic in the political debate over LLRW disposal was whether nuclear waste disposal, in general, should be controlled by the federal or state governments. Pursuant to the AEA and, later, the Nuclear Waste Policy Act of 1982,207 the Department of Energy (DOE) has control over the disposal of HLW and spent fuel. However, federal efforts, both at siting a HLW depository at Yucca Mountain, Nevada,208 and at constructing the Waste Isolation Pilot


205. Id. at 35,205-06. See also supra text accompanying notes 69-74.


208. The federal search for a HLW depository began with a 1963 proposal to store spent
Plant (WIPP) for the disposal of transuranic wastes at Carlsbad, New Mexico, have been fraught with difficulties and delays. These difficulties have led many to question whether federal authority over LLRW siting would be wise.

Some have suggested that comprehensive national regulation of waste was needed for the issue to be “handled properly.” Nuclear waste was said to have a “national character” warranting federal treatment. Soon after its formation in 1977, the DOE led an Interagency Review Group (“IRG”) which made recommendations to the President regarding nuclear waste management. After studying the LLRW disposal situation, the IRG proposed that the federal government establish a national strategy for LLRW disposal, giving the states the option to relinquish control of LLRW to the federal government. In view of the accidents and closings at the state controlled LLRW sites, the IRG may have believed that a federally-controlled LLRW program would be more reliable than a state-controlled program.

The states and their representatives in Congress vehemently disagreed. They were convinced that they had the “political, technical, and reactor fuel at the abandoned salt domes near Lyons, Kansas. In 1970 the AEC’s proposal to build a HLW depository at Lyons was met with substantial political opposition. Moreover, studies revealed that the Lyons salt domes were vulnerable to water infiltration. In 1973 the Lyons project was canceled. AEC then developed a plan for an interim “retrievable surface storage facility” (RSSF). The EPA, however, challenged the RSSF plan on numerous grounds, and ERDA, which succeeded the AEC in the HLW disposal arena, withdrew its request for RSSF funding in 1975. In 1976 ERDA announced a plan to study sites in 36 states for suitable locations for waste repositories. In 1977 significant local opposition from three Michigan counties under consideration led the government to abandon its search in Michigan. The siting process was hindered in other states as a result. Kasperson, supra note 111, at 26-28. Recently, the DOE began the process of characterizing the crystalline rock formations at Yucca Mountain, Nevada in preparation for a HLW repository. GERSHEY ET AL., supra note 15, at 7. The earliest anticipated date of operation, however, is 2003. Id. After the failure of the Lyons proposal, Sandia National Laboratory began planning the WIPP facility, which would be located in salt formations approximately 855 meters below ground in Carlsbad, New Mexico. GERSHEY ET AL., supra note 15, at 10. Site characterizations began in 1974 and actual construction began in 1983. Id. The WIPP facility, which has undergone numerous revisions of its stated mission, will receive transuranic waste, as well as “mixed waste.” On November 14, 1990, the EPA conditionally approved the site for accepting mixed waste. 21 [Current Developments] Env’t. Rep. (BNA) 1362 (Nov. 16, 1990). Nuclear Waste Management, Hearings before the Subcomm. on Nuclear Regulation of the Senate Comm. on Environment and Public Works, 95th Cong., 2d Sess. 24 (1978) [hereinafter 1978 Senate Hearings] (testimony of Victor Gilinsky, Commissioner, NRC).
economic resources to handle LLRW disposal” and wanted to keep control in their own hands.215 This desire to control the management of LLRW arose from a fear that the federal government would do so inadequately and without concern for the states. The eventual discovery of cover-ups of waste disposal problems at Hanford and Snake River and the failure of the federal government to site an HLW repository were seen by the states as a validation of their belief in federal incompetence.216 As Senator Pete Domenici of New Mexico explained, “no State is going to believe the federal government when it comes to their involvement in a waste disposal project.”217

For some members of Congress, nuclear waste siting decisions would affect their home constituencies. Few members of Congress relished the negative publicity associated with bringing radioactive waste home. As Senator Domenici explained to the Subcommittee on Nuclear Regulation:

I am personally convinced that a State’s only ultimate protection is a State veto over facility siting. . . . I have a particular interest, as you know, perhaps more specific that most States, because of the [Carlsbad] proposal in our State.”218

Regardless of whether states had the technical or economic resources to adequately handle LLRW disposal, with their Congressional delegations lending support, they held the trump cards in siting decisions. The federal government simply could not force a state to accept waste it did not want.219 Even if federal courts struck down every state blocking tactic, the delay involved could make a determined state the ultimate winner in any siting battle.

By the summer of 1980, the National Governor’s Association, the National Conference of State Legislatures, the Carter Administration’s State Planning Council, the Conservation Foundation, and the DOE all

215. OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 29.
216. See id. Public interest groups also encouraged the states to distrust the federal government. See e.g., NADER & ABBOTTS, supra note 72, at 154 (“[T]he inability of the federal government to handle its own wastes gives little confidence that the government can manage future commercial nuclear wastes.”).
217. Senate Hearings, Sept. 11, 1979, supra note 1, at 30.
218. 1978 Senate Hearings, supra note 210, at 280-81 (referring to a proposal to site the Waste Isolation Pilot Plant (WIPP) in New Mexico).

Representative Butler Derricks (S.C.) observed that “[t]he track record of the federal government in the area of nuclear waste does not lead me to believe we can solve the problem better or faster than the states.” House Hearing, Nov. 7, 1979, supra note 119, at 5.
219. See CARTER, supra note 69, at 185 (“[A] depository cannot be built over determined host-state opposition.”). For example, ERDA attempts to site a high level waste repository were blocked by state opposition in Ohio, Michigan, Mississippi, Texas, and Louisiana. See id. at 145-65; supra notes 208-09.
agreed that state control of LLRW facilities was desirable. This preference for State control was explicitly included in the LLRWPA.

4. The Demand for Interstate Parity

The major question remaining after the summer of 1980, however, was which states should host LLRW disposal sites and, hence, have the dubious honor of controlling those sites. Concerns about interstate parity are usually expressed by states seeking to increase their share of a perceived benefit enjoyed by other states. For example, predominantly rural states might complain of federal subsidies to states with large cities. The states receiving the perceived benefit, of course, would have no cause to complain.

The storage of LLRW, on the other hand, is clearly perceived to be an undesirable function, and one that entails great risks. Thus, the states which have assumed this "negative benefit" complain, as Colglazier and English have observed:

In the United States, our system is built on the conception of justice as fairness. We do not like to think we are taking on — or giving to someone else — more than a fair share, especially when what's being shared is perceived to be risk, not benefit... The equity issue, then, turns in part on the perceived risk of a LLRW disposal facility.

Officials from Washington, Nevada, and South Carolina were of the strong opinion that they should not handle LLRW for the entire country. Senator Strom Thurmond of South Carolina, who introduced the bill which eventually became the LLRWPA, repeatedly raised the issue of fairness in LLRW disposal. In calling for greater state participation in the handling of LLRW, he told the Senate:

It is extremely unfair to allow three States to become "dumping grounds" for waste which all 50 states generate. If other States are to share in the benefits of nuclear power production and nuclear medicine, they must begin to share in the responsibilities which include the unpleasant task of waste disposal.

He reminded the Senate that South Carolina had recently been storing eighty percent of the nation's LLRW and insisted that his state no longer serve as a "nuclear waste dump for the rest of the country."

220. See OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 29-30.
222. The term "interstate parity" in the context of LLRW disposal refers to a scenario in which no state is involuntarily required to bear the burden of waste from another state.
225. Id.
226. Id.
His constituents were “becoming increasingly fed up” with their role as national waste hosts.227

These sentiments were echoed by the citizens of Washington who, in November of 1980, passed a state-wide resolution prohibiting out-of-state waste from entering the state.228 Many citizens of Washington felt it unfair for Washington and Nevada, both Western states, to accept waste from the East Coast.229

The ideal solution to this inequitable situation appeared to split the country into geographic regions, each with its own LLRW disposal site. In support of this scheme, the LLRWPA proclaims that “low-level radioactive waste can be most safely and effectively managed on a regional basis.”230 Thus, the three sited states would be relieved of the burden of waste from beyond their immediate geographical regions, and the other forty-seven states would assume their “fair share” of the LLRW risk.

By 1985, with no new sites developed, and no regional compacts ratified by Congress, the three sited states again threatened to close their facilities. To avoid an immediate crisis, Congress had to reach a compromise to ensure that the sited states would not close their doors. As Representative Bonker explained:

The amendments now under consideration are the result of a delicately crafted compromise . . . . The bill would continue nationwide access to the three commercial disposal sites through the end of 1992. In exchange, areas without waste sites would have to meet a series of interim deadlines for opening their own disposal sites.231

Thus, concerns of states’ rights and interstate parity dominated the debate over the LLRWPA. These concerns quickly overshadowed the procedural complaints that originally caused Washington and South Carolina to temporarily close their sites in 1979.232 The great public fear of LLRW demanded changes more sweeping than minor reforms in pack-

227. Id.
229. 11 [Current Developments] Env’t Rep. (BNA) 1030 (1980). Representatives of other states shared this concern. See 131 CONG. REC. 35,210 (1985) (statement of Rep. Akaka (HI)) (“For too long, the people of the Northwest have shouldered more than their fair share of the responsibility for low level nuclear waste disposal.”).
aging and transportation regulations. It demanded a regulatory structure in which each state took responsibility for its own waste.

IV PROBLEMS WITH THE LLRWPA

The interstate compacting system has not achieved the results envisioned by Congress. Although nine regional compacts have been ratified by Congress, few, if any, non-sited states are close to establishing a LLRW disposal facility by the 1993 and 1996 milestone deadlines. This failure could result in various problems ranging from site shut-out to unwanted site proliferation.

A. The Threat of Shut-out

Under the terms of the Southeast Compact, the Barnwell, South Carolina, facility is scheduled to close in 1993. The only states that have reasonable expectations of operating functional LLRW disposal facilities by the 1993 and 1996 milestones are those already having facilities.

California, once progressing toward siting a Southwest Compact facility in the desert town of Ward Valley, recently became embroiled in politically-motivated delays. Texas, a "go-it-alone" state, and Nebraska, host state for the Central Compact, had been making more progress toward siting and constructing facilities than most other states, but are still not expected to meet the 1996 milestone. Considering that an

233. See Office of Technology Assessment, supra note 9, at 151-52.
236. Washington will serve the Northwest Compact with its existing Hanford site. Nevada plans to close its Beatty site; Colorado has been designated as the host state for the Rocky Mountain Compact. OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 33-35. Although South Carolina had planned to close its Barnwell site at the end of 1992 in favor of a planned site in North Carolina, South Carolina has chosen to keep the site open until 1996. 23 [Current Developments] Env't. Rep. (BNA) 709 (June 26, 1992).
238. Although Texas is still a "go-it-alone" state, the Texas legislature has enacted provisions permitting the state to enter into compact negotiations with other states. Texas Low-Level Radioactive Waste Disposal Authority Act, TEXAS HEALTH & SAFETY CODE ANN. § 402.219(c) (West 1991).
239. See Franklin, supra note 234, at 44; Texas Low-Level Radioactive Waste Disposal Authority, Briefing Summary: Milestones, Surcharges, and Penalties (Austin, Texas) (on file with author) (stating that Texas is in compliance with 1986, 1988, and 1990 milestones, but not with 1992 milestone; compliance is not anticipated for 1993 or 1996 milestones). However, Nebraska’s Boyd County site is expected to be operational by 1993. 20 [Current Developments] Env't. Rep. (BNA) 1576 (Jan. 12, 1990).
optimistic schedule for developing a LLRW disposal facility is seven years\textsuperscript{240} and that most states have not even begun the site selection process, it seems probable that most states will fail to meet the 1996 milestone.

The sited states have been aggressively warning their dilatory neighbors that shut-out from existing disposal facilities is imminent. They have sent warning letters to several states they believe are not making sufficient progress toward siting a facility.\textsuperscript{241} They have already attempted to deny access to all LLRW from Michigan.\textsuperscript{242} The implications of shut-out are drastic. One likely consequence is that shut-out states will be forced to curtail activities that generate LLRW. During the 1979 temporary closure of the Beatty and Hanford sites, several Massachusetts hospitals were forced to suspend cancer treatments and other medical activities relying on radioactive materials.\textsuperscript{243} Due to the current Michigan shut-out, researchers at Henry Ford Hospital have halted experiments involving animals.\textsuperscript{244}

Another possible result of shut-out is that generators of LLRW will be forced to store their own waste. This necessity will be particularly damaging to those generators lacking the space, facilities, or expertise to handle and store significant quantities of LLRW.\textsuperscript{245} The situation that will result if every hospital, university, and company that uses radioac-

\textsuperscript{240} OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 142.
\textsuperscript{241} Connecticut, Massachusetts, New Jersey, Maine and New York have already received warnings. 21 [Current Developments] Env't Rep. (BNA) 1498 (Nov. 30, 1990).

Currently, the plaintiff's members are storing their low-level radioactive waste in on-site temporary storage facilities. The plaintiff has not alleged that its members cannot provide the required storage capacity, but merely that they find it inconvenient...[T]he plaintiff's members will only be required to use these facilities on a temporary basis until the state of Michigan complies with the amendments to the act.

945 F.2d 150, 155 (6th Cir. 1991). The Sixth Circuit eventually held that the Michigan district court lacked personal jurisdiction over the Washington, Nevada and South Carolina defendants. 954 F.2d 1174 (6th Cir. 1992). Nevada also has denied access to generators from Vermont and Puerto Rico. 21 [Current Developments] Env't Rep. (BNA) 1498 (Nov. 30, 1990).

\textsuperscript{243} MASSACHUSETTS LOW-LEVEL RADIOACTIVE WASTE MANAGEMENT BOARD, 1991 ANNUAL REPORT TO THE COMMONWEALTH, vol. 1, at 7 [hereinafter MASSACHUSETTS 1991].
\textsuperscript{244} Radioactive animal carcasses must be treated as LLRW. Radiation Phobia: It Could be Hazardous to Your Health, NUCLEAR INDUSTRY, 3rd Quarter 1991.
\textsuperscript{245} One temporary offsetting benefit, however, will be reduced transportation costs for LLRW generators no longer having to pay for shipment to either Washington, South Carolina, or Nevada. See, e.g., Hittman Nuclear & Dev. Corp. v. Chem-Nuclear Sys., Inc., No. 78-2570, 1979 WL 1749 at *4 (D. Md. Nov. 26, 1979) (antitrust action in which court recognized that transportation costs are a significant item of expense in radioactive waste disposal).
tive materials has to store LLRW on its own premises may be termed a "super-proliferation" of disposal sites.246

Ironically, it was the "take title" provision of the LLRWPA Amendments that provided the best assurance that "super proliferation" of LLRW repositories would not occur. Any state in which dozens of private hospitals, universities, and corporations were forced to store their own LLRW would have faced extremely high tort liability exposure. Thus, most non-sited states would have attempted to deal with their LLRW, either by contracting with an existing facility in another region (at an exorbitant cost) or by constructing a disposal facility in-state.

Now that the take title provision has been held unconstitutional, states will have significantly less incentive to deal with their LLRW problem after 1996. The problem, in fact, will be faced by the waste generators, who will have to store their own LLRW or otherwise arrange for disposal. The states, on the other hand, will be freed from the need to address the politically dangerous LLRW problem.

B. Potential Site Proliferation

Independently of the take title provision, the LLRWPA provides other incentives toward inefficient site proliferation.247 Even if all the deadlines and recommendations of the Act are fully realized, many of the unaffiliated states will construct disposal facilities in addition to those created by the nine regional compacts.248 This situation could result in between fifteen to nineteen LLRW disposal facilities across the nation.249

In contrast, a set of 1981 DOE guidelines suggested that six regional facilities would serve the country's disposal needs.250 Since that time, the national LLRW volume has decreased by over fifty percent — from approximately 3.25 million cubic feet in 1980, to only 1.6 million cubic feet in 1989.251 Correlating the DOE estimates to this reduced volume, it

246. During the 1979 closure of the Beatty and Hanford sites, Yale University announced it would store drums of LLRW in an unused building previously devoted to nuclear research, and one Houston hospital was forced to stack barrels of waste on its roof. RADWASTE, supra note 180, at 163, 167.

247. The predominant incentive for unsited states to develop their own sites is, of course, the threat of shut-out. Another small but psychologically strong incentive is the potential for rebate of waste disposal surcharges under the 1985 Amendments. 42 U.S.C. § 202l(e)(2)(A) (1988). States can receive 25% of the surcharges paid by their waste generators so long as they make progress toward siting. See supra note 169 and accompanying text. For a state like Massachusetts, which produces 50,000 cubic feet of waste per year, OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 152, the amount of surcharge rebate for a $40 surcharge would be approximately $500,000.

248. See OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 151-52.

249. Id.

250. DONALD L. BARTLETT & JAMES B. STEELE, FOREVERMORE—NUCLEAR WASTE IN AMERICA 220 (1985). There were six LLRW disposal facilities servicing the nation in the early 1970's. See id. at 199.

251. OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 88. See also supra notes 35-
appears that three LLRW facilities would serve the country's needs adequately.

There are four major inefficiencies associated with the proliferation of disposal sites: (1) decreased economies of scale; (2) increased possibility of financial failure; (3) greater risk of site misplacement; and (4) increased safety risk from disaggregation.

1. **Lower Volume, Higher Cost**

The first two inefficiencies arise from the decreased volume of waste which would be available to each new site. This decreased volume is a result of the declining national waste stream being split among many more disposal facilities. The decreased volume handled by each site will cause each to lose valuable economies of scale.

Many of a site's expenses arise from site characterization, environmental testing, and technologies that are relatively independent of the size of the site being constructed. Thus, the fixed costs for a site with small capacity are comparable to those for a site with large capacity. For example, a shallow land burial site like the one at Barnwell, South Carolina, is essentially a large pit into which drums of waste are deposited. Once the initial cost of digging the pit is incurred, the cost of monitoring each additional drum is minimal. Thus, small sites will each have to charge disposal rates much higher than a large site.252 The effect of lower volumes on unit disposal costs is shown in Table 4:

<table>
<thead>
<tr>
<th>Type of Facility</th>
<th>Capacity in thousands of cubic feet per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shallow Land Burial</td>
<td>10 $460  60 $110  150 $50  230 $44  350 $30</td>
</tr>
<tr>
<td>Concrete Containers/Vaults</td>
<td>590  140  80  55  40</td>
</tr>
<tr>
<td>Above grade earth covered</td>
<td>670  160  90  65  50</td>
</tr>
<tr>
<td>Above ground bunker</td>
<td>780  180  105  75  55</td>
</tr>
</tbody>
</table>

Some regions and unaffiliated states might be left with disposal facilities handling too little waste to be economically viable. Massachusetts, for example, annually generates approximately 50,000 cubic feet of waste.254 If the annual revenue requirement for an operating site is twenty million dollars, then Massachusetts would have to charge its gen-

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252. It is generally acknowledged that smaller waste volumes will entail higher disposal costs. See, e.g., OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 146; Thomas P. Hanrahan, Economic Aspects of Compact Progress 6 (1991) (study prepared for U.S. Ecology, Inc., on file with the author).

253. See OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 145.

254. Id. at 152.
erators four hundred dollars per cubic foot of waste stored. This price is almost *seven times* the current cost for disposal, including surcharges. Members of the Rocky Mountain Compact, which generated only 4,000 cubic feet of LLRW in 1989, would have to pay even more.

2. **Site Misplacement**

Another problem with the regionalization of disposal facilities is that sites may not be placed in technically optimal locations. Factors such as geology and population density make some regions of the country inherently more suitable for sites than others. These factors arguably make the approval and maintenance of disposal facilities in many parts of the West both less expensive and less risky than facilities in the East.

3. **Safety Risk Increase Due to Proliferation**

Simply put, the more sites there are, the greater the risk that there will be an accident. For the same total funding, each of three sites can be equipped with more safety features than could each of fifteen sites.

The increased safety risk that would follow from the super proliferation of sites if a state were shut out from existing disposal facilities is even greater. Shut-out will transform each LLRW generator into a sepa-

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256. The current unit cost of disposal is approximately $42 per cubic foot. Office of Technology Assessment, *supra* note 9, at 144-45.

257. *Id.*

258. Many experts argue that locations in the West are simply more suitable for disposal sites than the East. The annual rainfall in Beatty, Nevada, for instance, is only four inches per year and the water table is 300 feet below ground. In most of the Northeast, the annual rainfall ranges from 35 to 45 inches per year and the water table is only tens of feet under the surface. Likewise, the population density of Nevada is seven persons per square mile, whereas the population density of Pennsylvania, another potential host state, is 264 persons per square mile. Bartlett & Steele, *supra* note 250, at 236-37.

259. For example, assume that any one site is 99% likely to be accident-free. With three identical sites, the probability that there will be no accidents is about 97%; with fifteen sites, the probability falls to about 85%.

260. For example, a sprinkler system that will protect 200,000 cubic feet of waste from fire is not much more expensive than a sprinkler that will protect only 50,000 cubic feet. Thus, for the cost to two sites of two sprinkler systems, one larger site can buy one sprinkler plus additional safety equipment.

261. Increasing the number of sites might arguably reduce some of the risk inherent in transporting LLRW across the country. So far, however, transportation of LLRW appears to pose only a negligible risk. Between 1971 and 1985, over 35 million packages of LLRW were shipped in the United States. Of those, 2552 were involved in some form of accident; only 67 packages actually leaked. U.S. Council for Energy Awareness, *Transporting Low-Level Radioactive Waste* 3 (1990). Of the packages that leaked, most resulted in exposures of less than 1 mrem, and none resulted in an exposure of more than 10 mrem. Bernard L. Cohen, *Exaggerating the Risks in BOTH SIDES*, *supra* note 54, at 74-75.
rate storage facility with attendant risks. The safety impact of shut-out would be less in states with fewer and larger LLRW generators.

C. The Failure of Interstate Compacting

1. Fear in Congress

From the outset, the politics of public fear governed the formation of regional compacts for the disposal of LLRW. Even after passage of the LLRWPA provisions mandating the formation of compacts, Congress itself could not initially agree to ratify any of the compacts presented to it. As Representative Udall observed, "[i]t was neither wise nor politically possible to ratify the compacts of the sited regions, leaving the unsited States and regions without disposal capacity." Timothy Peckinpaugh describes the Congressional deadlock that ensued: "Congressmen from Massachusetts, for example, opposed ratification of a compact for the Northwest because that ratification would effectively close the Hanford site to Massachusetts generators of waste. Parochial politics essentially prevented Congress from ratifying compacts before the 1986 exclusionary date." No regional compacts were ratified by Congress until passage of the 1985 LLRWPA Amendments, which authorized seven regional compacts.

262. For example, with 100 sites, each with a 99% annual probability of avoiding an accident, the overall probability of having no accidents is 37%. If, however, we assume that each site has only a 98% chance of avoiding an accident, the annual probability of having no accidents drops to only 13%. This increased risk for waste stored on-site is realistic. For example, if laboratories cannot export vials of scintillation fluid, each laboratory has an increased chance of spillage and fire from the stored vials. NAT'L ACADEMY OF SCIENCES, DISPOSAL OF LOW-LEVEL RADIOACTIVE BIOMEDICAL WASTES 59 (1980).

263. For example, in Texas, nuclear power plants will generate approximately 70% of the LLRW volume by 1993, hospitals and universities 23%, and industry 7%. TEXAS LOW-LEVEL RADIOACTIVE WASTE DISPOSAL AUTHORITY, LOW-LEVEL RADIOACTIVE WASTE DISPOSAL IN TEXAS: TRANSPORTATION AND PACKAGING 1 (1991). Because nuclear power plants are arguably better equipped to handle and dispose of LLRW, the problems associated with super-proliferation and shut-out may have less of an impact in Texas than in Massachusetts.

However, another factor to consider is the radioactivity level of the material to be stored on-site. Most health and research LLRW generators produce almost exclusively Class A waste, which is less radioactive than the Class B or C waste generated by utility users. See MASSACHUSETTS LOW-LEVEL RADIOACTIVE WASTE MANAGEMENT BOARD, 1990 ANNUAL REPORT 10-11 (1991) [hereinafter MASSACHUSETTS 1990] (stating that 35 health and academic generators produced approximately 4500 cubic feet of Class A waste and four cubic feet of Class B waste, for a total of 27 Curies, whereas two utility generators produced 16,485 cubic feet of Class A waste and 1149 cubic feet of Class B waste, for a total of 300 Curies).

265. Peckinpaugh, supra note 199, at 49.
266. Id. at 53.
2. Risk Misperception by the States

Fear of LLRW proved to be stronger in the states than Congress anticipated in 1985. The LLRWPA gave the states free rein to form compacts for LLRW disposal. Under this "free market" approach, states would ostensibly negotiate with one another until the optimal number of disposal sites was achieved.

The viability of this plan, however, required a rational assessment of the risk involved in LLRW storage. Congress did not anticipate that, in fact, no state would be willing to accept waste from another major waste producing state. Many compacts formed in which one major waste producer, whose waste no other state was willing to take, joined with several smaller waste producers to develop a site primarily for the use of the major producer. Many compact agreements contain threshold provisions requiring any members producing more than a specified percentage of waste to host their own disposal site. In the Northeast Compact, both members, Connecticut and New Jersey, must host facilities. The failure of major waste producers to form regional compacts was based on the same two political concerns that motivated the LLRWPA in the first place: the desire for state sovereignty and the demand for interstate parity.

3. State Sovereignty Revisited

Just as states were unwilling to concede authority over LLRW disposal to the federal government, they were also unwilling to concede authority to regional planning boards. One reason the original Northeast Compact floundered was the obsessive concern of states such as Massachusetts with maintaining absolute control over planning decisions.

In 1982, Massachusetts passed legislation requiring state-wide voter approval and certification by the general court before a LLRW site could be constructed in state. The following year, the Massachusetts Special Legislative Commission on LLRW rejected the Northeast Compact document drafted by the Coalition of Northeast Governors (CONEG).

267. See infra note 275.
268. OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 151.
269. As Massachusetts stated in its Administrative Perspective on the Northeast Compact, "no one is thrilled at having an in-state facility and the compact at least lessens the probability of a Massachusetts facility, where going it alone . . . makes likely an in-state facility." MASSACHUSETTS 1985, supra note 15, Related Document 4 at 4.
270. See Nuclear Power and Waste Disposal Voter Approval and Legislative Certification Act, MASS. GEN. L. ch. 164, App. § 3-4(a-b) (1982). This legislation was found to violate the Massachusetts Constitution in an advisory opinion of the Massachusetts Supreme Judicial Court in 1986. Opinion of the Justices to the Senate, 493 N.E.2d 859, 864 (Mass. 1986) ("[A] resolution not rising to the level of a 'law' or a 'constitutional amendment' cannot be submitted to the voters under art. 48 [of the Amendments to the Constitution of Massachusetts].").
The Commission proposed an alternative draft which limited the power of the Regional Commission and provided, among other things, that the host state have an additional member on the Regional Commission and veto power over matters affecting it. The Commission also proposed a siting procedure which would, for all practical purposes, eliminate from consideration any areas within Massachusetts.\textsuperscript{272} As might be expected, the other Northeast states did not accept the Commission’s revised draft, and Massachusetts was left out of the compact that Congress ratified in 1985.\textsuperscript{273}

Resistance to regional control also caused Michigan’s expulsion from the Midwest Compact. After Michigan had been chosen as the site state, friction arose between regional and state planners. State authorities charged the regional board with disregarding state environmental and public health regulations during the siting process and refusing to provide funds for the process.\textsuperscript{274}

4. Interstate Parity Revisited

Another hindrance to compact negotiations was conflict between major and minor producers of waste. States producing small amounts of LLRW were unwilling to provide disposal sites that would primarily benefit out-of-state parties, and large producers were unwilling to concede that they might be the most practical hosts. For instance, of the eleven states party to the Northeast Compact negotiations, Maine, Vermont, New Hampshire, Rhode Island, and Delaware produce only five percent of the region’s waste. They proposed that states generating less than three percent of the waste be exempt from the obligation of hosting a site.\textsuperscript{275} The major producers of waste, however, objected to this suggestion.\textsuperscript{276} Massachusetts was so focused on the idea of parity that it pro-

\textsuperscript{272.} See id., Related Document 5, at 30-31. The host state was to be selected “using the protection of public health, safety, and the environment as the principle considerations,” Id., Related Document 5, at 272-74. The principle criterion for choosing a host state was “institutional control in a manner consistent with protecting the public health and safety and the environment.” Id. at 28. Areas eliminated from consideration would include those “(C) subject to frequent flooding or ponding or which are generally not well drained . . . (H) restricted by a party state because of their critical environmental nature . . . (O) critical to the habitat of endangered or threatened species of plants or animals; (P) of historical or architectural significance.” Id. at 30-31. The Commission re-draft also proposed that “[a]ny party state that . . . believes that its entire land area is unsuitable as a regional facility site shall have the opportunity to present its objections in an adjudicatory proceeding . . .” Id. at 32.

\textsuperscript{273.} OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 45.


\textsuperscript{275.} BARTLETT & STEELE, supra note 250, at 231-34. Other compacts had threshold provisions as well. For example, in the Rocky Mountain Compact, any state producing 20% of the region’s waste must host a site. Thresholds for the Central Midwest and Appalachian compacts are 10% and 25%, respectively. Condon, supra note 151, at 70.

\textsuperscript{276.} BARTLETT & STEELE, supra note 250, at 231-34. The larger LLRW producers are Pennsylvania, Massachusetts, New York, New Jersey, Connecticut, and Maryland. Id. Be-
posed, among other alternatives, that the host state be chosen at random — after states deemed to have no suitable land area were eliminated from the drawing.\textsuperscript{277}

Concern over interstate parity affected negotiations in other regions as well. California was denied admission to both the Northwest and the Rocky Mountain Compacts because of its large waste volume.\textsuperscript{278} Eventually, it formed the Southwest Compact with Arizona, North Dakota, and South Dakota, of which only Arizona generates any sizable amount of waste.\textsuperscript{279}

Illinois, originally part of the Midwest Compact negotiations, seemed to be an ideal host state to the other seven midwest states of the compact. It generated fifty-one percent of the volume and seventy-one percent of the radiation in the region.\textsuperscript{280} Illinois, however, was unwilling to be the host, recalling, perhaps, its defunct Sheffield site.\textsuperscript{281} In 1984, Illinois withdrew from the Midwest Compact to form the Central Midwest Compact with Kentucky, a minor waste producer. Illinois agreed to host the regional site as long as Kentucky produced less than ten percent of the region's waste.\textsuperscript{282}

\section*{D. High Costs of Site Development and Disposal}

\subsection*{1. Increasing Costs}

The cost of building and operating a new facility has far exceeded all predictions and will impart tremendous costs to waste generators.

\subsection*{a. Site Development Costs}

A number of economic studies were conducted in the early 1980's to determine the approximate cost of new LLRW disposal facilities. In these studies development cost estimates generally include the estimated costs of site licensing, land, buildings, security, equipment, and supplies. Operating costs typically include staff salaries and benefits, equipment upkeep and replacement, taxes, insurance, utilities, and legal fees. A summary of these early estimates is presented in Table 5:

\begin{table}
\centering
\begin{tabular}{|c|c|}
\hline
Cause & Cost Estimate \\
\hline
Site Development Costs & \\
Operating Costs & \\
\hline
\end{tabular}
\caption{Summary of Early Estimates}
\end{table}

cause of its inability to join a compact or otherwise plan for its LLRW disposal, New York, with partial success, brought a action seeking to invalidate the LLRWPA Amendments. See supra Part III.B.

\textsuperscript{277} MASSACHUSETTS 1985, supra note 15, Related Document 5, at 34.

\textsuperscript{278} BARTLETT & STEELE, supra note 250, at 221-24. California produced 34,000 Ci. and 194,000 cubic feet of waste in 1982, while the entire Northwest Compact produced only 1100 Ci and 76,000 cubic feet. \textit{Id}.

\textsuperscript{279} OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 152. In 1983, they produced less than 1000 cubic feet of LLRW combined.

\textsuperscript{280} \textit{Id}. at 224-25.

\textsuperscript{281} \textit{Id}. at 225. Illinois' Sheffield LLRW disposal facility was closed in 1978 when it ran out of storage capacity. See RADWASTE, supra note 180, at 146.

\textsuperscript{282} BARTLETT & STEELE, supra note 250, at 227.
Today, as can be seen in Table 6, five planned LLRW disposal facilities have incurred far greater costs before construction has even begun:

### Table 6

**1991 Costs for LLRW Disposal Facilities**

<table>
<thead>
<tr>
<th>Site</th>
<th>Current Pre-Construction Cost</th>
<th>Estimated Total Development Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>$29,406,460</td>
<td>$30,000,000</td>
</tr>
<tr>
<td>Nebraska</td>
<td>31,760,000</td>
<td>75,000,000</td>
</tr>
<tr>
<td>North Carolina</td>
<td>45,785,909</td>
<td>90,000,000</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>29,000,000</td>
<td>55,000,000</td>
</tr>
<tr>
<td>Illinois</td>
<td>75,000,000</td>
<td>n/a</td>
</tr>
</tbody>
</table>

The high cost of building new LLRW disposal sites will be borne in great part by the waste producers. In fact, in most compacts and states, the costs of new LLRW facilities are being assessed against waste generators long before those sites open. New York, for example, planned to collect over forty million dollars from waste producers by 1991 in order to fund its site development process.286

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283. See Massachusetts 1985, supra note 15, at 210-45. The figures are not adjusted for inflation.

284. Hanrahan, supra note 252, at 2. For Illinois data, see Franklin, supra note 234, at 44. The figures in the table are not adjusted for inflation.

285. In Massachusetts, the proposal currently before the legislature would assess waste generators for the cost of running the LLRW board and staff, as well as the cost of construction and operation of the site. The cost of siting, however, would be paid by an issuance of state bonds. Massachusetts 1991, supra note 243, at 17-18.

286. Rick Zuercher, Massachusetts, New Jersey Governors Told LLRW Siting Process In-
b. Disposal Costs

In 1975, the average cost of disposing of one cubic foot of Class A LLRW (the "unit cost") was about one dollar. In 1980, the unit cost had risen to $15; by 1988 the average unit cost was over $42, and it continues to increase today.\textsuperscript{287}

In recent years, the unit cost of disposal has increased for two reasons. First, federal and state regulatory requirements have become increasingly rigorous. This is especially true in the eighty percent of the states and compacts that have banned or restricted use of shallow land burial.\textsuperscript{288} Disposal facilities in these states must now use more expensive disposal technologies. Second, the increasing schedule of surcharges allowed by the LLRWPA has significantly raised disposal rates.\textsuperscript{289} In 1992, the surcharge rose to $40 per cubic foot, which will have a significant impact on disposal costs.\textsuperscript{290}

Disposal unit costs will continue to increase due to site proliferation and declining waste volumes. The sevenfold increase in unit charges for Massachusetts' waste disposal is but one example of what to expect.\textsuperscript{291}

2. The Impact of Risk Misperception on Costs

Political and social resistance to LLRW facility siting did not end with the formation of regional compacts. The lines of resistance, however, shifted from state borders to boundaries of counties and municipalities, as residents of potential host communities opposed the placement of facilities nearby. As a result of direct public resistance to siting and indirect resistance in the form of excessive regulation of the siting process, the costs of facility siting continue to increase.

Citizen opposition to the siting process can be very expensive. Even after siting decisions have been painstakingly made, lawsuits can delay facility construction, increase legal expenses, and even block siting altogether. A recent example is found in County of El Paso v. The Texas Low-Level Radioactive Waste Disposal Authority.\textsuperscript{292} The case concerned a Texas administrative agency decision to place a disposal facility in Hudspeth County, Texas, an arid, sparsely populated region of West Texas. The decision was challenged by citizens in neighboring El Paso.

\textit{sufficient, NUCLEONICS WEEK, Jan 31, 1991, at 4.}
\textsuperscript{287} Office of Technology Assessment, \textit{supra} note 9, at 144-45.
\textsuperscript{288} See id. at 135-36.
\textsuperscript{289} See \textit{supra} note 169 for a summary of surcharges authorized under the LLRWPA Amendments of 1985.
\textsuperscript{290} \textit{Id.}
\textsuperscript{291} See \textit{infra} Sec. IV.B.1.
\textsuperscript{292} County of El Paso v. Texas Low-Level Radioactive Waste Disposal Authority, No. 2588-34 (D. Tex. - Hudspeth County Jan. 29, 1991), rev. and rem. 740 S.W.2d 7 (TX App.- El Paso 1987, writ dismissed w.o.j.) (per curiam). (Ed. note, per the author's request, this citation is in official Texas citation format.)
county. District Judge William Moody colorfully described the ensuing lawsuit as a war:

Both sides have fired numerous salvos, spent millions of dollars, hired countless experts, filed thousands of exhibits, churned out paperwork which must be in excess of 100,000 pieces of paper, taken up over several months of court time and left the poor trial judge weary and in need of a pair of reading glasses.

Nonetheless, Judge Moody ruled against the siting decision, justifying his holding on seismic, hydrological, and aesthetic grounds:

Of less human concern but of historical and archaeological concern are the extremely beautiful and fragile rock art that lies on and in very close proximity to the site. . . . Again and again the echoing question of why here, rang through my ears as I stood atop the Diable Rim looking into that beautiful West Texas sunset. Clearly any proud Texan if they stood there would be moved to say, “this is not the proper place, this is unjust”; the splendor of this land and these people should not be risked merely because the time to choose a site is running short or the Authority has already spent millions to qualify this site.

State legislatures, responding to public pressure, have implemented tremendously complicated mechanisms for site study and selection adding costs and delaying siting. Potential host states require independent environmental characterization studies, all of which must be conducted by outside contractors. Requirements of citizen participation at all levels of the siting process similarly increase the administrative burden and generate higher costs. As one Massachusetts official boasts: “The Northeast political process is deliberative, open, and participatory. It is not surprising therefore, that the Northeast Compact is the longest, most complex, and the latest of all the regional compacts to be drafted.”

293. Id. at 4.
294. Id. at 5-6 (emphasis added). Shortly after this decision, the Texas Legislature acted to approve the Authority’s site. Texas Low-Level Radioactive Waste Disposal Act (codified at TEXAS HEALTH & SAFETY CODE § 402.0921 (West 1991)).
295. For example, a draft of the Massachusetts regulations governing the selection of a LLRW site operator was 22 pages long, the result of five meetings of an “Operator Selection Criteria Committee” between January and June of 1990. MASSACHUSETTS 1990, supra note 263, app. A.
296. Id.
297. MASSACHUSETTS 1985, supra note 15, Related Document 4, at 2. See BARTLETT & STEELE, supra note 250, at 235. Cf. Senate Hearings, July 19, 1979, supra note 202, at 372 (testimony of Steven V. Sklar) (“If you gave States absolute authority to say yes or no, it would be unlikely for a state to say yes . . . . It would be extremely difficult to have State voters at a general election say they would prefer to have their state for [sic] a site within it become the dumping ground for the nuclear garbage of the region.”).
E. BRC Waste, a Microcosm of LLRW Regulation

A good example of the consequences of risk misperception in the area of LLRW disposal can be found in the NRC's recent effort to classify certain waste as "below regulatory concern" ("BRC") pursuant to the 1985 LLRWPA Amendments. In its Policy Statement of July 3, 1990, the NRC announced that it would allow radioactive materials users to apply for deregulation of activities which produced an average individual radiation dose to the public of less than ten mrem per year. Deregulated waste could be disposed of as ordinary garbage in landfills or through incineration.

NRC received two petitions for deregulation review: one for biomedical institutions and the other for the nuclear power industry. The first petition proposed on-site incineration of solid biomedical waste. The estimated exposures from this process were 0.55 mrem per year to maximally exposed individuals and 0.0034 mrem per year to workers. Delegation would have reduced the volume of medical LLRW by ninety percent. The exemption requested by the nuclear industry would have reduced the volume of utility LLRW by an estimated thirty to forty percent, and would have saved the industry between fifty and seventy-five million dollars per year.

The BRC policy announcement sparked protest at all levels. Environmental groups responded with ominous pamphlets, alarming statistics, and public demonstrations. Public Citizen sued the NRC to

298. 42 U.S.C. § 2021j (1988). ("The Commission shall establish standards and procedures . . . for considering and acting upon petitions to exempt specific radioactive waste streams from regulation by the Commission due to the presence of radionuclides in such waste streams in sufficiently low concentrations or quantities as to be below regulatory concern."). Id. § 2021j(a).

299. See NRC BRC, supra note 53, at 8. The NRC had previously published guidelines for petitioning for exemption in 51 Fed. Reg. 30,839 (1986), and in December, 1988, released its draft advance notice of the development of a Commission policy on exemption from regulatory control practices whose public health and safety impacts are below regulatory concern.

300. GERSHEY ET AL., supra note 15, at 32.

301. Id.

302. OFFICE OF TECHNOLOGY ASSESSMENT, supra note 9, at 104.


304. See, e.g., MASSACHUSETTS CITIZENS FOR SAFE ENERGY, LETHAL LANDFILLS: HOW RADIOACTIVE WASTE COULD END UP IN YOUR COMMUNITY'S LANDFILL (1990); RADIOACTIVE WASTE Headed for Everyone's Backyard, MCSE SPECIAL REPORT — RADIOACTIVE WASTE MANAGEMENT IN MASSACHUSETTS (supplement to MCSE's newsletter, SAFE ENERGY REPORT, Boston, Mass.), Spring 1990-91, at 1 [hereinafter MCSE SPECIAL REPORT].

305. A Massachusetts Citizens for Safe Energy newsletter printed a table entitled "What is safe?" which showed 6000 deaths resulting from the NRC's BRC policy. Only in a footnote did it mention that this figure was derived by hypothesizing that every person in Massachusetts would be exposed to the maximum level of annual radiation from all BRC waste streams, a highly unlikely situation. MCSE SPECIAL REPORT, supra note 304, at 3. Another organization, Public Citizen, projected that the policy would result in 12,412 additional cancer deaths per year, but did not provide a basis for this startling figure. See 21 [Current Developments]
enjoin implementation of the BRC policy.307 Local governments passed ordinances barring the disposal of radioactive substances in local landfills. In Massachusetts alone, over forty municipalities voted to oppose the BRC policy by the beginning of 1991.308 State governments also responded with new legislative proposals that would effectively nullify the NRC policy.309

The flurry of anti-BRC activism caused many potential applicants for regulatory exemption to reconsider. Said one nuclear power representative, "[e]ven if the BRC proposal eventually passes, Yankee [Atomic Electric Co.] has no plans to take advantage of it in light of the public relations drawbacks."310 On February 26, 1991, the NRC announced it would defer action on BRC petitions until it could reach a more general consensus on the policy,311 and sought a moratorium on its BRC program that May.312 The target date for reaching a new consensus is December, 1992.313

Thus, the same fundamental fears and political concerns that shaped the LLRWPA and hampered the formation of regional LLRW compacts have also halted the NRC's latest attempt to establish a "consistent risk-based framework" for the regulation of LLRW.314 The BRC episode reiterates the lesson that regulatory decisions concerning radioactive waste cannot be made solely on the basis of "technically" or "economically" rational assessments. As Section V will discuss, the problem of LLRW disposal must be addressed as a political, as well as a technological, problem.


306. At one recent NRC hearing on the BRC issue, protesters lay on the floor to represent BRC "casualties" and displayed a banner proclaiming "BRC IS MURDER." Interview with Janis Stelluto, Director of the New England Consortium of Radioactive Materials Users (NELRAD), (Mar. 12, 1991).

307. Public Citizen, Inc. v. NRC, 940 F.2d 679 (D.C. Cir. 1991) (holding that the policy statement was not ripe for review because a moratorium was placed on implementation of BRC policy).


313. See Public Citizen, 940 F.2d at 685.

314. NRC BRC, supra note 53, at 3.
TOWARD A COMPREHENSIVELY RATIONAL SOLUTION

The problems surrounding LLRW disposal facility siting are gaining importance as states without disposal capabilities approach the deadline for shut-out from existing facilities. As hospitals and laboratories face the prospect of sharply curtailing their LLRW generating activities, Congress may again be forced to address the situation and consider LLRW disposal options. This section presents a "comprehensively rational" proposal for siting LLRW facilities once the time for decision arrives.

A. Political Issues and Rationality

The debate over LLRW facility siting is often conducted in the rhetoric of rationality and irrationality. Proponents of nuclear power and industries generating LLRW often view citizen opposition to LLRW facility siting as irrational. They generally propose that siting decisions be based on scientific assessments of risk. These groups often criticize the American political system's susceptibility to "irrational" popular fear and conclude that the statutory and political structure governing LLRW is, itself, imperfect and irrational.

315. A perceived crisis led to the passage of both the 1980 LLRWPA and its 1985 Amendments. See 131 CONG. REC. 35,210 (1985) (statement of Rep. Campbell (SC)) ("[E]ither we enact H.R. 1083 and place radioactive waste disposal under uniform, comprehensive disposal compacts; or, we again face a crisis that would threaten, and affect, every segment of our society."); 131 CONG. REC. 38,408 (1985) (statement of Sen. Hollings (SC)) ("To avoid a major crisis over low-level radioactive wastes, we must act now.").

316. See, e.g., MICHAEL O'HARE, ET AL., FACILITY SITING AND PUBLIC OPPOSITION 27 (1983) (dubbing this reliance on scientific expertise in siting decisions the "engineer's fallacy"). Professor Eisenbud, a leading authority on environmental radiation, concludes his article on misperception of LLRW's risk with the exhortation that "scientists, physicians, and public health workers... [should] take the time to study the facts and speak out about the need for rationality." Eisenbud, supra note 66, at 80. Cf. JOHN D. GRAHAM ET. AL., IN SEARCH OF SAFETY: CHEMICALS AND CANCER RISK 217-18 (1988), criticizing the view that scientific understanding alone should govern policy in the area of carcinogen regulation.

317. See Lutzker, supra note 2, at 181-82. Dr. Lutzker laments the fact that "[i]n a democracy, it is right and proper that public officials, elected or appointed, be responsive to the expressed concerns of the citizenry. As long as there are citizens who express unreasonable and inconsistent fears, there will be politicians who will respond to those fears and even exploit them." Id.

318. See Peckinpaugh, supra note 199, at 56 ("It is seemingly impossible to draft perfect
The mere presentation of scientific evidence and arguments, however, has neither succeeded in alleviating public fear of radioactive waste, nor achieved a workable regulatory or statutory structure for the governance of LLRW disposal. As one group of observers notes, "federal radioactive waste management continues its preoccupation with technical problems and technical solutions. The Department of Energy has yet to initiate a broad-based research program on social and institutional problems . . . ." Many scientists forget that the American political system, as it was intended to operate, reflects the sentiments of the public, whether or not they correctly weigh the actual risks. Thus, Congress' consideration of public fear, state sovereignty, and interstate parity issues in the LLRWPA debate indicates that the political system operated properly.

Some commentators, however, view LLRW regulation exclusively as a political matter best resolved by citizen participation and legislative compromise, regardless of technical considerations. Yet basing complex technical decisions solely on the opinions of the majority may not lead to a socially desirable result in cases where the majority is uninformed.

Rationality may be in the eye of the beholder. In his well-known work, *Reason in Society*, Paul Diesing describes five forms of rationality that guide human and institutional decision making: technical, economic, social, legal, and political. Diesing contends that decisions in certain legislative remedies in the highly emotional and political environment that dominates nuclear waste issues.

319. Many have argued that the way to correct the public misperception of risk is to educate the public about the actual risks involved with LLRW. See, e.g., *Ronnie Lipschutz, Radioactive Waste: Politics, Technology, and Risk* 174 (1980) ("[A] waste management program that maximizes public education and involvement can and will minimize public objections to the goals of the program thus greatly enhancing the program's chances of success.").


321. This view is characterized in *Graham, et al.*, supra note 316, 217-18 (1988) ("[P]olitics is and should be the master of influences on regulatory decisions. . . . [S]cience and scientists. . . . are merely ammunition in a larger political struggle. . . ."). Ackerman and Stewart also argue that the formulation of environmental policies should be given to legislative processes, not cost-calculating agencies. They refer to it as "the quintessentially political question that should be answered by the legislative process." Bruce A. Ackerman & Richard B. Stewart, *Reforming Environmental Law*, 37 STAN. L. REV. 1333, 1352-53 (1985) (emphasis in original). O'Hare dubs this polar viewpoint the "planner's fallacy." O'HARE ET AL., supra note 316, at 28.

322. *Paul Diesing, Reason in Society* 2 (1962). He defines technical rationality as the
spheres of activity may be rational, even if they are not technically or economically optimal, and that technical and economic rationality are merely two forms of rational thought in a wider range of interactions.\textsuperscript{323} Thus, politically motivated decisions made in a political context are just as rational as technical decisions made in a technical context.

The complex LLRW disposal problem extends directly to the technical, economic, and political spheres. It encompasses questions of the safest and most efficient means of LLRW storage; cost distribution among waste generators, facility operators, and the public; and reconciliation of public fears with the necessity for disposal facilities. A true solution to the problem of LLRW disposal must concurrently satisfy the demands of technical, economic, and political rationality to be comprehensively rational.\textsuperscript{324}

The political reality of public risk misperception must be taken into account in solving the LLRW disposal problem. Fischhoff, et al. recognize the prudence of involving the public in technical decision making:

Even if the experts were much better judges of risk than lay people, giving experts an exclusive franchise for hazard management would mean substituting short-term efficiency for the long-term effort needed to create an informed citizenry.

From a political standpoint, exclusion may breed anger as well as ignorance. Citizens in a democratic society will eventually interfere with decisions in which they do not feel represented. . . . [E]arly public involvement may lead to decisions that take longer to make, but require less time to implement and are more likely to stick.\textsuperscript{325}

\textbf{B. The Difficulty of Siting a LLRW Disposal Facility}

1. \textit{NIMBY} and \textit{LULU}'s

LLRW disposal facilities are similar in many ways to other "locally undesirable land uses" ("LULU's") such as airports, prisons, sewage treatment plants, landfills, and even FBI offices.\textsuperscript{326} Siting any of these facilities is difficult because the communities nearest the sites bear a bur-

\textsuperscript{323} See also \textit{Diesing}, supra note 1, at 1.

\textsuperscript{324} Such an approach is recommended by \textit{Lipschutz}, supra note 319, at 168-74. See also \textit{Graham}, et al., supra note 316, at 218 (stating that scientists must give their best estimates to policy makers while recognizing that policy decisions also incorporate non-technical considerations).

\textsuperscript{325} \textit{Acceptable Risk}, supra note 81, at 148.

\textsuperscript{326} For a discussion of siting difficulties, see \textit{Science, Politics, and Fear}, supra note 2, at 293-94.
den disproportionate to the benefits they receive. They often respond with the so-called “not-in-my-backyard” (NIMBY) syndrome. The siting of radioactive waste facilities is particularly difficult because of the unique burden the host community perceives from living near radioactive waste.\(^{327}\) Moreover, in the radioactive waste context, even defining the appropriate “backyard” is difficult. The “backyard” might be the area in the immediate proximity of the disposal facility, the county in which it is located, the surrounding counties, or the watershed or aquifer.\(^{328}\) As Kates and Braine realize, “the final backyard is still unknown.”\(^{329}\)

2. The Need for Compensation

An unwilling community will not be persuaded to accept a facility merely because a cost-benefit analysis demonstrates that the benefits of LLRW-generating activities usually outweigh the costs of LLRW storage.\(^{330}\) The host community, however, should be compensated for the externalities it is forced to bear.\(^{331}\)

a. Compensation is Possible

Though fear of radiation is strong, it is not so strong that financial compensation has not persuaded communities to host LLRW sites.\(^{332}\)

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\(^{327}\) See House Hearing, June 29, 1979, supra note 318, at 42 (statement of Michael O'Hare) (suggesting that there are two problems with siting a nuclear waste facility: (1) there are many beneficiaries who receive a small benefit compared with a few sufferers who absorb a large cost; and (2) it is scary).


\(^{329}\) Id. Ironically, it is often the wider state population, not the host community, that most strongly opposes the siting of a radioactive waste facility. For example, in 1984, 80% of the residents of Edgemont, South Dakota, voted to host a new LLRW disposal facility. The proposal was subsequently defeated in a state-wide referendum. Bord, supra note 124, at 198. Similarly, the local leaders of San Juan County, Utah during a period of widespread unemployment and closure of local industries strongly supported a 1982 ERDA proposal to site the Federal Waste Isolation Pilot Plant (“WIPP”) in the nearby Paradox Basin. Opposition to the site came from other Utah residents who objected to the pollution of the Basin's red rock canyons, as Luther Carter terms it, their “recreational backyard.” CARTER, supra note 69, at 151-53. See also id. at 165-67 (Hanford, Washington), 175-76 (Yucca Mountain, Nevada); Slocvic & Fischhoff, supra note 134, at 126-27 (stating that in 1969, ninety-five percent of the residents of Hermiston, Oregon favored an Army nerve gas storage facility which ninety percent of the citizens of Oregon as a whole opposed.).


\(^{331}\) Some commentators still feel that no compensation will be adequate. See, e.g., Bord,
Examples are found in the communities that have already permitted the construction of LLRW facilities, not to mention HLW repositories and other LULU's. Though no direct monetary compensation has been awarded to many of these communities, the benefits of employment and economic growth have often been sufficient to overcome their "nuclear fear."

b. Equity Considerations

Compensation for the prospective neighbors of a LLRW facility or any LULU must address equity, as well as economic, concerns. This view has been expressed by numerous commentators and was recently adopted by the NRC in its most recent BRC policy statement. Two broad equity areas important to the radioactive waste siting discussion are "the locus problem," and "the legacy problem."

Of these, the "locus," or distributional problem, has attracted the most attention. Although the benefits of LULU's are typically distributed throughout a state or region, many of the costs directly associated with the LULU are borne by the community hosting it. In many in-

supra note 124, at 203 ("It is unlikely that the provision of material incentives will go very far in diminishing public intransigence in the face of LLRW sites.").

333. One book describes the public sentiment near Hanford, Washington, site of a major plutonium works and the Richland LLRW disposal facility: "Hanford is a world unto itself, fiercely proud of its role in atomic development. Nearby Pasco boasts a grocery store called Atomic Foods. The sports teams at neighboring Richland High School are called the Bombers. The school's symbol is a mushroom cloud." BARTLETT & STEELE, supra note 250, at 253.

334. These costs are mitigated to varying degrees by the economic benefits of a nearby site, especially increased employment, local tax revenue, and local purchasing by the facility. For example, the Barnwell, South Carolina, LLRW disposal facility employs 210 local residents; has a payroll of approximately $3,000,000; pays local taxes, license fees, and fringe benefits amounting to $1,350,000; and spends another $6,000,000 per year on local purchases of supplies and equipment. CHEM-NUCLEAR SYSTEMS, INC., CHEM-NUCLEAR AND BARNWELL 7 (informational pamphlet).

The West Valley, New York, facility produced some local benefits in the form of modest tax gains and income for the host community, although not to the extent expected. A "boom-town" never arose. Locus, Equity & West Valley, supra note 328, at 103-05. See also NAS SOCIAL AND ECONOMIC, supra note 108, at 89 ("A recent review of socioeconomic impacts at 12 nuclear power stations, however, found few economic benefits to localities." (citation omitted)).

335. See Public Citizen, Inc. v. United States, 940 F.2d 679, 681 (D.C. Cir. 1991) (holding that the BRC rulemaking requires "social justification" and must make exposure as low as reasonably achievable).


337. Seley and Wolpert have identified eight locational impacts associated with noxious facilities: property effects, health and environmental effects, social changes, economic effects, traffic effects, public service and fiscal structure effects, and location transfer costs for displaced persons. John E. Seley & Julian Wolpert, Equity and Location, in EQUITY ISSUES, supra note 78, at 70-80. Of these, health and environmental effects are the most prevalent in the LLRW discussion. Id.
stances the political process locates noxious facilities in communities with low wealth but high population. This result should be avoided.

Of particular importance to the LLRW siting question is the equity issue of "legacy:" imposing costs and risks on future generations. Should compensation be paid to unborn residents of a host community? How are benefits and costs to be estimated for future generations? One commentator suggests that trusts may be used to bestow compensation on future generations.

c. An Appropriate Level of Compensation

Though compensation of local communities is clearly necessary for the siting of new LLRW disposal facilities, it is unclear how much compensation should be required. A compensation program has been developed in Spain, under which the towns surrounding the El Cabril LLRW facility will split an initial payment of $820,000 and continuing payments of $836 per cubic meter of waste. The current Massachusetts LLRW statute provides a schedule of compensation payments for the host and neighboring communities ranging from $60,000 to $400,000 in the first year plus four percent of the facility’s annual gross operating receipts thereafter for host communities and one percent of the receipts for neighboring communities. In New York, the state “benefits package” offered to a community willing to host its LLRW disposal facility is approximately $4.2 million.

In Texas, the legislature implemented a series of “impact assistance” measures to compensate the host county. These provisions direct that, when practicable, all “supplies, equipment, . . . material” and personnel necessary to construct the site will be obtained from the site county.

338. Id. at 85-87.
342. MASS. GEN. LAWS ANN. ch. 111H, § 33(a)(3)-(4) (West Supp. 1992). However § 33(a)(2) gives the Massachusetts LLRW Board authority to grant extra compensation in the event of increased infrastructure costs. “The board shall abide by any additional covenants undertaken for the benefit of site, affected or neighboring communities which it deems necessary and appropriate.” Id. § (a)(2).
343. See Mayerat v. Town Board of Ashford, 575 N.Y.S.2d 765, 766 (N.Y. Sup. Ct. 1991) (annulling a town board resolution accepting an unpopular LLRW facility on the grounds that the town board failed to prepare an environmental impact study as required by New York state law).
344. TEX. REV. CIV. STAT. ANN. art. 4590f-1, § 3.11 (West 1987) (repealed 1989). The Authority estimates that approximately two million dollars in goods and services will be required annually. Additionally, it estimates that one hundred workers will be needed during construction. TEXAS LOW-LEVEL RADIOACTIVE WASTE DISPOSAL AUTHORITY, BRIEFING SUMMARY (1991) [hereinafter TLLRWDA SOCIOECONOMIC IMPACTS].
During the operation of the facility, the site county will also receive 10% of all disposal fees.\textsuperscript{345} It remains to be seen what level of compensation is adequate.\textsuperscript{346}

d. An Economic Basis for Compensation

In discussing the appropriate level of compensation for hosting a LLRW disposal facility, the economic models in Figures 1 and 2 are helpful.

i. The Standard Precaution Model

The model in Figure 1 illustrates the relationship between the marginal cost to generators of safety precautions for protecting the surrounding community from LLRW radiation (MC) and the marginal benefit (in dollar equivalents) to the community of those increased safety precautions (MB).\textsuperscript{347} At the lower limits, inexpensive precautions such as storing waste in drums yield a high benefit; while at the upper limits, expensive measures such as exhaustive hydrological and ecological surveys yield relatively few real benefits to the community. The intersection of MC and MB corresponds to a level of precaution (q\textsubscript{equiv}) at which the cost of precautions is equal to the benefit conferred by them. The area under MC (A) is the cost to generators of providing q precautions; the area under MB (B) is the externality cost (in dollar equivalents) to the community from a facility with q precautions.\textsuperscript{348} Thus, unregulated producers will attempt to shift q to the left in order to minimize A, while the community will try to shift q to the right in order to minimize B. Shifting q away from q\textsubscript{equiv} however, creates an extra cost (C) which must be borne either by the producers or the community. This extra cost is inefficient and should be avoided.

ii. The Model with Risk Misperception and Compensation

If the community receives compensation for B they have no incentive to minimize B. Regardless of the value of q, the public will incur no

\textsuperscript{345} Tex. Rev. Civ. Stat. art. 4590f-1, \S\ 4.02(d) (West 1987) (repealed 1989). The Authority estimates that this figure will be between $1,000,000 and $1,300,000 annually. TL-LRWDA SOCIOECONOMIC IMPACTS, supra note 344.


\textsuperscript{347} See Tietenberg, supra note 331, at 160-62. See also Crouch & Wilson, supra note 77, at 95-97 (discussing individuals' willingness to accept compensation in return for increased risk).

\textsuperscript{348} The externalities borne by the community includes health risks from radiation exposure as well as economic dislocation resulting from the presence of a nearby LULU. See NAS Social and Economic, supra note 108, at 88-107 (describing various social and economic effects of radioactive waste depositories on nearby communities, such as property devaluation and increased costs of goods).
direct economic cost. In this case, the provider of compensation bears the extra cost (C).

With risk misperception, the Community overestimates the danger of the activity in comparison with other risky activities. Thus, it demands a level of safety, $q'$, from generators above the efficient value $q_{\text{equil}}$ and imagines that it must be paid $B + D$ in order to be efficiently compensated for the externality. This explains why the technically correct amount of risk compensation ($B$) will not persuade a community to host...
a LLRW site and why communities demand a level of precaution from LLRW sites well beyond what is efficient.

3. The Interests to be Balanced

Any siting strategy for a LLRW disposal facility must take into account the following concerns:

(a) Perceived Risk: Whether based on accurate risk assessments or not, public fear of radioactive waste exists and must be accommodated in any siting strategy.

(b) State Sovereignty: Due to the perceived risk of LLRW storage and past federal failures in the area of radioactive waste facility siting, states have demanded control over many of the critical aspects of LLRW management.

(c) Interstate Parity: Due to the perceived risk of LLRW storage, no state is willing altruistically to accept waste from other states, especially if those other states have not been doing their “fair share” to develop their own disposal facilities.

(d) Social Utility: The cost of LLRW management must not become so prohibitive that it causes a decrease in the beneficial uses of radiation.

(e) Efficiency: The unnecessary proliferation of LLRW sites should be discouraged, and LLRW generators should not be forced to store waste on their premises.

C. A Proposal

This section presents the outline of a proposal for LLRW facility siting that takes into account the political, social, and technical concerns discussed above. It will result in a structure for LLRW disposal that is more federally regulated than the present structure, but not so nationalized that the federal government takes primary responsibility for LLRW away from the states.

1. Preventing Shutout

The first prong of the proposal is for Congress to ensure that no LLRW generators are prevented from safely and economically disposing of their LLRW. There are several ways this result may be achieved:

(a) Congress may amend the LLRWPA Amendments to extend the date for milestone compliance beyond 1993. This option would be reminiscent of the 1985 Amendments to the LLRWPA, in which Congress extended the shutout deadline by seven years in return for ratifying the sited states’ regional compact agreements. Today, however, the sited states have no incentive to keep their doors open, and Congress has no bargaining chip comparable to the one it had in 1985. Thus, it seems
unlikely that the sited states would voluntarily abandon their demand for interstate parity despite a Congressional plea for a time extension.

(b) Alternatively, the NRC may seek to preserve access to existing sites under the Emergency Access provisions of the LLRWPA Amendments.\footnote{349} These provisions permit the NRC to grant emergency access to a disposal facility “if necessary to eliminate an immediate and serious threat to the public health and safety or the common defense and security.”\footnote{350} However, the Amendments also provide that in order for the emergency access to be “necessary,” it must not be possible to mitigate the threat by other means such as on-site storage, the purchase of disposal capacity, discontinuation of waste-generating activities, or storage at a consenting facility.\footnote{351}

Though it is possible that the NRC could force existing sites to accept extra-regional LLRW after the 1993 deadline under the emergency provisions, such action would hardly be politic. The sited states might view it as an unwarranted federal derogation of their sovereignty.

(c) Congress may permit LLRW generators that are shut-out from commercial disposal facilities to temporarily store LLRW at federal sites until other facilities become available. This solution would satisfy the political concerns of both sited and non-sited states, presuming that federal sites had enough capacity to handle the volume of waste required.

2. Limitation of LLRW Disposal Licenses

To avoid the inefficient proliferation of LLRW sites, the NRC should restrict the number of licenses it issues for new LLRW disposal facilities. At present, several new LLRW facilities are planned or under construction pursuant to the provisions of the LLRWPA Amendments. To protect these developing sites from being deprived of their expected licenses, the NRC should establish a fixed transition period in which it would grant a license to any site which has made minimal progress toward construction of a new facility. After this transition period, however, the NRC should grant new licenses only in anticipation of new LLRW disposal capacity requirements.

3. Siting Auction

When the NRC determines that a new LLRW disposal facility is or will soon be required, it should conduct a national or regional siting auction to identify the location for the new facility. Bids would be submitted by individual municipalities or counties and would represent the amount of compensation the bidder would accept in return for hosting the pro-

\footnote{350} Id. § 2021f(a).
\footnote{351} Id. § 2021f(c)(1)(A)-(B).
posed site. The theory of the auction is that the community least opposed to the new facility should host it.\textsuperscript{352}

A community's bid would comprise the one-time payment that would persuade it to accept a generic LLRW facility, \textit{independent of its construction costs}.\textsuperscript{353} This amount is called the community's "acceptance cost," and represents the sum $B + D$ in Figure 2. $B$ represents the community's compensation for any health externality it would actually suffer from the facility; $D$ represents an additional amount of compensation for perceived externalities.\textsuperscript{354} These bids may be extremely high given the level of risk misperception regarding LLRW in the United States. However, the key to successfully siting a LLRW facility is to work \textit{with} rather than \textit{against} this risk misperception. The question of how much to compensate communities must be answered by the communities themselves; no community will be willing to host a facility unless it sets its own level of compensation.\textsuperscript{355}

4. \textit{Commission Analysis}

Once the NRC receives bids from all of the communities willing to host a facility, it should create a pool of "finalists" comprising the five or ten lowest bidders. It should then estimate the cost of constructing a LLRW facility having a predetermined level of safety ($q$) at each of the finalist sites. These costs might differ greatly. For example, to achieve a collective population dosage of no more than 30 rem per year, a site in the arid, sparsely populated regions of Nevada might require fewer safety expenditures than one in the humid marshes near New Orleans. The Commission should add the bids to the estimated construction costs to arrive at an overall cost for each site. The site with the lowest overall cost should become the "preferred site."\textsuperscript{356} This manner of siting a new facility would place the facility in the most efficient location, taking into account both the costs of construction and the public risk misperception in potential host communities.

\textsuperscript{352} The participatory nature of the auction process makes the risk assumed by the host community seem less "involuntary," and thus less objectionable, than siting decreed by a regulatory agency. \textit{See supra} notes 138-41 and notes 207-09.

\textsuperscript{353} A one-time payment rather than a series of continuing payments is proposed because the host community's greatest objection comes in accepting a site in the first place, not in accepting additional waste each year after it is constructed.

\textsuperscript{354} It is assumed that a community's bid would represent the sum of payments which would have to be made to \textit{individual residents} of the community in order to accept the site.

\textsuperscript{355} \textit{See} Herbert Inhaber, \textit{supra} note 330, at 19. Inhaber suggests a "reverse Dutch auction" for the siting of LLRW facilities. Under this system, the government would make a series of increasing offers to potential host communities; the first community to accept the offer would become the host.

\textsuperscript{356} Alternatively, the Commission may choose one of the other low bidders if it believes that the equities do not favor the site with the lowest cost. For example, the Commission might determine that a very low bid from a community experiencing an acute period of unemployment might not accurately represent the community's costs.
The NRC should grant a LLRW disposal license only to a contractor willing to construct a facility at the preferred site for close to the estimated overall cost.

5. *Who Should Pay?*

The cost of constructing new LLRW facilities should be borne by waste generators. The present system allows site operators to recover their construction costs through disposal charges to generators. When waste generators pay for construction of disposal facilities, they generally recover their costs by passing them along to their customers. Thus, the ultimate consumers of LLRW disposal services pay for the construction and operation of LLRW disposal facilities. This charge is part of the price associated with the benefit from the waste-generating activity: power, medical treatment, or research. Thus, it is fair that the consumer should pay for that benefit.

The "acceptance cost" required to persuade a host community to accept the facility, however, should not be borne by the consumer. This cost is a result of societal misperception of the risk from hosting a LLRW disposal facility. The host community is compensated for both its actual harm and its perceived harm. The real beneficiaries are the residents of communities not hosting a LLRW facility. They benefit from the absence of the LULU in their town, yet pay nothing for this benefit. Thus, they should bear the "acceptance cost" of the host community.

There are several acceptable ways to allocate the acceptance cost among non-sited communities while respecting the spirit of the regional disposal system envisioned by the LLRWPA. For example, states in non-sited regions and non-sited go-it-alone states could raise this money through a small tax. When spread over the number of non-sited states, the actual cost per state would be relatively small. For example, an acceptance cost of one hundred million dollars split among, say, forty-five non-sited states would yield an average cost per state of slightly over two million dollars. The portion of the acceptance cost that each state would be responsible for could be based on land area, population, or volume of waste generated.

The most important aspect of this allocation of responsibility is maintenance of interstate parity in LLRW disposal. As long as non-sited states are relieved of the burden of the acceptance cost of LLRW facilities, sited states will feel imposed upon. With the proposed responsibility-sharing, sited states would know that non-sited states were bearing their fair share of the LLRW burden. As the events of the past decade have revealed, this political gesture is far more important than any technical consideration.
CONCLUSION

This comment proposes an approach to LLRW disposal facility siting. In doing so, it seeks to address the major issues that led to passage of the 1980 LLRWPA and its 1985 Amendments, namely, public fear of radiation, the desire for state sovereignty over disposal matters, and the desire for interstate parity. At root, each of these concerns is founded in a public misperception of the small risk involved in LLRW disposal. This misperception, however, is so widespread that it cannot be ignored. Technical and political truth often diverge, and as Congressman Markey has noted, "perception is reality." A community cannot be forced to accept unwanted waste. The decision to host a LLRW disposal facility must come from within the community — from, as Albert Einstein termed it, "the village square." Any solution to the LLRW problem must be acceptable in political as well as technical and economic terms. With an auction-based approach to LLRW facility siting, this comment seeks to provide one such comprehensively rational solution.
