TRANSFORMING IMAGES OF NUCLEAR WASTE IN THE UNITED STATES

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At the turn of the millennium, proclamations of an imminent nuclear energy renaissance began to populate newspaper headlines, political circles, and energy trend forecasts. Twenty years later, many of the new technologies that spurred such lofty declarations have come to fruition–but the predictions themselves have not. Despite its coveted “clean energy” label, decades of dependable operations, and an emerging generation of safer and cheaper “advanced” reactors, Americans remain, at best, ambivalent towards nuclear power. One explanation for this shortfall is the large gap between public understandings of nuclear energy and the technical reality. Of all the complicated aspects of nuclear energy, perhaps the most misunderstood is nuclear waste. Although satisfactory storage and management solutions for radioactive waste have been available since the late twentieth century, years of anti-nuclear activism and high-profile nuclear accidents have imprinted most Americans with an outsized fear and confusion about nuclear waste. Today, several flashy new uses for spent nuclear fuel–that which comprises the most radioactive portion of “nuclear waste”–have the potential to alter this impression. These novel, peaceful applications for spent nuclear fuel could help improve the public image of nuclear power, allowing it to play an increasingly important role in the energy portfolio of the U.S. as it moves away from fossil fuels in the coming years.

The United States has a long history of nuclear electricity generation–and emphatic public resistance. In 1957, the country’s first commercial nuclear power plant, Shippingport Atomic Power Station, began operating on the Ohio River, using technology developed largely by the U.S. Navy following World War II. While a variety of reactor designs operated in early years, the nuclear industry soon settled on one type, light-water reactors, for ease of licensing. In the following decade, anti-nuclear activist organizations such as Greenpeace and Friends of the Earth began mounting campaigns against nuclear energy. Though nuclear power plants do not produce greenhouse gas emissions or particulate air pollution, these groups often cited the potential environmental consequences of radioactive waste production. Both the U.S. nuclear power plant fleet and the ranks of anti-nuclear protestors continued to swell throughout the 1960s and 1970s until the debate reached a climax in 1979. In late March of that year, a reactor at the Three Mile Island power plant in Pennsylvania experienced a partial meltdown. Although the surrounding population and ecosystem were found to have suffered no notable ill effects as a result of the accident, the events at Three Mile Island crystallized public unease into a sweeping rejection of nuclear power. Significant expansion of the U.S.'s nuclear generation capacity was halted as a result of widespread public opposition. Though many of the reactors active at the time continued operations into the twenty-first century, they did so alongside a lingering sense of fear and distrust of nuclear energy.

Americans have held onto these misgivings, but you might have received a different impression in the early 2000s. "A New Dawn for Nuclear Power?" questioned *The Economist* in 2001, citing George W. Bush's enthusiasm for the industry. "Nuclear Energy is Making a Global Comeback," a *New York Times* headline confirmed three years later, noting nuclear power's sustainable record. A new generation of "inherently safe" advanced reactors, which tackled many of the challenges conventionally associated with nuclear power, was quickly coming into focus in the U.S. In 2005, President George W. Bush signed into law a new Energy Policy Act promoting nuclear power with subsidies and 4.3 billion dollars' worth of tax reductions. Just three weeks later, Hurricane Katrina had annihilated swaths of the United States, along with its residents' skepticism that climate change would exacerbate natural disasters. Thousands of United Nations climate scientists affirmed that the evidence for anthropogenic climate change was "unequivocal," which should have boosted nuclear power–a way to generate electricity with no air pollution, no greenhouse gas emissions, and little waste by volume. So why has the foretold "nuclear renaissance" failed to appear?

All of these factors might have brought about a convalescence for the nuclear power industry, but public opinion had changed only incrementally, and the problem child was nuclear waste. "Public acceptance of a new technology is essential to its growth," explained nuclear energy scholar Richard Rhodes in a 2001 *New York Times* op-ed predicting nuclear revival, "and disposal continues to be the nuclear industry's Number 1 public-relations problem." As the Nuclear Energy Institute pronounced the industry "poised for growth" in 2006, a concurrent UK survey of 1,491 individuals found that 80% of respondents were "very or fairly concerned" with nuclear waste. In fact, they were "far more" worried about the waste than the nuclear power plants themselves. The next year, an MIT Energy Survey found that approximately 2/3 of Americans would support a "significant expansion" of nuclear power–if only the problem of nuclear waste could be solved.

If you had asked the experts, the problem *was* solved, and had been for decades. Most nuclear waste, around 90% by volume, is considered "low-level," made up of things like lightly contaminated uniforms and tools. Disposal of this waste is "straightforward," states the World Nuclear Association (WNA), "and can be undertaken safely almost anywhere." Only 3% of nuclear waste is "high-level" spent nuclear fuel, what most people are really thinking of when they say, "nuclear waste." Because nuclear fuel is so energy-dense, only a modest quantity of this spent fuel is produced. The WNA offers a remarkable visualization of just how much waste is actually created by nuclear power plants in the U.S.: "On average, the waste from a reactor supplying a person's electricity needs for a year would be about the size of a brick. Only 5 grams of this is high-level waste – about the same weight as a sheet of paper." The WNA identifies deep geological disposal, where waste is stored in geologically stable underground repositories, as the most widely favored storage option for high-level waste. The primary risk associated with deep geological disposal is seepage of radioactive waste into neighboring ecosystems. Because the waste is packaged and isolated within both engineered (copper canisters, cement) and natural (rock, clay) barriers, the chance of environmental contamination is infinitesimal. “The risk is as negligible as it is possible to imagine,” wrote physicist Harold Lewis in 1990, dismissing the disposal problem as “embarrassingly easy to solve.” The health risks further shrink in comparison to those associated with conventional energy sources: The World Health Organization estimates that air pollution created by burning fossil fuels is responsible for 3 million deaths a year, 15,000 of which are caused by coal particulates alone.

Despite these staggering statistics, the public continues to perceive nuclear energy as a dangerous way to generate electricity. Of the respondents to the UK poll that identified a public fixation on nuclear waste, 70% said nuclear energy was “a health hazard,” while only 51% said the same of coal. One needs only to look to the U.S.’s proposed Yucca Mountain Nuclear Waste Repository to understand the influence of a resistant public. In *Perceived Risk, Trust, and Nuclear Waste: Lessons from Yucca Mountain*, Slovic and Layman track the events that led to the abandonment of the Yucca Mountain project. First proposed as a storage solution for nuclear waste in 1987, goals of building a repository at Yucca Mountain, Nevada were swiftly crushed by “overwhelming political opposition, fueled by perceptions of the public that the risks are immense.” These perceptions stood in “stark contrast to the prevailing view of the technical community,” who knew that the risks of health hazards or environmental contamination were, in fact, extremely limited. Nonetheless, the public’s sharp backlash, “impervious to influence from the assessments of technical experts,” persists to this day, and the U.S. still lacks a nuclear waste repository. But if the disposal of nuclear waste is a “rather trivial technical problem,” as nuclear physicist Bernard Cohen claimed, why does it remain the “Achilles’ heel” of nuclear power?

The answer lies with the flexibility of public opinion. One study of nuclear risk assessment, *The Future of Nuclear Power: Value Orientations and Risk Perception*, found that public perceptions of nuclear power are “asymmetrically plastic,” meaning they shift more easily, quickly, and to a greater extent towards the negative than they do towards the positive. In other words, it is “relatively easy” to strengthen opposition to nuclear power, but “very difficult" to increase support. “Public opinion on nuclear energy topics is based largely on impressions, as few feel very well informed about the topic,” explains Ann Bisconti of Bisconti Research, Inc. The importance of impressions is particularly pertinent to nuclear waste, with which little positive imagery is linked in the first place. When asked to think of six words they associated with the phrase “nuclear waste repository,” the *Yucca Mountain* study’s 3334 respondents most frequently associated the words “dangerous” (539 responses), “danger” (378 responses), “death” (306 responses), and “pollution” (276 responses). Only 1 percent of the associated words could be considered positive.

Changing perceptions of nuclear waste, then, is not necessarily a question of how to best educate the public. The nuclear industry has considered the question of waste resolved for decades and has spent that time trying to inform the public of this fact–to little avail. Bisconti Research’s 2019 “Public Opinions on Nuclear Energy” poll revealed that only 19% of Americans feel well informed about nuclear energy. The ultimate goal should not be education, but altering the connotations of nuclear waste so that they invoke positive, rather than negative, images. This has proved equally difficult. Because public perceptions turn negative more easily than positive, relatively impressive advances are required to pull public opinion into a firmly pro-nuclear camp. A contributing element to the inertia of public association is the fact that, while some advancements in storage and disposal have been made since the late twentieth century, not much has fundamentally changed regarding nuclear power's waste cycle in the U.S. Since the nuclear power industry selected light-water reactors for commercialization in the 1960s and 1970s, the U.S. nuclear fleet has become increasingly uniform, with innovation dormant. As such, there have been limited opportunities to rebrand. While extended periods of safe operations and geological storage improvements may be considered significant within the nuclear energy community, these advances do little to excite an already cynical public. Fundamental changes in nuclear fuel cycles and spectacular new ideas in waste management will be required to move the needle. These changes must not only catch and hold the public's attention but must also overcome the mammoth hurdle of convincing the populace that nuclear waste can be *good*.

After a half-century of stagnation, it seems the U.S. nuclear industry may finally be prepared to popularize some of these changes. In 2019, the Nuclear Energy Innovation and Modernization Act, or NEIMA, was signed into law in the U.S. NEIMA requires the Nuclear Regulatory Commission (NRC), the U.S. body which oversees nuclear power plant licensing and operations, to develop a new regulatory framework for advanced nuclear reactors by 2028. This framework will allow the next generation of nuclear reactors to be efficiently licensed and operated in the United States, marking a major departure from the government's previous commitment to light-water reactors. Among the ranks of these next generation reactors are molten salt reactors and sodium-cooled fast reactors, both of which are capable of using nuclear waste from other reactors as fuel. In doing so, these reactors fundamentally alter the profile of spent nuclear fuel from dangerous waste to a valuable resource. Recycling fuel would also improve the U.S.'s energy security. In France, where over 70% of the country's electricity is generated by nuclear power plants, a fuel recycling policy increases security of supply and reduces the waste burden. This “makes a significant contribution to the country’s energy independence,” according to Denis Lépée, Head of the Nuclear Fuel Division and Senior Vice President at the country’s managing electric utility. Though increased energy independence may not seem like the most attention-grabbing subject, a study published in the October 2019 edition of *Energy Policy* found that energy security risk is one of few factors that “has consistently driven support for nuclear energy in the US,” even offsetting the negative effects of plant accidents.

Though the promise of reactors that use spent fuel to generate electricity is certainly intriguing, even more beguiling uses for nuclear waste are developing in the extra-terrestrial sphere. The European Space Agency (ESA), in partnership with the University of Leicester, has developed a space battery that runs on americium, an element found in spent nuclear fuel. Nuclear batteries are essential to deep space exploration as they provide consistent, durable, and long-lasting energy without the need for solar power or rare earth metals like lithium. Most nuclear space batteries are powered by the decay of expensive and scarce plutonium-238, but this may not be sustainable. In a 2015 presentation, the Department of Energy’s director of space power systems, Alice Caponiti, revealed that NASA only had enough plutonium left for three nuclear batteries. Americans care about space–a recent Pew Research Center poll found that over 70 percent of U.S. citizens believe it is “essential” that the U.S. is a leader in space exploration. With plutonium-238 in increasingly short supply, batteries powered by americium extracted from spent nuclear fuel could become key to space exploration efforts, while simultaneously boosting the image of nuclear waste. The UK’s National Nuclear Laboratory americium project account director, Tim Tinsley, put it simply in describing americium batteries as "recycling something that is a waste from one industry into a significant asset in another."

In reality, these exciting new ideas are not actually new. Several other countries besides France already regularly recycle nuclear waste to reuse as fuel, including Japan, Germany, Belgium, and Russia. The U.S. chooses not to recycle spent nuclear fuel, not because it lacks the ability but because it is more expensive than simply mining new uranium. Many of the so-called next-generation reactors, including those which "consume" nuclear waste to produce energy, are not even novel concepts: both molten salt reactors and sodium-cooled fast reactors operated in the U.S. in the 1960s before favor shifted to light-water reactors. And NASA already uses nuclear batteries for space exploration, just not ones powered by americium.

Fortunately, it does not matter if the technology is truly original–it only matters if it piques the interest of the public. Decades of misunderstanding provide ample evidence that Americans do not respond to the technical reality of nuclear energy. Instead, they respond to whatever catches their attention. In the past, only negative events have been able to accomplish this feat. Today, nuclear waste finally has the opportunity to invoke images other than danger and toxicity. It is no longer a burden, a deadly thing that nobody wants in their backyard. Now, it can power schools and warm homes, it can propel humanity into the far reaches of outer space, it can boost U.S. energy security and protect U.S. independence. The percentage of spent nuclear fuel that is actually recycled, or the number of waste-consuming reactors in the nuclear fleet is irrelevant. If the U.S. nuclear industry is capable of seizing upon these sensational topics and moving past technicalities, it could finally give nuclear waste a much-needed makeover and transform public attitudes towards nuclear power.

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