# Nuclear energy and climate change

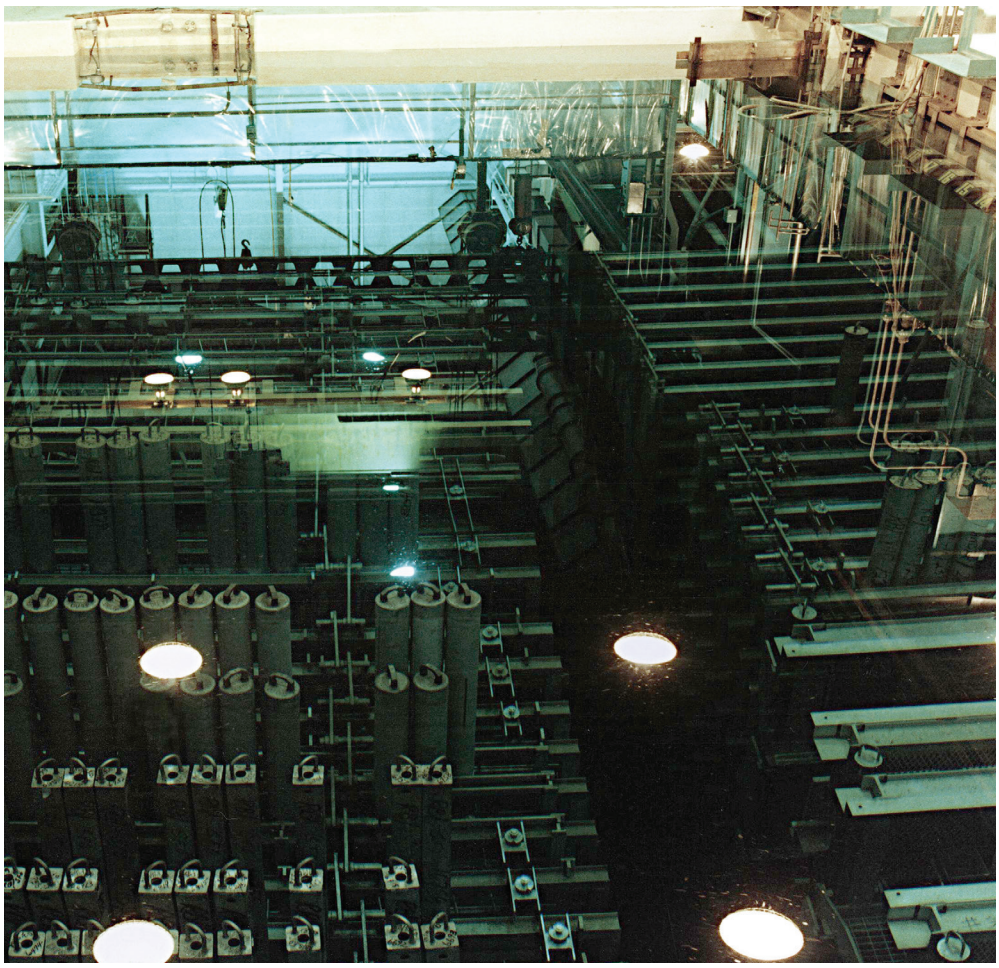
Toni Feder's piece "What is nuclear energy's role in mitigating climate change?" (PHYSICS TODAY, July 2024, page 22) doesn't discuss the need to deal with hazardous wastes. Feder writes, "Proponents say that nuclear energy is necessary in the climate change equation and that to wield influence in the nuclear arena, the US and other Western nations must be at the forefront of nuclear energy development and exports." But no one should receive a permit for reactor construction until the issue of waste disposal is addressed.

Plutonium-239, a byproduct of all reactors running on uranium-235, is radioactive and carcinogenic. There are two main methods for its safe long-term disposal: deep repositories and nuclear transmutation. The first has received serious attention worldwide, and Finland is the closest to operating such a site. But in the US, funding to build an underground waste repository under Nevada's Yucca Mountain was eliminated during the Obama administration. Currently, spent fuel is stored in cooling pools on-site and, after a period typically between one and two years, moved into dry storage casks. "Spent fuel storage at power plant sites is considered temporary, with the ultimate goal being permanent disposal," says the US Nuclear Regulatory Commission.[1]

The second method, transmutation, has received insufficient attention. Back in the 1970s, when I was getting my PhD in astronomy at the University of California (UC), Santa Cruz, I teamed up with F. William Reuter III, who was getting a master's in nuclear engineering at UC Berkeley. We investigated the tuned subatomic particle accelerator bombardment of $^{239}$Pu to transform it into shorter-lived or stable nuclei as a disposal technique. We calculated that the energy needed to do that for each $^{239}$Pu nucleus was greater than the energy liberated from each $^{235}$U nucleus. We concluded that it was a losing ball game and never published the result.

It has since occurred to me that renewable energy could be used as the accelerator power source to get rid of the waste, which would avoid the carbon dioxide emission of fossil-fuel power and the energy deficit issue of fission power. Additionally, others have looked at schemes that incorporate the wastes into a reactor designed for the purpose of self-powered transmutation.[2]

Small modular reactors (SMRs)—those generating under 300 megawatts electric (MWe) as opposed to the 1 GWe of traditional reactors—are being promoted as safer and cheaper. To date, one design has been approved by the Nuclear Regulatory Commission. The SMRs' modular uniform design might be better for ensuring safe operation, and their small sizes increase the potential for adjusting electricity generation to meet



**A RECEIVING BASIN** for spent fuel rods at the Savannah River Site in South Carolina. (Courtesy of the US Department of Energy.)

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demand, which is desirable for utility operations. But installing and operating a lot of SMRs would increase the need for qualified operators, secure transportation, and waste-disposal sites, and it would mean more reactors spread over the landscape. Proponents of SMRs claim that they create less waste. But one study shows that those small reactors would have a lower burnup of $^{235}$U and generate more spent nuclear fuel (high-level waste) and more intermediate and low-level wastes per unit of thermal power output than large reactors.[3]

Other new reactor designs include large plants that use primary coolants other than water and breeders, which convert $^{238}$U (not a reactor fuel isotope) to $^{239}$Pu. The US's first commercial breeder reactor, Fermi 1, was a failure, and radioactive parts of the facility are still on-site and still in need of further disposal. Other examples of breeders include the uneconomical and now-shut-down Phénix and Superphénix in France; they had numerous problems with their liquid sodium coolant, which ignites on contact with air.[4,5]

Issues such as those mentioned above ought to be resolved with speed. In the meantime, we can supply our electrical energy needs with known renewable energy technologies at lower direct and indirect costs. Renewables come with their own problems, but they do not represent the same regional threats to health or security as nuclear energy does.

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# The mucociliary escalator

Medical and nursing students will doubtlessly find the admirable article "The connection between Darwin's finches and bacterial flagellar motors" (Physics Today, March 2024, page 28) of interest. When teaching about potential and other energy considerations (for example, those associated with gravitation), I've taught my students about the important, similar mechanism of the mucociliary escalator. That system comprises motile cilia, which are waving flagellar-like fronds, on cells that line the main tubes between the mouth and lungs. Each escalator cell has about 200 cilia.

The air we breathe contains dust and other pollutants, and it's necessary to have a protective mechanism to prevent foreign, toxic solid materials from accumulating deep in the lungs. Sticky mucus is continuously produced in the main proximal tubes, and it traps those contaminating particles before they move very far from the mouth and nose. This loaded, contaminated mucus is continuously removed by the mucociliary escalator,[1] which transports it upward. Finally, in the mouth, it is usually then swallowed unconsciously, and so the lungs are continuously cleared of trapped foreign bodies and toxins.

That process is useful for illustrating the conservation of energy to medical and nursing students, but there is an additional bonus: discouraging smoking. Gases emitted by cigarettes and vapes kill cilia, and the steadily increasing amounts of pollutants deep in the smoker's lungs can be removed only through coughing—hence the existence of "smoker's cough," that bout of coughing that each smoker experiences on waking in the morning and clearing contaminated mucus that has been produced but not expelled during sleep.

## Reference


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