Nuclear Waste Facility Siting and Local Opposition

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Introduction

On the historic evidence, but also for the distinctive qualities of the challenge, nuclear waste siting conflicts are assuredly among the most refractory in the large variety of NIMBY (Not In My Back Yard) facility siting disputes. Since the president brought the Yucca Mountain process to a halt in 2010 (or, more accurately, issued its death certificate), the search for a permanent waste fuel repository is at the starting line again. However, over the years since that search began the first time, much has been learned about the NIMBY phenomenon and its political and administrative management, both from experience in the US and abroad and through continued scholarship in the academic community. The present essay collects the most important findings from this research and some implications from history, and offers recommendations for a framework in which to resolve the nuclear waste disposal challenge.

The focus here is on policy looking forward, not post-mortem dissection of the convoluted past efforts, and not on disposal (or transport) technology. Except to the degree that responsibly characterized sites with carefully engineered placement and packaging differ in their appearance to members of the public, I will not advance the debate over technical choices or geological options.

Although disposal of low-level radioactive waste remains a problem, with only four operating facilities and restricted access to these (GAO 2004; Society 2009), and will become more pressing as existing power plants are decommissioned, the salient challenge at present is the 170,000-odd fuel assemblies, nearly all stored at operating reactor sites, and the additional spent fuel currently accumulating at about 8000 per year (EIA 2002) that will be generated if the nuclear power industry continues (let alone increases) its contribution to US electricity generation. The national government promised to deal with this wastedecades ago and has failed so far to deliver. Although dry-cask storage mostly at operating plants (N.R.C. 2008) has greatly eased the time pressure of power station pools filling up, a broad consensus continues to demand some sort of permanent, almost certainly underground, disposal as a necessary condition for a new generation of nuclear electric power whose attractiveness has increased with global warming. As the global warming emissions from nuclear electric generation are very small, climate change alone has put a revived nuclear industry back on the table as an important future energy source despite continued concerns about its intrinsic risks (Gronlund, Lochbaum et al. 2007).

Permanent disposal of spent fuel will almost certainly occur at a very few locations in the US, or only one. Whether it will be possible to place spent fuel at a disposal site will depend on the proper management of a complex, timeconsuming, negotiation process involving all levels of government, local citizens, environmental and other NGOs, industrial players, and the media. If history and theory are any guides, that process will unfold with conflict among the stakeholders that evidences typical (and distinctive) qualities of NIMBY disputes.

Analytics of facility siting conflict

In this section, I review the standard characterization of a generic siting dispute, and will then identify some distinctive characteristics of the nuclear waste storage and disposal context.

A NIMBY is either an local opponent of a facility (in which case the term has a pejorative intent, implying selfishness or cupidity (Hermansson 2007)) or a land use opposed locally (hence the alternate acronym LULU (Locally Unwanted Land Use)). The term appears to have originated in 1980 in a newspaper article (Livezey 1980), though a similar phrase for the same phenomenon is in the title of a 1977 journal article (O'Hare 1977). I will use it in the second sense, more generally to describe the political conflict associated with something people generally want, but few (at least initially) want near them.

The key elements of a NIMBY dispute are

- a location-specific proposed land use,
- that prospective neighbors see as noisome (dangerous, noisy, ugly, and/or reputationally damaging, etc.), and
- that creates net benefits for a large population including many stakeholders far from its site.

Note that an ill-conceived facility–something with negative total net benefits–opposed by neighbors is just a bad idea, not a NIMBY. The core of the NIMBY problem is the likelihood of not building something *that's good for society as a whole, counting the local costs is imposes*, because it is politically impossible in any particular location. The present essay assumes that a nuclear waste disposal or storage option facing NIMBY opposition has passed a net benefits test to the satisfaction of an appropriate authority, but not received whatever authorization is required for its implementation.

At a sufficiently high level of abstraction, on the utilitarian principle of net benefits maximization as a guide to action, NIMBY conflicts are impossible in theory. If the benefits of the project sufficiently exceed its costs, a notional decision maker like society or "the government" proceeds with the project. Such a determination is not, of course, a simple exercise, but conventional methods of policy analysis are useful. These include, approximately, a prediction of the futures conditional on [various versions of] the project under review and without it, some effort to measure value in consistent units even for effects that don't have accepted market prices in money (like environmental damage), and reduction of the comparison to few or one dimension of merit. For an extended explication of this practice, see (Weimer and Vining 2010); for a shorter one, (Bardach 2008).

Implementing the analytically preferred policy can run aground for three main reasons. First, the distribution of effective decision influence and power does not always match other distributions like voting strength or wealth. Second, individuals do not experience a proportional share of net benefits; often some expect net costs from a net beneficial project. And finally, net benefits maximization, at least with benefits measured on dimensions like money and even health, often appears to ignore dimensions like fairness and justice, values for which people are often willing to sacrifice value conventionally assessed, and which apply not only to actions and outcomes but to the process by which the latter are chosen.

NIMBY opposition derives from real perceived costs, and considerable (if arguable) fairness judgments

Local opposition to NIMBYs derives from a combination of perceived costs, among which are often real costs, and also a combination of process-related perceptions including mistrust of government or business, and a sense of unfair treatment (Hunter and Leyden 1995; Gibson 2005). Most of the early research on NIMBYs concerned things like hazardous waste processing and disposal sites and LNG terminals that posed real risks (however large or small in fact) of toxic or other injury to neighbors. However, local opposition also obstructs construction of things like airports (on grounds of noise, traffic, land taking and community disruption), landfills (Feinerman, Finkelshtain et al. 2004), and social service facilities like homeless shelters (Gibson 2005), projects whose physical or health risks to neighbors are small and whose neighbors are mainly concerned about economic or symbolic costs.

The strategic disposition of a NIMBY dispute begins with the facts that (i) local opposition (sometimes in alliance with geographically dispersed interests) can at least sometimes prevent implementation of a project, using a variety of political and other means, and (ii) an expectation that local costs will follow operation of the new facility. Note that the second "fact" is the expectation, not the costs. Neighbors (who may fall into subgroups with different interests and attitudes) face a decision, when a project is proposed, whether to incur costs to oppose it, using a wide variety of well-known tactics. The project developer and his allies have a variety of response options, and a successful enterprise depends on correctly reading, and modifying, the neighbors' (and other opponents') decision structures.

It bears emphasis that *local opponents* is a great simplification of the dynamic, overlapping, varied membership of the many "groups" that can be identified in a NIMBY situation. *Local* can mean spitting-distance neighbors of a selected site, or residents of the state in which it is proposed; not all locals by any definition are opponents, and not all supporters or opponents stay in those categories over time. And opposition can focus on particular features of a proposal, on the general idea in any form, or anything in between.

Figure 1 illustrates the generic choice facing a possible NIMBY project opponent as a decision tree. One branch, labeled "Oppose" has costs of time, attention, stress, and money, and leads to two outcomes, "Build" and "No-build" with probabilities attached (that is, the successful implementation of the project and its failure or abandonment respectively). In turn, "Build" leads to a variety of results, again with associated probabilities. The other action choice, "Accept", may have immediate costs (for example, social pressure if other neighbors have chosen the other branch) and similarly leads to two possible project outcomes with possible consequences. A NIMBY conflict arises when enough people, with enough power, see the "Oppose" branch as preferred and move along it; a siting failure occurs when that group is able to annul the proposed siting decision.

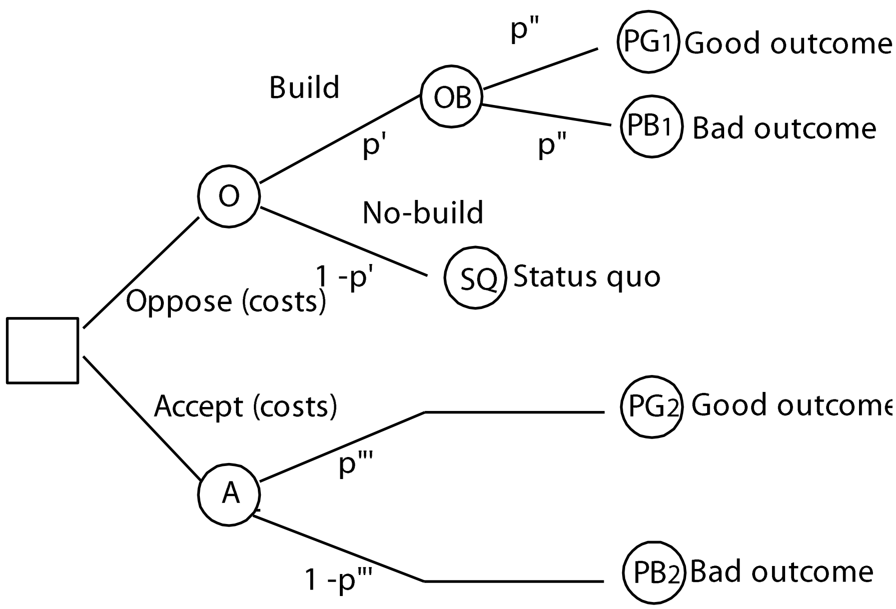

Figure 1: Decision of a possible opponent

Nodes PG1 and PG2 are not usually the same. One motivation for opposition to the project initially proposed may be to force the developer to modify it to embody community preferences, and the dispute may have this result even if opposition is initially flat-footed.

The complexity collapsed into this simple diagram bears note. Outcomes occur over time, possibly over a very long time and to unborn generations. They are multidimensional, including economic, reputational, and health consequences. The decision to engage, and its analysis, varies across stakeholders, for example between an elected official in the site jurisdiction and a resident with no particular responsibilities for land use or economic planning, and between technical experts well versed in the relevant technology and citizens whose interests and training are otherwise. Some parties have more action and response stages in their mental maps of the future, and in their practical option repertory, than others.

The figure is presented in this condensed form, however, to emphasize a larger principle: project advocates and opponents can change this decision tree for other parties in only two generic ways. First, they can change participants' *probabilities* of different outcomes from nodes A, O, and OB, by sharing information and evidence from expert analysis, or by reference to comparable projects elsewhere, or by reference to more general evidence (or assertions) about how the world works. Second, they can (sometimes) decisively attach additional *consequences* (rewards and punishments) that change the net value of being at the end of different branches. Both approaches impose costs on the project, costs that may not be recoverable if the project does not proceed. These generic approaches, the first operating on knowledge and the second on outcomes, correspond to distinctive models of the relationship of a society to its government and among members of the society, including not only individuals but enterprises.

Collective action and strategy

The distribution of costs and benefits in a facility siting conflict is central to the probable outcome, and to effective strategies for countering NIMBY opposition. In particular, a project disfavored by neighbors almost always imposes large *per capita* costs on them (or they think it will), while the positive net benefits balance depends on small *per capita* benefits delivered to a very large population, many of whom don't necessarily know they are in it.

Mancur Olson provided the key theoretical explanation of why a small group with high individual stakes in a decision will have a great strategic advantage over a large, diffuse group even when the latter has more to gain or lose in total (Olson 1971). A small group of neighbors is able to identify and coerce slackers in the opposition effort, feel responsible to each other and to their community, and can condition private benefits on participation, while the population of a large polity faces powerful free-rider incentives to remain tacit and has to act through complicated, slow-moving, bureaucratic, political, and legislative machinery. Major project conflicts are even more complicated, as local opponents typically form coalitions with other stakeholders opposed to the project as a whole, to the project's basic technology, or just seizing an opportunity to build their own power and influence with a live controversy.

Olson's model is the basis for the analysis of the NIMBY problem in (O'Hare, Bacow et al. 1983)[1] and, less directly, for most subsequent research in the field. Briefly, we argued that neither the legal right to proceed with a project (permits, etc.) nor a demonstration persuasive to a neutral third party or objective observer that local costs are actually small, are likely to make the

[1] Much of the discussion in this essay derives from the analysis in this work.

“Accept” branch of a local opponent’s choice preferable to “Oppose” for a controversial siting decision. We also argued that local opposition will, by Olson’s model, probably succeed through well-known means of opposition, including extra-legal means, that seem efficacious to this small group (of which the classic meme is “standing in front of the bulldozers with baby carriages”). The large, diffuse group of project beneficiaries often cannot deliver the political force necessary to overcome determined local resistance.

Distinctive characteristics of nuclear waste disposal

Risks and perceptions

Nuclear waste disposal presents the typical qualities of a NIMBY dispute, complicated by distinctive features of its own almost all of which aggravate political management of a typical industrial risk like chemical waste disposal. The most salient bad outcome of a disposal or storage site is release of radioactive material into the air, groundwater, or food through leakage or terrorist attack. Radiation is invisible, tasteless and odorless, and known to cause a variety of cancers, an especially feared disease. Furthermore, the entire nuclear enterprise originated with weapons of unmatched destructive power unleashed from physically small sources, and nuclear fears of all sorts have been repeatedly resurrected in popular experience by accidents at power plants and disposal sites (Slovic, Flynn et al. 1991) whose salience and implications are magnified by social mechanisms of transmission and construction (Kasperson, Renn et al. 1988).

For example, the steady, unexciting generation of electricity in hundreds of reliable power plants worldwide, and the sixty-five-years-and-counting without hostile use of nuclear weapons, probably account for a tiny percentage of the public’s engagement with “nuclear news” (including fictional ‘news’ like *The China Syndrome* (Bridges 1979)), with the rest describing genuinely scary and sometimes actually damaging (Rocky Flats, Chernobyl) excursions from an uneventful status quo. Any proposal to accumulate and store nuclear materials can be expected to trigger highly salient concerns about explosion, leakage, radiation exposure, and chronic illness, the last of which are especially alarming because the injury may be under way long before the effects are noticed.

Nuclear storage risks also have the distinctive quality of extremely long duration in time; nuclides are not biodegraded, not made harmless by chemical reaction, and have half-lives extending to centuries and millenia. These time scales exceed the length of the historical past, and raise perplexing questions not previously encountered in policy making. If waste is buried with the intention that no-one digs or drills into it by accident, for example, and the site is to be marked as such for ten millennia, what is the sign made of, and what language is it written in?

Like most NIMBY triggers (prisons, chemical waste processing, airports) nuclear waste disposal is a cost associated with a larger enterprise of beneficial intent. However, nuclear energy does not have the broad public support of consumer goods production or air transportation; there is a body of public and political opinion that regards nuclear power as a bad idea in itself, on grounds of risk, cost, or other considerations (Kovacs, Eng et al. 2010) and another with even stronger views about nuclear weapons.

All of the above–that is, that many people look strongly askance at living near a storage or disposal site–induces important second-order perceptions of economic and reputational injury that are almost independent of actual risk. If one thinks *others will be afraid* to live in one's house, one can expect the money value of that house to be less. If one thinks *others view* processing or receiving waste or dangerous materials as stigmatizing or status-lowering, one will regard any nearby waste facility as lowering one's, or one's community's status, and concern specifically about stigma appears to figure importantly in opposition to nuclear waste siting (Flynn, Burns et al. 1992) and certainly affected the unfolding of the Yucca Mountain project.

This essay does not engage the large and extensively studied question "how safe is nuclear energy and waste disposal, and compared to what?" The important issues here are *that* some people are afraid of and/or opposed to it to a greater or lesser degree, not without reason, and *how* that fear can best be engaged after the scientific risk estimation has been done or is under way.

Institutional context

The last question highlights the importance of the institutional context in which a siting process will unfold, and that context is especially discouraging for nuclear waste disposal. First, all the science, from reactor physics and engineering to atomic decay to geologic stability and isolation, is complicated and mysterious compared to activities like burning something to boil water for a turbine. Almost every important process in the cycle is invisible because it's too small to see, underground, or hidden by security arrangements, much of it is counterintuitive to the untrained observer, and the parlous state of science education in the US is a truism of the popular press. Second, the nuclear enterprise as a whole has unfolded from the beginning in an atmosphere of extreme secrecy, managed by government agencies both military and civilian with toxic reputations for transparency and public accountability. The siting process for waste disposal itself comprises more than two decades of false starts and failures that radiate a general inability of government to do its job effectively, punctuated with disasters like Hanford, Rocky Flats, and West Valley that undermine the technical and safety reputation of the nuclear industry as a whole (Saillan 2010). Worse, implicit attitudes may be more negative than people will reveal in an explicit survey (Siegrist, Keller et al. 2006).

The shorthand for the affective orientation that makes a public more likely to follow an indicated path is the phrase "trust and confidence." These are what we want to regard our leaders with. In the present context, it's worth distinguishing the two ideas the formula comprises even though the literature and surveys usually just use *trust*. *Trust* describes the degree to which you think someone has your interest at heart. *Confidence* is your estimate of her ability to deliver what you need. These are not the same thing; most people trust their mothers implicitly but would not have mom do even a simple neurosurgical procedure on them. Conversely, one can have great confidence in the abilities of a highly-paid lobbyist but not trust such a person to advance the best policies.

A more general trust deficit characterizes the relationship between US citizens and their government (Nye, Zelikow et al. 1997) and in the spring of 2010, Pew Research described "a perfect storm of conditions associated with distrust of government – a dismal economy, an unhappy public, bitter partisan-based backlash, and epic discontent with Congress and elected officials" associated with an index at historic lows (Pew 2010). Trust in news media is also minimal (Gallup 2010) (Jones 2004), and the rapid decline in public belief in global warming from 2006 to 2010, anthropogenic or other, offers little reassurance of the public credibility of science (Pew 2010). In addition, the attention of the press, public, and government, and resources for government agencies, are currently absorbed by a historic economic recession that promises to be slow to dissipate. All these attitudes may change over time but they are especially inauspicious at present for focusing attention on waste fuel disposal.

Formal Decision Structure

The formal, legal framework of nuclear waste management, finally, incorporates an unusual number of agencies and levels of government, including the White House, the Environmental Protection Agency, the Department of Energy (whose subagencies in this area have been reorganized and renamed repeatedly), the Department of Defense, and state and local governments, with ample evidence of willingness to intervene and redirect the site selection and project implementation process at all levels (Stewart 2009; Saillan 2010).

One or two national nuclear waste sites present the further complication (compared to dozens distributed across the country) of greatly enlarging the population that feels distinctively threatened by any one compared (for example) to a state hazardous waste center or a prison. The population of a whole state may fear identification as "a national dumping ground", as in Nevada (Kunreuther, Easterling et al. 1990), in fact opposition to Yucca Mountain actually increased with distance within the state (Flynn and Slovic 1995). A regional or national facility of this kind is likely to exhibit a greatly enlarged, and geometrically complicated, version of the "target" pattern common with other NIMBYs, wherein residents of the actual site, whose property will be purchased and will generally have resources to relocate if they wish, residents of a surrounding annulus who will not experience a taking but anticipate ongoing costs and possible loss in home values, and residents of a larger annulus, who will not be near neighbors but may see the prospect of lower taxes and employment, all have very different attitudes to the proposal. As these zones rarely match jurisdiction boundaries, elected officials and other leaders typically find it complicated and frustrating to represent constituents' opinion.

Experience

The history of spent fuel disposal siting is too long and complicated to relate in detail here (see (Stewart 2009; Bewick 2010; Saillan 2010) for recent reviews). However, a few illustrative examples bear note as cautionary or promising. Different constitutional forms and local traditions caution against inferring too much from practices in other countries, but some examples may provide guidance for an American program. Sweden, despite a period of political uncertainty about maintaining a nuclear electric capacity, and despite false steps in the 80s, appears to be on track to open a permanent repository following an invitation to communities to volunteer for feasibility studies under a policy promising to respect a local veto at any point and to provide financial incentives to hosts. The currently "live" site is in a town with an operating nuclear power plant, and the disposal technology is encapsulation in copper canisters, surrounded by bentonite clay, in saturated granite bedrock 500 meters deep. Finland is implementing a site using the same technology, with local and parliamentary approval , following a process with extensive local engagement and a promise of local veto power (Upson 2009).

France and the United Kingdom have proceeded initially with minimal local engagement and have not yet selected sites; a variety of proposals have been defeated by local opposition. In other European countries, site selection for permanent disposal is either at early stages (Van Der Zwaan 2008) or in limbo with a general policy favoring geologic disposal in place but no site determined (Sailer 2008). The Swiss site selection process, currently at the local public hearing stage, is expected to take until 2017 (Vogel-Misicka 2010).

In the US, several programs in addition to the Yucca Mountain trainwreck seem instructive. The Waste Isolation Pilot Plant in New Mexico is receiving transuranic waste with community approval that has increased markedly since its opening (Jenkins-Smith, Silva et al. 2011), and is at least being considered for fuel disposal (Bewick 2010). On-site storage of some low-level waste has been accepted at cleanup sites in Washington and Ohio (Bewick 2010). On the other hand, only two new LLRW sites (Texas and Utah) have been opened since the passage of the Low-Level Radioactive Waste Policy Act in 1980, despite incentive (compensation) packages. Ward Valley in California became, over fourteen years, a textbook case of failure to coordinate levels of government sufficiently to open a facility (Bedsworth, Lowenthal et al. 2004), and the Skull Valley interim storage proposal in Utah, strongly advocated by residents of the economically depressed area, remains stalled by opposition from state-level politicians fearing the waste will not be removed, and Interior Department permit denials (Bewick 2010; Fahys 2010).

Except for (possibly) the Finnish and Swedish examples, this history is far from a vein of successes to emulate. Bringing a permanent waste disposal facility to operation has been high-centered again and again, sometimes because of technical problems with proposed sites but in almost every case in the face of effective local opposition.

NIMBY Strategies

From the "decide, announce, defend" model under which a government could effectively ordain construction of a NIMBY facility, either under pressure of war or as a source of employment in hard times, and whose effectiveness was largely lost in the turmoil of the '60s and '70s, a framework for approaching these disputes has evolved over the last three decades with a few characteristic elements, each of which can be regarded as a necessary but not sufficient condition for success. The following pages review these strategies and tactics.

Scientific and engineering legitimacy

A non-coercive approach to the NIMBY problem is to reduce, with data and evidence, the probabilities of bad outcomes in the mind of stakeholders. Risk analysis, design, and operations management of a nuclear facility must obviously be state of the art. For a facility of this kind, the operational definition of this standard is itself arguable; to what extent does consensus among experts, and among what spectrum of experts (nuclear engineers, physicists, geologists, hydrologists, radiation medicine specialists, etc.), establish this legitimacy? For the present discussion, it suffices to note that large gaps or inconsistencies in the engineering analysis of a disposal site and technology are probably fatal (though claims of such deficiencies by opponents are not necessarily so).

Neighbors' prior experience

A consistent finding from survey research on attitudes to nuclear facilities of all kinds is that local acceptance increases as such facilities operate over the years without accidents (see, for example, (Jenkins-Smith, Silva et al. 2011). This effect probably results from ongoing processing of experience data as well as selection of residents through immigration and departure that gradually favors a "pro-nuclear" community. Furthermore, a positive feeling about one's community's economic base and the employer of many of its residents obviously reduces cognitive dissonance and anxiety. As the Swedish experience suggests, if it is possible to locate a disposal site near an operating nuclear plant, prospects of success are almost certainly increased.

Information and communication

The culture of professional communities is to understand how things work and why; in the case of engineers, also to do something. Emotional distance and control of affective bias is a principle of professional legitimacy for them. In contrast, public stakeholders usually do not have an interest in becoming informed about risk mechanisms and objective measures, if only because they have lives to live and work of their own: "…the principal obstacles to [public] understanding [of risk] are lay time and attention, not intelligence"(Morgan, Fischhoff et al. 2002). People also want to feel comfortable about what they are doing.

Often, stakeholders want to know what to do (in the sense of Figure 1) and will accept guidance from authority they trust and respect. But the mismatch between the affective relationship of full-time experts in a technology or policy area to the substance, and that of citizens with whom they interact, is an important challenge to managing a risk-driven public choice process. As this challenge has wrong-footed public engagement with nuclear waste disposal frequently, and the problem is hard to see from the specialist's side, I will illustrate it with three anecdotes.

> 1. The author remembers speaking, as a state official, to a public meeting about a proposed hazardous waste facility his agency was promoting. After a fair amount of description with slides and charts, one audience member asked, "Is it safe?"
>
> "Good question," I replied. "But it's complicated [thinking at that point about my colleagues at MIT and what would impress them]: do you smoke? How about diet soft drinks? What do you mean by *safe*?"
>
> The questioner and many of his neighbors were simply furious and the meeting didn't go well after that. I had bungled the situation by confusing the words of the question with its meaning and the context that determined it. What he meant, or close to it, was something much more complicated, like "Speaking as a specialist representing our government, do you think a decent person would raise his children near this thing?" And the correct answer, without the condescension of restating the question that way, was "Yes."
>
> 2. During the same program, the state staff engaged with the project was in a meeting developing a public education campaign about hazardous waste and the importance to local industry of treating it properly. Most of us had been working between half- and full-time on the issue for months. After a couple of hours, we had ideas for public service announcements on radio and TV, door-to-door leaflets, high school science lessons, public hearings to a fare-thee-

well, and more. We were well pleased with our progress. One member of the group blurted out during a pause, "how many minutes during a year do we think the average citizen is willing to commit to this issue?" As we realized that the answer was in single digits, the meeting's underlying assumptions, and the plan, changed radically.

3. In a meeting of academic and industrial waste management experts, one presenter showed a flow chart of a process with many steps, including a box labeled *purification* with one arrow going in and another going out to the next box. I asked about the missing out arrow and its destination, trying to explain that anything called "purification" that doesn't account for what is removed from the material raises questions that could undermine trust in the source of the information in a public forum. The presenter and many attendees found this question unconstructive and petty: 'obviously' purification generated filtrate or some other waste, but that wasn't the point of the process; why complicate the diagram with a side issue?

Perceptions of risk, and the degree to which it is being properly managed by technology, do not generally match what experts think they should be. Many very small objective risks are treated as though they are much greater than the evidence indicates, and beliefs of this kind can survive large amounts of contradictory evidence. Risk perception is modified as information spreads through a society in several ways (Kasperson, Renn et al. 1988), especially by the familiar heuristics and approximations (availability, prospect theory, anchoring, etc.)(Gilovich, Griffin et al. 2002) and the intrinsic bias of dog-bites-man information theoretic selection. "Nothing new today, again" is an important part of estimating occurrence frequency for rare events, but information resides in surprise, and a safely-operating system with very few excursions only makes news when an unusual (bad) thing happens. Lay experience of the event is thus greatly increased by its repetition in media, while experience of the predominant safe condition is rare. Especially if second-hand experience is itself costly, the engineer/economist's expected cost measure as probability(assessed from observed frequencies) x cost (assessed as direct and indirect economic effects) will be far from the risk severity estimate stakeholders use. But the latter is what will direct the choice process.

The risk analysis literature has confirmed repeatedly that risks are undertaken as a package with benefits and there is no more a level of acceptable risk *tout court* than there is an "acceptable price" independent of the product on offer (Fischoff, Lichtenstein et al. 1981). Nor is there a simple scalar measure of risk intensity like "expected cost" if outcome *cost* is measured in any conventional way, or even dissected into the familiar *dread* and *unknown* dimensions (Slovic 1987) or further.

Risk communication has been studied as a distinct enterprise at the government/industrial/public interfaces and the lessons of this research (for an overview, see (Morgan, Fischhoff et al. 2002), particularly the importance of listening before talking to determine what a public knows (especially what it knows that is wrong) and what it wants in the way of information, for what purpose, are central to a successful siting process.

In any case, risk estimates are only part of the information that needs to be made available to candidate communities throughout a siting process. Economic and social effects, as well as the details of the site selection and approval process, are key elements in opinion formation and action decisions. In general, the results of technical and political exploration are best made available as soon as possible rather than being kept close to an agency's chest until it believes it has a persuasive and complete case; the siting processes that succeed in this context are iterative, untidy, and recursive. Web posting of documents with good site design probably offers an important opportunity to improve this process from its traditional reliance on live meetings, official notices and press releases, and political speeches.

Finally, there is good reason to empower site communities to get their own information, including funding access to independent consultants. Suspicion that information from official sources is tendentious and biased is endemic in this process.

Legal legitimacy

Obviously, having the permits specified in existing law, and succeeding in litigation brought to demonstrate the opposite, along with authorization to proceed (for a government operator) and appropriated resources are all necessary for a facility to begin operations. This criterion is mentioned here mainly to assert its insufficiency, especially in a dynamic context where the rules are liable to change underfoot as has happened in the present context again and again (Stewart 2009) and in ways that (as with the enactment of the Nuclear Waste Policy Act Amendments) appear to some to reflect political muscle more than constitutional or legal principles (Flynn and Slovic 1995).

Compensation

Figure 1 invites attention not only to information strategies like more or better science (what a Bayesian would equate to changing probabilities), but to directly altering promised outcomes. A classic non-coercive approach to the NIMBY problem is a mechanism to attach compensation of some sort for the costs the project imposes on neighbors so they will not want to oppose the project. A variety of schemes to determine, and to pay, money or in-kind compensation have been put forward, including structured negotiations with a designated community body (O'Hare, Bacow et al. 1983), and an auction of the facility to the site willing to accept the smallest compensation payment (Kunreuther and Kleindorfer 1986). If enough compensation is provided at node

PG2, a citizen will presumably prefer the Accept branch more strongly, as elaborated in the risk/benefit model in (Kunreuther, Easterling et al. 1990).

Compensation schemes are theoretically sound and especially attractive on conventional economic grounds, because a net-beneficial project, by definition, can come up with payments that offset its costs; the approach is in essence one of converting a policy that meets a Kaldor-Hicks test into a Pareto-superior change. They also have the advantage that, again in theory, projects that look net beneficial but really aren't will be so revealed, because the local costs are made manifest in the negotiation or auction process. And they are empirically supported by the thousands of cases in which facilities of various kinds, including not only the ideal smokeless, noiseless hi-tech operation whose PhD employees commute on bicycles, but also prisons and refineries, are accepted because they promise employment and economic growth (even if the promise is not always fulfilled)(King, Mauer et al. 2004).

More recently, however, compensation as a mechanism for defusing NIMBY disputes, especially for nuclear waste sites, has been shown to actually reduce public acceptance of a risky facility except in a carefully managed political process (O'Hare and Sanderson 1993; Frey and Oberholzer-Gee 1996; Frey, Oberholzer-Gee et al. 1996) at least for especially risky or controversial facilities (Kunreuther 1996). The problem is that to the degree that citizens impute moral content to their behavior, compensation payments can easily look like a disreputable transaction. Crudely caricatured, a compensation offer can appear to ask, "How much do we have to pay you to give your children cancer? to let the government push you around?" [2]

Compensation can take many forms, not only cash payments; even these can be made to (for example) a non-profit community trust, local government, or direct to individuals, all with different motivational effects. For example, it can be conditional, like property value guarantees to homeowners and businesses or payments triggered by specified excursions or bad events during operation. It can be all-at-once or spaced out over time. And it can be in-kind, a type that seems to trigger the "bribery" reaction less than money, like recreational facilities to replace land used by the facility, or a new gym for the high school, or medical care for residents. Generally, this kind of compensation, that seeks to maintain life as it is rather than certifying injury by paying money for it, is better received and more effective in coping with NIMBY opposition than money .

[2] This reaction is usually expressed by calling the payment a bribe, even though the characterization is inaccurate because a bribe is intrinsically secret, a payment to covertly change someone's motivation from what it appears to be or should be. Real bribery does surface as a concern of citizens about their elected officials' motivations ("Has the mayor sold out to the developers?"?).

Local control

How much we fear a fire in our homes has a lot to do with whether we know where the fire extinguisher is: if things start to go wrong do we want to be able to correct the situation, The same psychology is behind recent efforts to loosen gun laws so law-abiding citizens (it is claimed) will be able to interrupt and neutralize mayhem. Local veto power over the facility site, or some amount of local control of its operation once established, increases acceptability; in Sweden, for example, the waste management operator's implicit granting of a local veto to beginning site investigation has been important in advancing the (so far) successful siting program for underground disposal (Sjöberg 2004).

As with the citizen wanting to pack heat in case a bad guy needs shooting or frightening, this attitude is not necessarily consistent with a technical analysis. Even if one will not draw a weapon in time to get the drop on a hostile party, and even if two or three people playing civilian peacemaker are likely to shoot each other or innocent parties, the reassurance a weapon provides to those who want one is undeniable. Similarly, local control of a risky and technically complex operation drives a wedge between trust (on which lay citizens of the community score high in their own eyes) and competence, on which they presumably score much lower than the facility operator's technicians, or the scientists making a technical site selection analysis.

Control implies a duty to exercise it, and this is the other edge of a sword whose utility in managing NIMBY conflicts is ambiguous. If a risky facility requires attention by its locality, that locality may resent the burden of having to do so. In addition neighbors can forsee having the risk presented to them again and again. If being aware of a risk even though nothing has happened (yet) is a real cost, and it probably is, local control amplifies this perceived cost at the beginning of the process, even though, paradoxically, overestimating the worry that will actually burden neighbors after the project is in place is a known bias.

Process legitimacy

Local veto and control are dimensions of a much larger set of issues implied by the broad agreement among scholars that facility siting is path dependent (see, for example,(O'Hare and Sanderson 1993) , the discussion of process in (Schively 2007) and the recommendations in (Stewart 2009)). The proposition that the same facility, operated in the same way, in the same place, might be desirable or not depending on the political and deliberative process that led to it is, in general, irksome to engineers and many economists (but not all (Frey and Oberholzer-Gee 1996) and even Kunreuther, an early advocate of auction-based siting (Kunreuther and Kleindorfer 1986) comes to favor a much more process-sensitive mechanism a decade later (Kunreuther 1996)) .

It appears, in sum, that what make a siting process more legitimate are qualities of fairness (including outcome distributional issues recently studied under the umbrella of *environmental justice* (Pastor, Sadd et al. 2002), inclusion and participation (or at least access to the decision process), and technical legitimacy of the project itself (Easterling 1992). A Hobson's choice, in the form of attempts to gang up on a state or locality and force acceptance of a facility or to browbeat citizens with (i) technical arguments that no other path is possible or (ii) preaching an obligation to serve society, undercuts participation and legitimacy from the start. An extensive and prescriptive review of waste management emphasizes the importance of adaptation and flexibility to legitimacy of the type required for a successful outcome as follows:

> While technical competence is essential, experience indicates that a purely technocratic model is too narrow and rigid to be successful. In the future, successful development of new storage facilities or repositories will require considerable engagement with states and localities, with the utility and nuclear industry, and with environmental and local NGOs, and a capacity for negotiation within those various stakeholders.(Stewart 2009)

Finally, administrative arrangements for facility licensing and operation should probably include a clear separation between operators and regulators. While the governance process is less tidy, it's extremely difficult to assure the public of the safety of a risky facility without oversight by an agency whose funding and internal culture are independent of the facility's operation (Stewart 2009; Saillan 2010).

Leadership

In reflecting on Massachusetts' experience with a hazardous waste siting law built around compensation negotiated with a local site community (O'Hare, Bacow et al. 1983), Sanderson and I concluded that a key missing element in NIMBY analysis (and often, siting practice) had been the idea of leadership (O'Hare and Sanderson 1993). Ronald Heifetz, in an influential book (Heifetz 1986), identifies leadership as the process by which groups find and undertake adaptive work, a view that separates leadership from formal authority (which sometimes provides it). *Adaptive work*, in turn, is work no-one (including the leader) knows how to do, in contrast to *technical work*, which may be difficult, expensive, or demanding, but someone knows how to do it. What makes leadership difficult is groups' practiced routines at avoiding adaptive work, mostly motivated by fear of failure or change, or that it will demand competences the group does not possess, for example: blaming authority, denying the need to do it, blaming outside forces, transferring responsibility for the work to leadership, internal dissension, and so on.

Among the tools of leadership are the two kinds of authority captured in remarks like "You don't have the authority to send me out for coffee!" and "He's the world's greatest authority on tropical butterflies." In the second case, no-one expects the butterflies (or even his graduate students, actually) to fly and sit at the expert's command. These kinds of authority match, respectively, the capacities (i) to change other' decision trees by imposing conditional outcomes at the end of the branches, like rewards and punishments, and (ii) to change decision makers' probabilities at chance nodes, in other words, to alter their view of how the world works. They are not equally useful, however; recall that leadership is concerned with work no-one knows how to do, so being able to give orders to do it is usually pointless. Formal or positional authority is useful mainly for ordaining structure (committees, information distribution systems, task forces, and the like) and for its ability to command attention (as distinct from compliance). Players with positional authority can identify the work, and do so with assurance that most players know it to have been identified.

A look back at the history of nuclear waste siting, at least in the US, reveals a pattern of treating the problem as a matter of technical work, whether finding suitable geology and packaging in engineering terms, or constructing a piece of administrative machinery or a statute. There has been very little, especially from elected officials to whom Americans typically look for leadership, of putting adaptive work on the public's table and a great deal of responding to an unspoken but real desire to "have the problem solved with no heavy lifting by us", a mode of work avoidance and mutual seduction by leaders and groups that can be very difficult to resist.

What could leadership in this context look like? Most adaptive work is exogenous, either a need imposed by a change in an organization's environment that puts current welfare levels at risk (Toyota for General Motors in the 1970s), or presenting an opportunity for more or better value creation (Toyota practices for General Motors, up to the present). The nuclear waste challenge has elements of both: climate change has positioned nuclear power as a partial solution to a problem we certainly face, and even if civilian nuclear electric power is wound down instead of up, an existing inventory of waste, plus some from ongoing military activities, already exists, will continue to grow even if slowly, and has to be somewhere. Effective leadership toward permanent nuclear waste disposal probably requires at least the following elements:

- Clear, insistent, calm restatement of the adaptive work to be done emphasizing the problems that have not been resolved at any point.
- Separation of the program into tolerable increments, orchestrating and celebrating small successes, and
- Constraining the scope of failures and forcing them to be constructive learning opportunities
- Reassurance and demonstration that decisions will be constrained and guided by science
- Simultaneous emphasis on the importance of success and reassurance that failure and delay are not catastrophic
- Clear explanation of the moral basis of the political process and the impossibility of a world without risk. (Löfquist,2008)

It also requires resistance to at least three characteristic temptations. One is expect salvation from engineering, in either of two forms. An irresistible demonstration that technology A in geology B at location C is so superior to any other option on grounds of cost and risk will not settle the issue and carry the day. Nor will it be useful to assail public fears with more and more technical studies that prove the risk is much smaller than people think, or that they accept in other contexts.

The second is to put too much faith in reorganization and administrative procedural reform. New agencies with reallocated responsibilities and fresh blood in charge may or may not be useful, but the implicit faith of, for example, Prof. Stewart in his well-thought-out reconstruction of the nuclear waste regime (Stewart 2009) enables a subconscious hope that "if we just get the right machinery in place, flip the switch on and stand back, this problem will solve itself."

The third, of course, is to take a path that promises a comfortable route through the next election (O'Hare and Sanderson 1993) (though it is certainly self-indulgent and suicidal for any public official to wrap himself in moral rightness and ignore where the electorate has got to at a given time). Adaptive work is never comfortable; indeed, comfort is an indicator that it is being slacked.

Metaphors

Leadership for nuclear waste siting probably requires explicit and consistent acceptance of a metaphor for the adaptive political work to be done, and another for the particular technology and practice being proposed. The following paragraphs sketch (to the point of caricature) such possible metaphors or conceptual models. Good leadership will recognize them as alternatives and characterize them so actors in the political process will recognize which seem to underlie their own actions and those of others. Without affirmative political management, the more dysfunctional among them can easily come to dominate debate.

Siting

Government and industry against some citizens.

Nuclear waste was created by utilities earning profits, protected and subsidized by a government that is a distinct, independent, entity above or outside society as a whole. (This idea of government radiates from a great deal of recent right-wing and more historic left-wing political discourse, and fits comfortably with much American historic tradition and imagery. It is thus easily accessible, subconsciously and explicitly, in any NIMBY dispute.) Accordingly, the waste is theirs to deal with, and a siting controversy is a matter of government forcing us to bear a burden that is not fair to impose.

Collective responsibility

Nuclear waste was created by everyone who turned on a light or bought a product in the last forty years, even if their own utility burns coal or taps a river. If we want to protect the planet from climate change, we will need to go on making it, and more. The institutions we set up to make electricity safely, including utilities, their suppliers, and government regulators, are acting on our authority and need our guidance about how to manage the waste stream, and allocate the costs of doing so–just as the coal power stations needed us to work through government to stop acidifying downwind lakes.

Service as a burden

A unique or rare land use that imposes some risk *forces* its neighbors to bear costs for society as a whole, usually as a result of residential choices made long ago and with no awareness that (for example) a suitable geological formation is underneath. A citizen's duty is to do his fair share, and no more. (For a reflective examination of this perspective, see (Hermansson 2007).) In fact, a NIMBY almost assures doing more, and for strangers, so a reasonable person will try to avoid being a patsy (O'Hare and Sanderson 1993). It's a short step to "…his fair share, and maybe even a little less, with luck" and even the *amoral familialism* (Banfield 1967) pithily expressed by Sonny Corleone: "They're chumps because they risk their lives for strangers!" (Coppola 1974_ENREF_6)

This metaphor entails an interesting branch regarding future generations; on the one hand, "posterity never did nuthin' for me" and on the other "a waste dump here puts my children and grandchildren at risk."

Service as an opportunity

A unique or rare land use that imposes some risk *allows* its neighbors to bear costs for society as a whole. This is a piece of good fortune, though they did nothing to court the opportunity. Consider the following parable:

> On a cold northern night, a traveler driving by a frozen pond opens the window of his car to throw out an apple core, and just at that moment, hears a cry for help. Stopping the car and getting out, he realizes a child has fallen through the ice. Without thinking, he wades into armpit-deep water and saves the child.
>
> Later, a familiar scene; flashing red lights, police radios going on and off, people milling about, and the driver sitting shivering on a log wrapped in a blanket. A TV reporter thrusts a microphone before him. "You saved that little girl! How do you feel now?"
>
> "I'll tell you how I feel; I'm furious! My clothes are ruined, I'm freezing cold, I could have drowned, and I'm late for dinner. It's completely unfair that this happened to me; it could have been anyone. I don't even know that girl or her family; don't they have a

fire department for this kind of thing? I'm going to sue everyone; the kid's parents, the town, and the owner of the pond."

Most people find the last paragraph of this story ridiculous, unimaginable, absurd. The traveler would say something completely different, like "I'm just grateful I was able to help; her poor parents!"

Technology

Once and for all

Nuclear waste needs to put where it will never need attention again, or for as long as makes no difference (10^{4-6} years). The value of the electricity that caused it was consumed by us, and it's unjust to burden future generations with duties of active care. Furthermore, worrying about something going wrong is itself costly. Where and how this is done is an engineering/geological question.

Continued care

A wide variety of tasks must performed again and again, year after year, for the mankind to flourish or even survive. Plant and harvest crops, raise and educate children, protect and enrich the cultural patrimony, maintain the levees, reencode everything into new data storage modes (objects and languages)…skip any of these for even one cycle and catastrophe will ensue. Indefinite management of nuclear waste is just one of these; the task is not impossible and anyway, the duty matches a variety of endowments passed to future generations that were made possible by the power it generated.

Conclusions

Despite the disheartening implications of recent history, a solution to the problem of permanent nuclear waste disposal is not impossible. Furthermore, the task deserves to be undertaken; the waste exists and more is on the way, and it cannot be "thrown away" if only because there is no such place.

Experience to date, not only with waste disposal but with other critical adaptive political work confronting the nation, from race relations to climate change to deficit reduction to health care, demonstrates that success may be long in coming and the process discouraging. On the other hand, above-ground interim storage, whether on-site or remote (if a site can be found) greatly relaxes the time pressure for adopting a national permanent disposal approach, while the promise of nuclear power as a climate stabilization strategy, together with the cost of alternatives to fossil fuels, gives the problem salience and urgency.

Selecting and opening a disposal site is not subject to a magic bullet solution or to one key policy trick. The science and engineering must confirm that the risks a repository poses to neighbors are reasonable (not zero) and that any requirements for long-continued care are within the means of future societies. Neighbors need assurance of reasonable compensation for real costs, compensation provided in creative forms attentive to their symbolic content. Terms and conditions must be arrived at through a combination of moral suasion and recognition that the hosts of a repository are acting in the public interest, and assurance that a repository will not be imposed against the community's will. Regulatory requirements must be plausible and realistic, and especially not fantastic promises that anything we can do now will assure security for ten thousand (much less a million) years. And the public agencies tasked with (i) the siting process itself (ii) development and operation of the repository (iii) regulatory oversight and licensing must be, and be seen to be, both politically responsive and receptive, and in service to the public interest rather than short-term advantage or expediency.

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