Nuclear fuel recycling could offer plentiful energy (w/ Video)

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Frances Dozier conducts research on recycling used nuclear fuel in a glovebox at Argonne National Laboratory.

Imagine the mess if we mined one ton of coal, burned five percent of it for energy, and then threw away the rest.

That is what happens with uranium for nuclear fuel today. Currently, only about five percent of the uranium in a fuel rod gets fissioned for energy; after that, the rods are taken out of the reactor and put into permanent storage.

There is a way, however, to use almost all of the uranium in a fuel rod. Recycling used nuclear fuel could produce hundreds of years of energy from just the uranium we've already mined, all of it carbon-free.

Problems with older technology put a halt to recycling used nuclear fuel in the United States, but new techniques developed by scientists at the U.S. Department of Energy's (DOE) Argonne National Laboratory address many of those issues.

One of the reasons why so little uranium is used is that almost every commercial reactor today is a type called a light-water reactor, or LWR. While LWRs are good at many things, they aren't designed to wring every last watt of energy out of fuel.

But LWRs aren't the only type of reactor. Another class, called *fast reactors*, boasts the ability to "recycle" used fuel to get much more energy out of it.

The main difference between the types of reactors is what cools the core. LWRs use ordinary water. Fast reactors use a different coolant, such as sodium or lead. This coolant doesn't slow the neutrons as much, and consequently, the reactor can fission a host of different isotopes. This means that fast reactors can get electricity out of many kinds of fuel, including all of that leftover used fuel from LWRs. (LWRs can burn recycled fuel too, with some modification, but they aren't as good at it.)

If we built fast reactors, it would be entirely possible to take all of the used fuel we've generated over the past 60 years, currently stored at reactor sites, and feed it back into fast reactors. Some of it would still need to be permanently stored, but far less; recycling all of the uranium and other actinides would reduce the volume of waste we have to store permanently by 80 percent. To get used fuel ready to put back into a reactor, however, it needs some processing. This has been done for decades in other countries using a technique called PUREX, which has its roots in 1940s U.S. research to separate plutonium out of used fuel. The problem with PUREX is the risk that the process could be diverted to extract weapons-grade plutonium, a concern that prompted then-president Jimmy Carter to ban PUREX reprocessing in 1978.

This spurred scientists at Argonne to search for a different, more efficient way to reprocess used fuel. Their brainchild is a technique called "pyroprocessing", which uses an electrical current to sift out the useful elements and does not separate pure plutonium.

How it works

When used fuel comes out of a light-water reactor, it's in a hard ceramic form, and almost all of it is still just uranium – about 95 percent, along with one percent other long-lived radioactive elements, called actinides. Both of these can be recycled as fuel. The remaining four percent are fission products, which are truly unusable.

Pyroprocessing begins by chopping the ceramic fuel into little pieces and converting it into metal. Then it's submerged in a vat of molten salts, and an electric current separates out uranium and other reusable elements, which can be shaped back into fuel rods.

The truly useless fission products stay behind to be removed from the electrorefiner and cast into stable glass discs. These leftovers do have to be put into permanent storage, but they revert back to the radioactivity of naturally occurring uranium in a few hundred years – far less than the thousands of years that untreated used fuel needs to be stored.

Why don't we use pyroprocessing already?

- **Lack of financial incentive.** Raw uranium is cheap. At the moment, it's cheapest to run the fuel through once and then store it, mostly because other methods would have to be researched and tested. Light-water reactors are cheaper to build, because both utilities and the U.S. Nuclear Regulatory Committee are familiar with the technology. Since the process for approving a new reactor design takes years, there's not much incentive to build different types of reactors, including fast reactors.

- **Proliferation fears**. Some worry that the spread of reprocessing technology will help terrorists gain access to plutonium and uranium for weapons. Pyroprocessing concepts address this fear in two ways. First, the technique itself laces the plutonium with uranium and highly radioactive actinides, making both stealing it and creating weapons with it more difficult. Second, pyroprocessing plants with fast reactors can be built directly on the site of a former light-water reactor to create an enclosed recycling facility. This approach reduces the security risk by eliminating the need to transport the used fuel from and new fuel to the fast reactors at the site.

Looking ahead

To date, nuclear energy remains the only stable, large-scale source of carbon-free electricity. Reactors are sprouting across Asia as its developing powers need more energy; China alone has quintupled its nuclear capacity in just the past decade.

Argonne scientists and engineers continue to work on ways to make fuel recycling safer, cheaper and more efficient. In the Engineering-Scale Electrorefiner, a large glovebox, Argonne scientists test pyroprocessing at a scale closer to what industry would use. They've also turned to computational modeling, which helps simulate the chemical processes down to molecules and up to whole facilities. Other Argonne research projects design and studysmall modular reactors and different types of fast reactors, including techniques to reduce the cost.

Provided by Argonne National Laboratory