Proliferation Resistance and Safeguardability of Different Fuel Cycles

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Abstract

Nuclear energy is a green source of electricity which can meet the growing demands for the global requirement of power. The nuclear fuel cycles are based on uranium, plutonium and thorium based fuels and can be classified as once through nuclear fuel cycle or the closed fuel cycle. One of the concerns of using nuclear energy is the risk of proliferation for acts of nuclear and radiological terrorism. There are predominantly two type of nuclear fuel cycles, viz. once through fuel cycle and closed fuel cycle. These fuel cycles are based on the type of fuels and have their own advantages and limitations with respect to proliferation risk. The current paper describes the two fuel cycles based on the different type of fuels and discusses the safeguardability concerns for such fuel cycles.

Keywords: Proliferation resistance; Safeguardability; Fuel cycles

Introduction

The three important drivers of revival of interest in nuclear energy are the perceived increasing global demand for energy, quest for energy security or diversity and the need to tackle climate change. Diversity of sources which include hydro, wind, solar, nuclear etc. is the most important guarantee for energy security. Nuclear power, like hydro and other renewable energy sources produce virtually no carbon (CO₂) directly [1]. Nuclear energy provides an attractive option for green and continuous or uninterrupted source of electricity. In spite of recent accidents like the one at Fukushima, Japan in 2011, there is still a growing interest in many countries for generation of electricity by nuclear power plants. One of the major concerns of nuclear energy is nuclear proliferation and there are various initiatives to develop fuel and fuel cycles that have high proliferation resistance (PR) [2].

There are two types of nuclear fuel cycle followed worldwide – Once through fuel cycle and the closed fuel cycle. In once through fuel cycle, nuclear fuel is used for production of electricity in a reactor and the discharged spent fuel is stored in a repository. Whereas, in closed fuel cycle, the discharge spent fuel is reprocessed for separation of fissile products for recycle. Another way of classifying the nuclear fuel cycle is based on the type of nuclear fuel used, viz. uranium, plutonium and thorium. Guido Mazzini et al. have discussed the use of thorium, particularly in the of Th/Pu fuel cycle [3]. Some of the recent developments on the symbiotic fuel cycle for Generation IV reactors have also been reported [4]. The different fuel cycles have distinct proliferation resistance and pose challenges for implementation of safeguards. The present paper compares and contrasts the fuel cycles from the viewpoint of proliferation resistance and safeguardability.

History of IAEA Safeguards

International Atomic Energy Agency (IAEA) safeguards make a vital contribution to international peace and security. Through safeguards, the IAEA is able to provide credible assurances that States are adhering to their international obligations to use nuclear material for peaceful purposes only. The objective of IAEA safeguards is to deter the spread of nuclear weapons by early detection of misuse of nuclear material or technology, thereby providing credible assurances that States are honoring their legal obligations. The Statute of the IAEA requires that safeguards be applied to nuclear plant and material furnished by the IAEA and to other nuclear activities assisted, sponsored, supervised or controlled by the IAEA. In 1967-68, the negotiators of the Nuclear Non-Proliferation Treaty (NPT) proposed that IAEA should be the principal body to apply safeguards to nuclear material in non-nuclear-weapon States. With the passage time, the IAEA safeguards system came to be described as a comprehensive set of internationally approved technical and legal measures, applied by the IAEA to verify the political undertakings of States not to use nuclear material to manufacture nuclear weapons. The tools used for safeguards implementation include nuclear material accounting, inspection by IAEA inspectors, containment and surveillance measures etc. Prompted by the discovery of an extensive clandestine nuclear weapon program in Iraq, IAEA reviewed the safeguards systems between 1991 and 1997. This resulted in a “Model Additional Protocol” approved by the IAEA in 1997 and published as document INFCIRC/540 as the standard for additional protocols that are to be concluded by States and other parties to comprehensive safeguards agreement with the IAEA. Safeguards measures can also be classified as legal, technical and administrative. Additionally, international efforts are being made to develop reactor systems and associated fuel cycles, which are proliferation resistant.

Nuclear Fuel Cycles

Nuclear fuel cycles can be classified in a number of ways. A major classification is the once through cycle and the closed fuel cycle [5]. In once through fuel cycle, uranium is mined and is subjected to various chemical, metallurgical operations before it is charged into a reactor. These are milling, conversion, enrichment in case of LEU (low enriched uranium) fuels and fuel fabrication. The fabricated fuel loaded into the reactor undergoes fission producing heat and electricity. The spent fuel discharged from the reactor is then sent for long term storage, either in wet storage or dry storage. The final disposal could be in deep geological repositories. The energy potential of once through fuel cycle is low as it uses ~1% of heavy metal.

The closed fuel cycle differs from the once through fuel cycle in the manner that the spent fuel discharged from the reactor, is reprocessed to separate plutonium, depleted uranium and fission products for the uranium plutonium fuel cycle. The separated plutonium and depleted uranium are refabricated as MOX (mixed oxide) which is then charged in the reactors for generation of power. This can be used either in the thermal reactors or the fast reactors. In case of thorium fuel cycle, the driver fuel is either plutonium or uranium and the fissile ²³⁵U obtained from thorium is separated after irradiation and refabricated for