Uranium Enrichment: For Peace or for Weapons

Centrifuge technology is at the heart of the enrichment process, and the line between its uses for civilian and military purposes is hard to distinguish. Once a country has mastered this technology, the centrifuges can be reconfigured into cascades to either produce fuel for an electricity-generating nuclear reactor or the 25 kilograms of weapon-grade uranium that is sufficient for a nuclear weapon. The process is fairly simple for both. The uranium found in nature contains only 0.7% of the chain-reacting isotope uranium-235 (U-235), which is useful in weapons and for fueling civilian reactors, while 99.3% is uranium-238 (U-238), which is not useful.

Centrifuges spin at enormous speeds and the heavier isotope, U-238, moves to the outside and is then removed, leaving a higher concentration of U-235 behind, which can be further enriched. Most nuclear reactors that produce electricity only require fuel that is enriched to between 3-5% U-235.

This fuel does not represent a proliferation threat primarily because of the critical mass issue — the amount of material necessary to maintain a self-sustaining neutron chain reaction. If the level of enrichment is low, then it holds that the amount of the material must go up in order for a chain reaction to be sustained. The size can quickly become impractical for weapons delivery, so low enriched uranium (LEU) is not a threat.

Highly enriched uranium (HEU) is anything enriched above 20% and weapon-grade uranium is commonly considered to have been enriched above 90% U-235. However, some research reactors use 90% enriched U-235 to produce medical isotopes, so there are civilian applications for this fuel too.

Uranium versus plutonium: the see-sawing proliferation threat in research reactors

An inherent problem in research reactors, those built for scientific or medical purposes, is that either the uranium fuel or the plutonium in the spent fuel could potentially have strategic value as fuel in a nuclear weapon. For research reactors, the proliferation threat from the uranium fuel or the recovered plutonium see-saws depending on the concentration of U-235 in the fuel.

When a research reactor uses U-235 fuel enriched above 90%, the potential proliferator already has weapon-grade fuel. However, it would take a very long time to produce enough of the chain-reacting isotope plutonium-239 (Pu-239) in the spent fuel that could be recovered for a nuclear weapon. In this case, the uranium is the greater proliferation threat.

Conversely, research reactors that use LEU or natural uranium fuel produce spent fuel with high concentrations of plutonium, so the plutonium is the greater threat. Not much plutonium is needed to make a simple nuclear weapon. The International Atomic Energy Agency (IAEA) assumes eight kilograms (kg) is enough plutonium for a first-generation nuclear bomb.

Nuclear reactors that produce electricity are different from research reactors and only contain about 1% of fissile plutonium in their spent fuel. It would take a very long time to accumulate a sufficient quantity of plutonium for a nuclear bomb, so they do not represent a major proliferation threat.

Why does the 20% uranium enrichment line matter?

The simple answer is that enriching uranium to 20% represents about 90% of the effort needed to produce weapons grade fissile material. Once a proliferator reaches this threshold, it could be ready to weaponize in a relatively short time. For research reactor fuels enriched to less than 20%, the plutonium component dominates proliferation concerns, which is why the 20% mark is a useful distinction to differentiate between civilian and military applications.

Once the international community knows what to watch for, there are remedies. If plutonium production is the problem, then shipping out the spent fuel or placing safeguards on the reprocessing facilities can give the world confidence a program remains peaceful. If uranium enrichment is the problem, safeguards including limits on numbers and types of centrifuges, as well as online enrichment monitors that report directly to the IAEA, can give the world confidence that a program remains peaceful.