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Reprocessing Key To Nuclear Plan

Nuclear waste impasse drives DOE to push for reprocessing spent fuel despite costs, technological hurdles

Jeff Johnson

"We do not need six new nuclear power plants in this country, we need 60, and the world needs 600. And we need them all in a fairly short period of time," said Clay Sell, deputy secretary of the Department of Energy.

Areva

LA HAGUE The proposed Department of Energy nuclear spent-fuel reprocessing facility would be the world's largest, even topping the French facility shown here.

Sell was speaking to a half-dozen reporters pressed into a narrow basement hallway in Washington, D.C.'s Mayflower Hotel last month. He had just wrapped up a speech to 100 high-level energy executives in which he touted the Bush Administration's energy plans and underscored its program to spur development of new nuclear power technologies. He ended his speech by announcing a $60 million offer to encourage nongovernment nuclear energy research, one of many DOE nuclear research projects announced this year.

Nuclear energy, a non-carbon-emitting power source, Sell stressed, helps reduce carbon dioxide in the atmosphere and at least slows down the rate of climate change. Nuclear energy produces 20% of U.S. electricity and 16% of the world's. DOE would like to see the nuclear contribution grow, and its programs to develop advanced nuclear technologies fit well with the Administration's overall emphasis on reducing CO_2 emissions through technological solutions rather than regulations, caps, or mandates.

DOE has poured large amounts of federal money and support into near-term nuclear power programs, including grants, loan guarantees, risk insurance for construction delays, tax credits, and a boost in R&D spending. The Nuclear Regulatory Commission (NRC) has also done its part through a simplified process to speed up licensing for new reactors.

As a result, Sell said, "I am fairly confident we will get the next six plants built in the U.S. I mean, the provisions in the Energy Policy Act of 2005 alone provide pretty rich incentives for the first six plants."

But to build the 60 new reactors that Sell thinks the U.S. needs, the country is going to have to "deal with nuclear waste in a way very different from how we deal with it now," he continued.

Currently, U.S. commercial nuclear waste or spent fuel is stored on-site at some 100 commercial reactors, awaiting the opening of the long-delayed Yucca Mountain underground repository in Nevada. Troubled by technical, legal, geological, and political problems, the Yucca Mountain site is not likely to accept waste until 2020 or later. Meanwhile, commercial reactors are humming along, producing electricity and radioactive waste. The U.S. is getting close to having generated enough spent fuel to reach Yucca Mountain's statutorily set disposal cap of 63,000 metric tons of commercially generated waste.

Sell's plan is to see this spent fuel moved to one or more interim storage facilities and then reprocessed—or "recycled," as he calls it—into new fuel, providing time for Yucca Mountain to be licensed by NRC and built (C&EN, Dec. 11, 2006, page 12).

"We think we can develop-on a temporary basis-the consolidation of spent nuclear fuel at U.S. recycling locations where it can be dealt with and where we can extract its great energy value while we are working on the long-term goal of licensing and building a permanent geological repository," Sell said. "Let's be real about 'temporary,' " he added. "We are talking about decades.

"We will still need Yucca Mountain," he continued, "but we need to make the waste smaller and safer, and we need to get greater energy value out of it. That means advanced recycling."

What Sell and DOE want is the Global Nuclear Energy Partnership (GNEP), a whole new regime for nuclear energy. GNEP was announced by DOE in May 2006 with much fanfare, including endorsement by nine DOE lab heads. However, critics warn that the program may wind up concentrating radioactive material at the proposed reprocessing plant and allow continued avoidance of the nuclear waste issue that has always vexed the nuclear power industry.

For GNEP to work, the Energy Department must ramp up R&D to settle on a technology to reprocess spent fuel, build a plant to reprocess the spent fuel into uranium and plutonium and other elements, and develop and build "fast neutron" reactors to burn the plutonium as fuel and generate electricity. DOE also plans to take its reprocessing system to the world, selling reactor fuel to other countries and taking back their spent fuel for further reprocessing.

GNEP has the far-reaching goal of encouraging nuclear energy development throughout the world. The U.S. would lead a consortium of countries that already have reprocessing programs, providing nuclear fuel services to countries that lack that capability. In return for being allowed to buy fresh fuel and return spent fuel for reprocessing, these countries would agree not to build uranium enrichment facilities or spent-fuel reprocessing plants.

By providing and retrieving this ready-to-use nuclear fuel, DOE hopes to discourage other nations, like Iran, from developing their own technologies that could produce weapons-grade nuclear material—either by obtaining plutonium through reprocessing of spent fuel or using cascades of centrifuges to enrich uranium beyond the 5% U-235 required for power generation to the higher levels needed to build a modern weapon.

GNEP is going to take time and money. Energy Secretary Samuel Bodman predicted that funding for the program would grow to billions of dollars by the end of the decade and could run to $40 billion over the next 10 years. A 1996 study by the National Academy of Sciences put the price tag higher—as much as $100 billion. Even under the best of circumstances, it would be decades before GNEP is up and running (C&EN, March 27, 2006, page 34).


DOE
Sell


Idaho National Lab
Finck

Many in Congress have doubts about GNEP because of its size and cost and are concerned about its potential to provide terrorists and others easier access to separated plutonium. Some also worry it will draw away funds that are needed to complete Yucca Mountain. For 2007, Congress cut the Administration's GNEP request of $250 million to $168 million. For 2008, DOE is seeking $405 million, but the House Appropriations Committee in early June cut the request to $120 million and said, "It is unnecessary to rush into a plan that continues to raise concerns among scientists and has only weak support from industry."

The most controversial part of GNEP is the Administration's plan to reintroduce spent-fuel reprocessing in the U.S.

GNEP calls for construction by 2020 of the world's largest nuclear fuel reprocessing facility, capable of reprocessing 2,000 to 3,000 tons of spent reactor fuel a year. This is significantly larger than the French La Hague reprocessing plant—currently the biggest in the world—and large enough to reprocess all the waste generated annually by the U.S.'s 103 commercial nuclear power plants.

Located on the Cotentin Peninsula in Normandy, La Hague can treat 1,650 tons of spent fuel a year. Built as a commercial facility in 1976, La Hague now handles less than half its top design capacity, as its international business has come to an end. In addition to the French plant, an 800-ton facility is nearly ready to open in Japan, but it is unclear what will happen to the plutonium that becomes separated through reprocessing there.

The U.S. ended a fledgling reprocessing program during Jimmy Carter's presidency because he feared global proliferation of nuclear weapons. Carter's concern was heightened following India's detonation of a nuclear bomb in 1974. That bomb was made from plutonium that was reprocessed from an Indian civilian reactor provided by Canada with U.S. technical support.

Although President Ronald Reagan revoked a Carter executive order banning spent-fuel reprocessing, the U.S. continued to steer clear of reprocessing due to its cost. As a result, U.S. commercial reactors use nuclear fuel one time through and then store the spent fuel on-site with the intention of moving it eventually to a geologic repository.

That policy, Sell said, "makes no sense in a world where nuclear power is expanding." Spent fuel, he said, is an "incredible energy resource. Ninety-five percent of the energy value of uranium still is contained in spent fuel." Japan, France, Russia, and the U.K. reprocess nuclear fuel, he added.

A host of arms control groups, physicists, and members of Congress, however, have big doubts about GNEP, both on proliferation and economic grounds. They point to the same countries identified by Sell and note that some 250 tons of separated plutonium has been generated due to their reprocessing efforts—enough to make 30,000 nuclear bombs. The countries have stockpiled the plutonium but are not close to building a system of reactors to recycle the plutonium or a permanent waste repository. Reprocessing for some of these countries, particularly the U.K., has also resulted in extensive radioactivity pollution problems.

Then there is the funding issue. "GNEP is a waste of money," said Richard Garwin, a nuclear physicist and frequent governmental adviser on nuclear issues, speaking at a symposium of the American Association for the Advancement of Science earlier this year. He urged the U.S. to continue on its current path of storing the waste on-site while developing a geological repository. This strategy is far cheaper as well as more

proliferation-resistant than reprocessing, he added.

Garwin is joined by Ernest Moniz and John Deutch, Massachusetts Institute of Technology professors, nuclear power advocates, and authors of an influential report on nuclear power. They, too, oppose GNEP's size and scope. Moniz warned that the U.S. has done far too little reprocessing research over the past 20-plus years to lay the groundwork for a commercial-scale facility. He noted as well that there is no uranium shortage to justify reprocessing and reusing spent fuel in the first place.

The push for reprocessing stretches back three or more decades when it was feared there would be a uranium shortage. At that time, the U.S. began exploring reprocessing spent fuel to separate out plutonium to be used as fuel in liquid-metal-cooled, fast-neutron breeder reactors. These breeder reactors could, by tapping the energy in U-238, produce more plutonium than was used to fuel the initial reactions. As it turns out, breeder reactors proved too costly and unreliable. Now, fewer than a half-dozen reprocessing and demonstration breeder reactor facilities operate worldwide.

GNEP, however, could be a sharp split from the past, says Phillip Finck, associate laboratory director for nuclear science and technology at DOE's Idaho National Laboratory, which is leading GNEP's development. The program must be seen as a "fully integrated nuclear waste management system," he says. Finck has led nuclear efforts in both France and the U.S.

Reprocessing and recycling as done by the French, Finck says, does not reduce the amount of high-level waste that will be stored in a U.S.-style repository, but it has provided a 15- to 20-year delay in the time when a waste repository will be needed. Even so, the French remain far behind the U.S. in siting a repository. At the same time, reprocessing and recycling could offer some breathing room for the U.S. nuclear industry to expand as DOE struggles to get Yucca Mountain licensed and constructed.

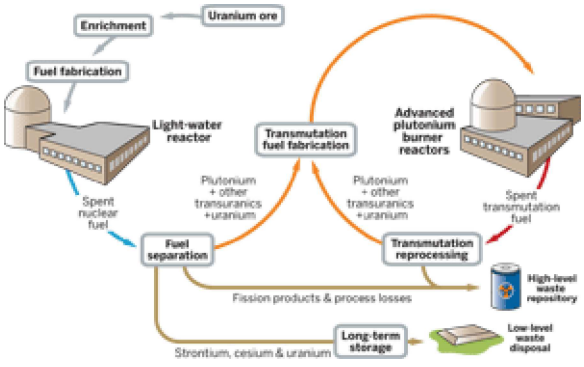
GNEP's plans basically would include three facilities: a commercial-scale plant to reprocess spent nuclear fuel; a prototype fast-neutron plutonium "burner" reactor to generate electricity while converting long-lived transuranic elements, particularly plutonium, into shorter-lived radioactive elements; and a research laboratory to study reprocessing and advanced-fuel technologies.

Eleven community-company consortia have applied to DOE to house the facilities. Only the laboratory is certain to be a government facility. DOE is strongly encouraging private companies to take charge and ownership of the others. DOE has spent more than $10 million to help the 11 groups prepare site studies.

The French use the PUREX (plutonium and uranium recovery by extraction) process to separate plutonium from spent fuel. The plutonium is used to produce mixed oxide fuel for the French power reactors, or it is stockpiled. Other elements are vitrified for future disposal in a repository.

PUREX is a U.S.-developed technology that goes back to the Manhattan Project, when it was used to separate plutonium for nuclear weapons. It uses an aqueous nitric acid solution along with an organic solvent to dissolve irradiated spent fuel, separating plutonium from uranium.

However, DOE's Argonne National Laboratory has developed what it calls the UREX process (uranium extraction), which does not focus on plutonium, Finck says. Instead, UREX isolates pure uranium from spent fuel. UREX is also a chemical process that is in some ways similar to PUREX.



View Enlarged Image

Refueling The Energy Department is proposing a closed fuel cycle and a very different way of treating and disposing of spent nuclear fuel and radioactive waste.

UREX output streams include uranium at a high level of purity, which can be re-enriched for use as reactor fuel or handled as low-level waste. It also separates long-lived fission products, technetium and iodine, that would be disposed of at Yucca Mountain. Several shorter lived and thermally hot fission products, Finck explains, including cesium and strontium, would be held aboveground for 100 to 200 years while they cooled for eventual disposal as low-level waste.

The key transuranics—plutonium, neptunium, americium, curium, and some uranium—from UREX would be fabricated into fuel for an advanced "recycling" fast-neutron "burner" reactor, Finck says. This transuranic burner reactor uses technology similar to a plutonium breeder reactor, he says, except for a modification to its core allowing it to burn transuranics rather than create more of them, as breeder reactors do.

A single pass through the burner reactor destroys up to 20% of the core's plutonium and other transuranics, shifting them to fission products intended for geologic storage. The remaining plutonium and uranium would be refabricated into new fuel and returned for another pass through the burner reactor.

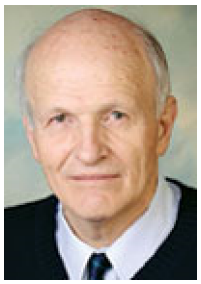
All this could result in a reduction of high-level nuclear waste if the components come together as planned. Finck says the amount of waste placed at Yucca Mountain could be increased by one to two orders of magnitude. Most of the gain would come through reducing thermal heat of the waste, which would allow waste to be more densely packed in the repository tunnels. Volume would also be reduced somewhat, Finck says.

Although much of the concern over GNEP has centered on spent-fuel reprocessing, the new burner reactor is actually the biggest and most costly part of the program.

To keep pace with the plutonium output from the reprocessing plant, the U.S. will need to license and construct more than 30 new fast-neutron burner reactors, each in the 1,000-MW range, Finck says. Otherwise, the U.S. will face a buildup of surplus plutonium, similar to but larger than what has occurred at the rest of the world's reprocessing facilities.

The reprocessing facility will separate about 24 tons of plutonium each year just to keep up with spent-fuel output of current reactors, says Frank von Hippel, a physicist, former White House official, and international affairs professor at Princeton University. Among his many concerns over GNEP, he particularly worries about the nonproliferation issues that ended reprocessing in the U.S. decades ago. He believes GNEP will provide a ready source of plutonium for states or terrorists that are seeking nuclear weapons.

To make the plutonium less accessible, Finck says, it should be mixed with hot fission products, as well as safeguarded.


Princeton U
Von Hippel

Von Hippel counters: "Once obtained, it would be trivial to separate out plutonium in this form. You could do it in an unshielded glove box with simple chemistry."

Finck acknowledged a glove box operation might succeed. "But this is true for any transuranic in spent fuel. It is a law of nature, unfortunately," he says. "The whole idea is to make it difficult to divert, and to put it in a form where it is unattractive. You must guard it well and mix it up with hot fission products."

Von Hippel, Moniz, Garwin, and other opponents all urged that the U.S. continue with its current fuel program, store the spent-fuel waste in dry casks at reactor sites, and move ahead with the Yucca Mountain repository. They also noted that the limit on capacity there is not a physical cap but one set by law, which could be increased. Von Hippel cites a study by the nuclear industry's research arm, the Electric Power Research Institute, that estimated the area that includes Yucca Mountain is sufficient to store 260,000 to 570,000 tons of spent fuel—far more than the 63,000-metric-ton legal cap for commercial reactors and two to five times the amount that will be generated by the currently operating U.S. power reactors.

"We need to focus on what we are doing now and do it better," von Hippel says. "I've got no problem with nuclear power. The problem is a group of people have been bitten by the plutonium breeder reactor bug and want to keep the R&D money flowing. This is a wasteful program and a dangerous one with regard to weapons material proliferation."

The commercial nuclear power industry takes a middle path on GNEP. The Nuclear Energy Institute supports research on reprocessing and advanced reactors, especially if construction of the new facilities is married to interim waste storage away from their reactor sites, an NEI spokesman says. The institute believes moving the waste from on-site storage at the reactor site is needed to trigger its hoped-for nuclear revival.

And the longer term interim storage would "decouple" the decision to build new nuclear power plants from ongoing problems over the repository, said John Rowe, Exelon Corp. chief executive officer and NEI board chairman, speaking at an industry conference on May 23.

"But we risk losing everything," Rowe says, "if we cannot tell our friends and neighbors with confidence that the federal government is meeting its commitment to safely store spent fuel."

GNEP's price tag and ambitious plan will come under increased scrutiny during Senate Energy & Natural Resources Committee and congressional appropriations hearings this summer. The committees are likely to explore whether GNEP is a real nuclear waste solution or an expensive program centralizing radioactive waste storage to help ease the way for new power plant construction without fixing the waste problems inherent in nuclear energy.

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