Center For Arms Control and Non-Proliferation

Nuclear Energy Technologies

The nuclear industry is developing several promising new technologies to advance peaceful uses of nuclear energy. These advancements can be categorized as either next-generation nuclear reactors or advanced nuclear fuels. Such technologies entail some proliferation risks that should be addressed and safeguarded as they develop.

Advanced Nuclear Reactors

Nuclear power has traditionally been generated through light water nuclear reactors, which use water to moderate neutron production and absorb the heat produced by the fission process to in turn produce steam. Several new reactor designs are currently being explored. These include advanced water-cooled reactors, non-water-cooled reactors, and fusion reactors. Advanced water-cooled reactors such as small modular reactors and micro reactors use the same principles as traditional reactors, simply on a smaller scale. Non-water-cooled reactor designs include molten salt reactors, which use molten salt as a coolant, and high temperature gas-cooled reactors, which moderate neutron generation with graphite and use helium as a coolant. Fusion reactors would use fusion principles (as opposed to fission) to produce energy and could be cooled using either water or gases. Commercial scale fusion technology remains the furthest from deployment, however.

In addition, there are numerous other fast breeder reactor designs being explored, such as lead-cooled and sodium-cooled, that would harness fast moving neutrons to produce plutonium fuel. There are questions over the viability of such advanced reactor designs, though stakeholders in the nuclear power industry claim these novel designs promise more efficient uranium consumption, lower operating costs and stronger proliferation safeguards. Alternatively, advanced reactors may pose new risks along nuclear supply chains and may require the development of new safeguards techniques.

Advanced Nuclear Fuels

Fuel for nuclear reactors has historically comprised uranium dioxide fuel pellets encapsulated within a zirconium alloy cladding assembly. Currently, industry and government are exploring several advanced fuel approaches. These include coated claddings, doped pellets, and iron-chromium-aluminum (FeCrAl) cladding. Coated claddings would involve an outermost layer of chromium or unique proprietary material on the cladding assemblies that are inserted into the nuclear reactor. Introducing a coat layer is said to enhance protection of the rods against debris fretting and corrosion. Doped pellets would have certain materials mixed into the uranium dioxide during manufacturing that industry claims would improve fission gas retention and reduce the release of radioactive gasses in the event of an accident. FeCrAl claddings are also emerging as an alternative to traditional zirconium alloy claddings because their characteristics purportedly improve plant efficiency and operations.

Many new reactor models will rely on high-assay low-enriched uranium (HALEU), or uranium-235 enriched up to 20 percent. Standard fuel for conventional reactors is enriched up to five percent and HALEU can be more easily enriched to weapons-grade compared with standard LEU, although it would still require an enrichment facility. HALEU is seen as advantageous to achieve smaller reactor designs that produce more power per unit of volume. Since there are not many sources of HALEU for purchase, some countries may seek indigenous enrichment capabilities.

Most current and proposed reactors use fuel that is not weapons-usable. Also, plutonium in spent fuel could not be used for weapons without a reprocessing facility. As long as safeguards and verification measures remain robust, many designs are fairly proliferation resistant. For instance, sealed core reactors where the reactor is transported as a single unit means the country where it is operating does not need to have any knowledge of the nuclear fuel cycle at all.