Safeguards and Security for Advanced Reactors Using HALEU

The American Nuclear Society (ANS) supports continued development and eventual deployment of advanced reactor designs including those that employ uranium fuel enriched to above 10 percent but below 20 percent in uranium-235 (U-235), commonly referred to as high-assay low-enriched uranium (HALEU).[a] Multiple emergent reactor designs at all scales, including microreactors, small modular reactors, and full-scale advanced reactors, plan to use HALEU, and many of those designs are supported by the U.S. Department of Energy's (DOE's) Advanced Reactor Demonstration Program. This fact underscores the importance of HALEU to the U.S. vision of the future of nuclear energy, both domestically and internationally.[2,3] Relative to the lower-enriched (typically 3 to 5 percent) uranium fuel used by light water reactors (LWRs), HALEU enables desirable improvements in reactor performance, including achieving higher power density, lengthening the refueling cycle, and increasing fuel utilization by enabling higher fuel burnup.

Therefore, ANS encourages the following actions by the U.S. government and advanced reactor vendors:

1. The DOE Office of Nuclear Energy, the National Nuclear Security Administration (NNSA), and the U.S. Nuclear Regulatory Commission (NRC) should jointly coordinate their engagement with vendors in the prelicensing stage by establishing a working group to develop a comprehensive and uniform approach guiding the integration of safeguards and security into advanced reactor designs. The approach would outline how the NNSA coordinates consultation between the vendors and the U.S. national laboratories and the International Atomic Energy Agency (IAEA).
2. Vendors should continue to seek assistance from the NNSA, U.S. national laboratories, and IAEA at an early stage of the design process to integrate safeguards and security into their designs to enable them to seamlessly transition to an international market, even if the goal to export such designs lies 10 or more years in the future.
3. The NRC should issue approved licensing guidance for facilities with special nuclear material of moderate strategic significance (Category II [CAT II]), which includes HALEU, to enable vendors designing those facilities to maximize their likelihood of submitting successful license applications.[1,4]

Integrating safeguards and security into advanced reactor designs will enhance U.S. vendors' offerings in the global market by ensuring their products (1) will help future international buyers and operators meet their obligations to protect nuclear material and (2) enable the IAEA to meet its safeguards objectives while reducing the burden of inspections on the IAEA and reactor operators alike. ANS urges vendors and the U.S. government to work together expeditiously to integrate safeguards and security into advanced reactor designs to enable the vendors to deploy their products, which are vital to the future of clean energy in the U.S. and abroad.

Challenges associated with safeguarding HALEU fuels are not fundamentally different from those associated with safeguarding low-enriched fuels (those enriched to less than 5 percent U-235). Though some concerns exist regarding construction and operation of HALEU enrichment facilities in non-weapon states, these concerns can be addressed through design-based safeguards and security

a. For the purposes of this position statement, HALEU refers to *special nuclear material of moderate strategic significance*, or Category II material, as defined in 10 CFR 73.2,[1] which is "uranium enriched to 10 percent or more but less than 20 percent in the U-235 isotope." However, elsewhere, the term HALEU is sometimes used to refer to uranium enriched to between 5 percent and 20 percent U-235.

as well as international agreements. The concerns should not be an impediment to the deployment of advanced reactors using HALEU in accordance with IAEA and U.S. national regulations.

Background

The term "HALEU" has come into usage only recently. All uranium enriched to less than 20 percent is low-enriched uranium (LEU), per the definition in 10 CFR 74.4,[5] although common usage of "LEU" has typically referred to uranium with an enrichment of less than 5 percent U-235. Certain other terms have also recently been used, including "LEU+," which commonly refers to enrichments greater than 5 percent but less than 10 percent. Ten percent enrichment is the point at which a change occurs from Category III material to Category II material, per 10 CFR 73.[1]

Some members of the scientific community have voiced concerns regarding potential proliferation risks associated with the use of HALEU.[6] The IAEA does not consider HALEU to be a direct-use material.[7] Instead, voiced concerns almost exclusively focus on the potential use of HALEU fuel as enrichment feedstock to produce weapons-usable high-enriched uranium (HEU), which is typically enriched to 90 percent or greater. Using HALEU as feedstock to an enrichment process can substantially reduce the quantity of feedstock, the separative work (a measure of energy consumed by the enrichment process), and the time necessary to produce HEU. However, relative to natural uranium, the uranium enriched to 3.5 percent typically used by LWRs already reduces the feedstock required to produce HEU by more than a factor of six, and it reduces the separative work to less than half.[8] Consequently, from regulatory and policy perspectives, HALEU fuel presents proliferation challenges that are only incrementally greater than those presented by lower-enriched uranium.

The IAEA has established an effective international system to safeguard all LEU, which encompasses HALEU. The IAEA's definition of a significant quantity (SQ) and its goal for timely detection of material diversion are the same for all uranium enriched to below 20 percent U-235, which the IAEA categorizes as "indirect use material."[9] Consequently, HALEU is effectively protected through the IAEA safeguards legal framework in the same manner as uranium typically used by LWRs.

Relative to fuel with lower enrichments of U-235, HALEU fuel enables higher fuel utilization and longer periods of operation between refueling (aside from designs that refuel on line) due to the higher fuel burnup achievable. Specifically, increasing fuel burnup increases the fraction of U-235 present in fresh fuel consumed by fission, and it transmutes a greater fraction of the plutonium-239 (Pu-239) by neutron capture to heavier, even-mass isotopes of plutonium (specifically, Pu-240 and Pu-242), which are less attractive for use in weapons due to their higher spontaneous fission rate. Higher burnup also generates more highly radioactive fission products, enhancing the spent fuel's self-protection. Assessments of proliferation risk should consider these factors and others (e.g., the fuel's physical form) when evaluating the entire HALEU fuel cycle.

Advanced reactors and fuel fabrication facilities should employ safeguards and security commensurate with their specific proliferation challenges. The NNSA actively engages advanced reactor vendors to provide them with resources that enable the vendors to integrate safeguards and security by design. The NNSA Offices of Nonproliferation and Arms Control and Global Material Security continue to provide advanced reactor vendors with guidance on implementing safeguards and security in their designs through collaboration with U.S. national laboratories and the IAEA.[10,11]

Finally, it is vitally important for the U.S. to establish a domestic supply chain for HALEU fuel, which will require facilities enriching, fabricating, storing, and shipping HALEU fuel to obtain NRC licenses for Category II materials. Guidance from the NRC for Category II license applications is important to establishing a domestic supply of HALEU for advanced reactors that could be used to fuel domestic reactors and assure the supply of HALEU for exported reactor technology. Furthermore, a robust domestic supply chain for HALEU will enable the U.S. to compete in the international uranium fuel market. The availability of a reliable international market for uranium, including an international fuel bank, will help ensure that non-weapon states that may import advanced reactors are not motivated to develop their own indigenous enrichment capability.[12]

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