Union of Concerned Scientists: https://www.ucsusa.org/about/news/analysis-published-science-finds-high-assay-low-enriched-uranium-fuel-be-produced-small

Analysis Published in Science Finds High Assay Low-Enriched Uranium Fuel to be Produced for Small Nuclear Power Reactors Poses a Greater Proliferation Threat than Previously Acknowledged

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An analysis published today in the journal Science found that, contrary to a widely held assumption, the high assay low-enriched uranium (HALEU) now being produced with federal subsidies to fuel the next generation of small nuclear power reactors can be used directly to make nuclear weapons, and thus presents greater terrorism and nuclear proliferation threats than publicly acknowledged by the federal government and industry.

"Were HALEU to become a standard reactor fuel without appropriate restrictions determined by an interagency security review, other countries would be able to obtain, produce, and process weapons-usable HALEU with impunity, eliminating the sharp distinction between peaceful and nonpeaceful nuclear programs," according to the analysis conducted by five of the world's leading academic and independent proliferation experts. "Such countries would be only days away from a bomb, giving the international community no warning of forthcoming nuclear proliferation and virtually no opportunity to prevent it."

The paper calls for additional measures to mitigate this risk as the United States and other countries pursue international deployment of HALEU-fueled reactors. "Given the stakes, we recommend that the US Congress direct the DOE's National Nuclear Security Administration to commission a fresh review of HALEU proliferation and security risks by US weapons laboratory experts."

Fuels for today's commercial reactors do not rely on HALEU, which is enriched to between 10% and 20% uranium-235, and instead typically use uranium enriched to below 5%. At those levels, the fuel cannot sustain an explosive chain reaction, which has prevented nations or terrorists from repurposing commercial reactor fuel for weapons.

However, for technical reasons, many of the nuclear reactor designs that engineers want to build today would use HALEU. Since HALEU is below the 20% enrichment lower bound that defines highly-enriched uranium (HEU), which is understood to be directly usable in nuclear weapons, development of these reactors has not raised significant proliferation concerns.

But by reviewing information in the open literature to analyze the quantities and enrichment levels of HALEU that the new reactors would use, the authors of the Science paper concluded that HALEU above about 12% uranium-235 could be used to make practical weapons with yields comparable to the bombs that destroyed Hiroshima and Nagasaki. Many proposed reactors could contain enough HALEU to make a nuclear weapon and thus pose serious security risks, according to the article.

These risks are increasing because, although the quantity of HALEU in commercial use today is relatively small, the federal government is actively encouraging HALEU use and funding its production.

The U.S. Energy Department is covering half of the cost of deployment of two demonstration nuclear plants that plan to use multi-ton quantities of HALEU fuel, including the "Natrium" fast reactor that TerraPower, a company founded by Bill Gates, plans to build in Kemmerer, Wyoming. And earlier this year, the federal government allocated $2.7 billion to subsidize production of enriched uranium, including HALEU, to fuel these and other reactor projects that are being considered for a range of applications, including powering data centers and oil and gas operations. Other countries are following suit.

Many HALEU-fueled reactors would use uranium enriched to just below the 20% limit, which poses the highest risk. The researchers suggest that "a reasonable balance of the risks and benefits would be struck if enrichments for power reactor fuels were restricted to less than 10 to 12% uranium-235," which would allow many reactor designs to move forward with only modest economic consequences. However, if higher enrichments continue to be used, the authors recommend that the security standards for protecting HALEU from theft be strengthened to the levels that apply for the weapon-usable materials HEU and plutonium.

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Stanford Report: https://news.stanford.edu/stories/2022/05/small-modular-reactors-produce-high-levels-nuclear-waste

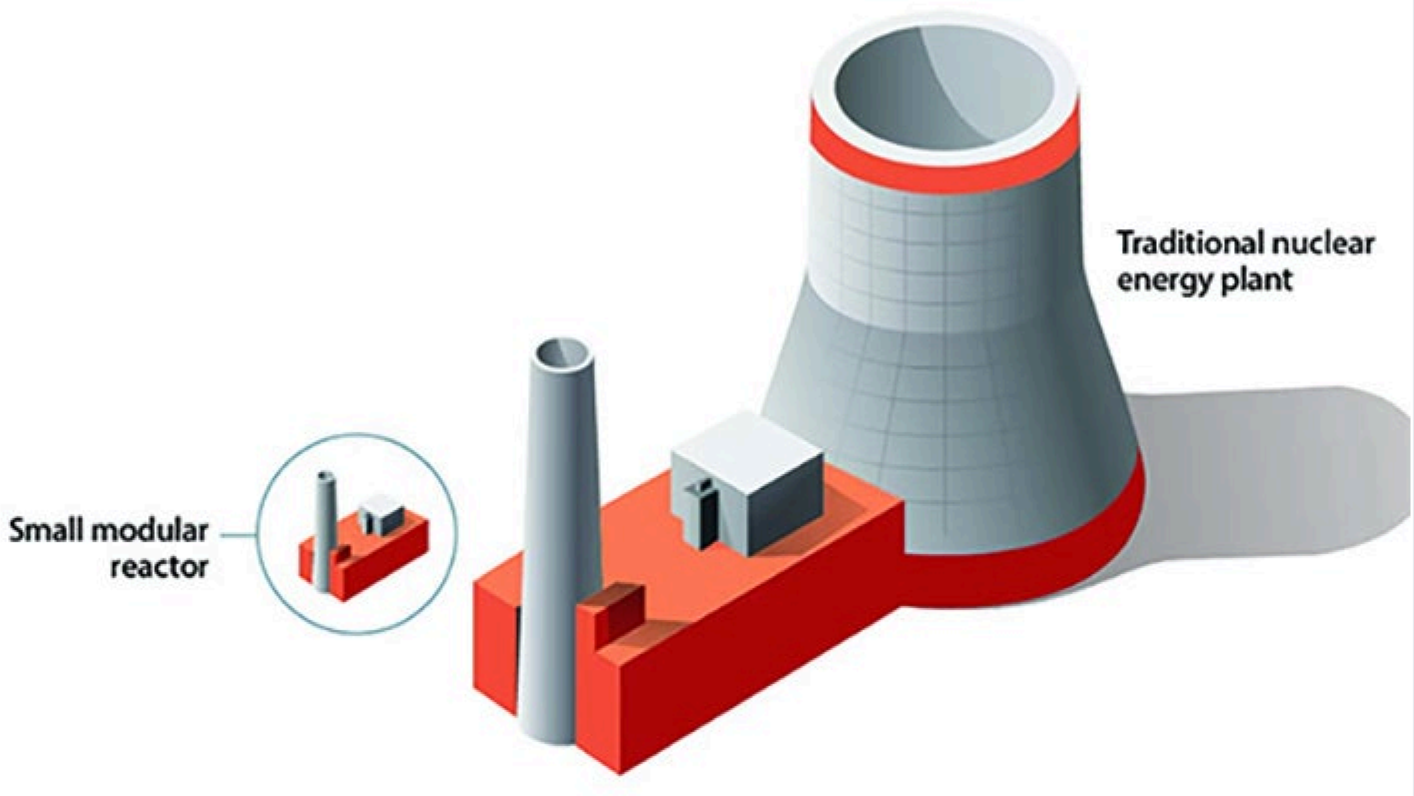
May 30th, 2022| 6 min read**Science & Engineering**

Stanford-led research finds small modular reactors will exacerbate

challenges of highly radioactive nuclear waste

Small modular reactors, long touted as the future of nuclear energy, will actually generate more radioactive waste than conventional nuclear power plants, according to research from Stanford and the University of British Columbia.

Nuclear reactors generate reliable supplies of electricity with limited greenhouse gas emissions. But a **nuclear power plant** that generates 1,000 megawatts of electric power also produces radioactive waste that must be isolated from the environment for hundreds of thousands of years. Furthermore, the cost of building a large nuclear power plant can be tens of billions of dollars.



Small modular reactors are about 1/10 to 1/4 the size of a traditional nuclear energy plant due to compact, simplified designs. (Image credit: Idaho National Laboratory)

To address these challenges, the nuclear industry is developing **small modular reactors** that generate less than 300 megawatts of electric power and can be assembled in factories. **Industry analysts** say these advanced modular designs will be cheaper and produce fewer radioactive byproducts than conventional large-scale reactors.

But a study **published** May 31 in *Proceedings of the National Academy of Sciences* has reached the opposite conclusion.

“Our results show that most small modular reactor designs will actually increase the volume of nuclear waste in need of management and disposal, by factors of 2 to 30 for the reactors in our case study,” said study lead author Lindsay Krall, a former MacArthur Postdoctoral Fellow at Stanford University’s **Center for International Security and Cooperation (CISAC)**. “These findings stand in sharp contrast to the cost and waste reduction benefits that advocates have claimed for advanced nuclear technologies.”

Global nuclear power

About 440 nuclear reactors operate **globally**, providing approximately 10 percent of the world’s electricity. In the **United States**, 93 nuclear reactors generate nearly a fifth of the country’s electricity supply.

Unlike power plants that run on coal or natural gas, nuclear plants emit little carbon dioxide, a major cause of global warming. Advocates say that as worldwide demand for clean energy increases, more nuclear power will be needed to minimize the effects of climate change.

But nuclear energy is not risk free. In the U.S. alone, commercial nuclear power plants have **produced** more than 88,000 metric tons of spent nuclear fuel, as well as substantial volumes of intermediate and low-level radioactive waste. The most highly radioactive waste, mainly spent fuel, will have to be isolated in deep-mined geologic repositories for hundreds of thousands of years. At present, the U.S. has no program to develop a geologic repository, after spending decades and billions of dollars on the Yucca Mountain site in Nevada. As a result, spent nuclear fuel is currently stored in pools or in dry casks at reactor sites, accumulating at a rate of about 2,000 metric tonnes per year.

Simple metrics

Some analysts maintain that small modular reactors will significantly reduce the mass of spent nuclear fuel generated compared to much larger, conventional nuclear reactors. But that conclusion is overly optimistic, according to Krall and her colleagues.

“Simple metrics, such as estimates of the mass of spent fuel, offer little insight into the resources that will be required to store, package, and dispose of the spent fuel and other radioactive waste,” said Krall, who is now a scientist at the **Swedish Nuclear Fuel and Waste Management Company**. “In fact, remarkably few studies have analyzed the management and disposal of nuclear waste streams from small modular reactors.”

Dozens of small modular reactor designs have been proposed. For this study, Krall analyzed the nuclear waste streams from three types of small modular reactors being developed by Toshiba, NuScale, and Terrestrial Energy. Each company uses a different design. Results from case studies were corroborated by theoretical calculations and a broader design survey. This three-pronged approach enabled the authors to draw powerful conclusions.

“The analysis was difficult, because none of these reactors are in operation yet,” said study co-author **Rodney Ewing**, the Frank Stanton Professor in Nuclear Security at Stanford and co-director of CISAC. “Also, the designs of some of the reactors are proprietary, adding additional hurdles to the research.”

Neutron leakage

Energy is produced in a nuclear reactor when a neutron splits a uranium atom in the reactor core, generating additional neutrons that go on to split other uranium atoms, creating a chain reaction. But some neutrons escape from the core – a problem called neutron leakage – and strike surrounding structural materials, such as steel and concrete. These materials become radioactive when “activated” by neutrons lost from the core.

The new study found that, because of their smaller size, small modular reactors will experience more neutron leakage than conventional reactors. This increased leakage affects the amount and composition of their waste streams.

“The more neutrons that are leaked, the greater the amount of radioactivity created by the activation process of neutrons,” Ewing said. “We found that small modular reactors will generate at least nine times more neutron-activated steel than conventional power plants. These radioactive materials have to be carefully managed prior to disposal, which will be expensive.”

The study also found that the spent nuclear fuel from small modular reactors will be discharged in greater volumes per unit energy extracted and can be far more complex than the spent fuel discharged from existing power plants.

“Some small modular reactor designs call for chemically exotic fuels and coolants that can produce difficult-to-manage wastes for disposal,” said co-author **Allison Macfarlane**, professor and director of the School of Public Policy and Global Affairs at the University of British Columbia. “Those exotic fuels and coolants may require costly chemical treatment prior to disposal.”

“The takeaway message for the industry and investors is that the back end of the fuel cycle may include hidden costs that must be addressed,” Macfarlane said. “It’s in the best interest of the reactor designer and the regulator to understand the waste implications of these reactors.”

Radiotoxicity

The study concludes that, overall, small modular designs are inferior to conventional reactors with respect to radioactive waste generation, management requirements, and disposal options.

One problem is long-term radiation from spent nuclear fuel. The research team estimated that after 10,000 years, the radiotoxicity of plutonium in spent fuels discharged from the three study modules would be at least 50 percent higher than the plutonium in conventional spent fuel per unit energy extracted.

Because of this high level of radiotoxicity, geologic repositories for small modular reactor wastes should be carefully chosen through a thorough siting process, the authors said.

“We shouldn’t be the ones doing this kind of study,” said Ewing. “The vendors, those who are proposing and receiving federal support to develop advanced reactors, should be concerned about the waste and conducting research that can be reviewed in the open literature.”

Rod Ewing is also a professor in the Department of Geological Sciences in the Stanford **School of Earth, Energy and Environmental Sciences**. The Center for International Security and Cooperation is part of the **Freeman Spogli Institute for International Studies** at Stanford.

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