Thorium: the wonder fuel that wasn't

Robert Alvarez

ROBERT ALVAREZ

A senior scholar at the Institute for Policy Studies, Robert Alvarez served as senior policy adviser to the Energy Department's secretary and deputy assistant secretary for national security and the environment from 1993 to 1999.

"Thorium-Fueled Automobile Engine Needs Refueling Once a Century," reads the headline of an October 2013 story in an online trade publication. This fantastic promise is just one part of a modern boomlet in enthusiasm about the energy potential of thorium, a radioactive element that is far more abundant than uranium. Thorium promoters consistently extol its supposed advantages over uranium. News outlets periodically foresee the possibility of "a cheaper, more efficient, and safer form of nuclear power that produces less nuclear waste than today's uranium-based technology."

Actually, though, the United States has tried to develop thorium as an energy source for some 50 years and is still struggling to deal with the legacy of those attempts. In addition to the billions of dollars it spent, mostly fruitlessly, to develop thorium fuels, the US government will have to spend billions more, at numerous federal nuclear sites, to deal with the wastes produced by those efforts. And America's energy-from-thorium quest now faces an ignominious conclusion: The US Energy Department appears to have lost track of 96 kilograms of uranium 233, a fissile material made from thorium that can be fashioned into a bomb, and is battling the state of Nevada over the proposed dumping of nearly a ton of left-over fissile materials in a government landfill, in apparent violation of international standards.

Early thorium optimism. The energy potential of the element thorium was discovered in 1940 at the University of California at Berkeley, during the very early days of the US nuclear weapons program. Although thorium atoms do not split, researchers found that they will absorb neutrons when irradiated. After that a small fraction of the thorium then transmutes into a fissionable material—uranium 233—that does undergo fission and can therefore be used in a reactor or bomb.

By the early 1960's, the US Atomic Energy Commission (AEC) had established a major thorium fuel research and development program, spurring utilities to build thorium-fueled reactors. Back then, the AEC was projecting that some 1,000 nuclear power reactors would dot the American landscape by the end of the 20th century, with a similar nuclear capacity abroad. As a result, the official reasoning held, world uranium supplies would be rapidly exhausted, and reactors that ran on the more-plentiful thorium would be needed.

With the strong endorsement of a congressionally created body, the Joint Committee on Atomic Energy, the United States began a major effort in the early 1960s to fund a two-track research and development effort for a new generation of reactors that would make any uranium shortage irrelevant by producing more fissile material fuel than they consumed.

The first track was development of plutonium-fueled "breeder" reactors, which held the promise of producing electricity and 30 percent more fuel than they consumed. This effort collapsed in the United States in the early 1980's because of cost and proliferation concerns and technological problems. (The plutonium "fast" reactor program has been able to stay alive and still receives hefty sums as part of the Energy Department's nuclear research and development portfolio.)

The second track—now largely forgotten—was based on thorium-fueled reactors. This option was attractive because thorium is far more abundant than uranium and holds the potential for producing an even larger amount of uranium 233 in reactors designed specifically for that purpose. In pursuing this track, the government produced a large amount of uranium 233, mainly at weapons production reactors. Approximately two tons of uranium 233 was produced, at an estimated total cost of $5.5 to $11 billion (2012 dollars), including associated cleanup costs.

The federal government established research and development projects to demonstrate the viability of uranium 233 breeder reactors in Minnesota, Tennessee, and Pennsylvania. By 1977, however, the government abandoned pursuit of the thorium fuel cycle in favor of plutonium-fueled breeders, leading to dissent in the ranks of the AEC. Alvin Weinberg, the long-time director of the Oak Ridge National Laboratory, was, in large part, fired because of his support of thorium over plutonium fuel.

By the late 1980's, after several failed attempts to use it commercially, the US nuclear power industry also walked away from thorium. The first commercial nuclear plant to use thorium was Indian Point Unit I, a pressurized water reactor near New York City that began operation in 1962. Attempts to recover uranium 233 from its irradiated thorium fuel were described, however, as a "financial disaster." The last serious attempt to use thorium in a commercial reactor was at the Fort St. Vrain plant in Colorado, which closed in 1989 after 10 years and hundreds of equipment failures, leaks, and fuel failures. There were four failed commercial thorium ventures; prior agreement makes the US government responsible for their wastes.

Where is the missing uranium 233? As it turned out, of course, the Atomic Energy Commission's prediction of future nuclear capacity was off by an order of magnitude—the US nuclear fleet topped out at about 100, rather than 1,000 reactors—and the predicted uranium shortage never occurred. America's experience with thorium fuels faded from public memory until 1996. Then, an Energy Department safety investigation found a national repository for uranium 233 in a building constructed in 1943 at the Oak Ridge National Laboratory. The repository was in dreadful condition; investigators reported an environmental release from a large fraction of the 1,100 containers "could be expected to occur within the next five years in that some of the packages are approaching 30 years of age and have not been regularly inspected." The Energy Department later concluded that the building had "deteriorated beyond cost-effective repair. Significant annual costs would be incurred to satisfy current DOE storage standards, and to provide continued protection against potential nuclear criticality accidents or theft of the material."

The neglect extended beyond the repository and storage containers; the government had also failed to keep proper track of its stores of uranium 233, officially classified as a Category I strategic special nuclear material that requires stringent security measures to prevent "an unauthorized opportunity to initiate or credibly threaten to initiate a nuclear dispersal or detonation."

A 1996 audit by the Energy Department's inspector general reported that the Oak Ridge National Laboratory, the Rocky Flats nuclear weapons facility, and the Idaho National Laboratory "had not performed all required physical inventories ... the longer complete physical inventories are delayed, the greater the risk that unauthorized movement of special nuclear materials could occur and go undetected." The amounts of uranium 233 that the Oak Ridge and Idaho national labs have reported in their inventories has significantly varied. Based on a review of Energy Department data, there appears to be an inventory discrepancy; 96 kilograms or 6 percent of the U-233 produced is not accounted for. The Energy Department has yet to address this discrepancy, which difference is enough to fuel at least a dozen nuclear weapons.

Uranium 233 compares favorably to plutonium in terms of weaponization; a critical mass of that isotope of uranium—about 6 kilograms, in its metal form—is about the same weight as a plutonium critical mass. Unlike plutonium, however, uranium 233 does not need implosion engineering to be used in a bomb. In fact, the US government produced uranium 233 in small quantities for weapons, and weapons designers conducted several nuclear weapons tests between 1955 and 1968 using uranium 233. Interest was renewed in the mid-1960s, but uranium 233 never gained wide use as a weapons material in the US military because of its high cost, associated with the radiation protection required to protect personnel from uranium 232, a highly radioactive contaminant co-produced with uranium 233.

For a terrorist, however, uranium 233 is a tempting theft target; it does not require advanced shaping and implosion technology to be fashioned into a workable nuclear device. The Energy Department recognizes this characteristic and requires any amount of more than two kilograms of uranium 233 to be maintained under its most stringent safeguards, to prevent "onsite assembly of an improvised nuclear device." As for the claim that radiation levels from uranium 232 make uranium 233 proliferation resistant, Oak Ridge researchers note that "if a diverter was motivated by foreign nationalistic purposes, personnel exposure would be of no concern since exposure ... would not result in immediate death."

The end of an unfortunate era. After its 1996 safety investigation at the Oak Ridge National Laboratory, the Energy Department spent millions to repackage about 450 kilograms of uranium 233 that is mixed with uranium 235 and sitting in the lab's Building 3019, and to dispose of diluted uranium 233 fuel stored at the Idaho National Lab. The Energy Department's nuclear weapons program managed to shift responsibility for the stockpile in Building 3019 from Oak Ridge to the Office of Nuclear Energy, which envisioned using the uranium 233 to make medical isotopes. This plan fell apart, and in 2005 Congress ordered the Energy Department to dispose of the uranium 233 stockpile as waste.

Since then, the Energy Department's Office of Environmental Management has considered uranium 233 disposal to be an unfunded mandate, disconnected from other, higher-priority environmental cleanup compliance agreements. After several fits and starts, including a turnover of four project managers in less than two years, the Energy Department's disposition project "had encountered a number of design delays, may exceed original cost estimates, and will likely not meet completion milestones," the department's inspector general reported in 2010. The cost of the project increased from $384 million to $473 million—or more than $1 million per kilogram for the disposal of uranium 233.

In an effort to reduce costs, the Energy Department developed a plan to ship nearly 75 percent of the fissile materials in Building 3019, *as is,* to a landfill at the Nevada Nuclear Security Site by the end of 2014. Because such disposal would violate the agency's formal safeguards and radioactive waste disposal requirements, the Energy Department changed those rules, which it can do without public notification or comment. Never before has the agency or its predecessors taken steps to deliberately dump a large amount of highly concentrated fissile material in a landfill, an action that violates international standards and norms.

In June 2013, Nevada Gov. Brian Sandoval and members of the state's congressional delegation announced their opposition to the landfill disposition plan. Energy Secretary Ernest Moniz visited with Sandoval but did not back down from the landfill plan. Even though the Oak Ridge material in its current form meets the legal definition for radioactive waste requiring geologic disposal, the Energy Department has taken the position that the sweeping authority granted to it under the Atomic Energy Act allows the department to dispose of the fissile material however it pleases, regardless of the state's objection.

The United States has spent nearly $10 billion to discourage practices like landfill dumping of fissile materials in the former Soviet Union, only to have the Energy Department try it at home. Heedless of the discrepancy between overseas and domestic disposal policies, the department's agenda—which focuses on saving money on guards who would be needed to secure the uranium 233—is placing the United States in an impossible position when it comes to criticizing the nuclear materials security of other countries. So ends America's official experience with thorium, the wonder fuel.