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INVITED LECTURE - Nuclear Fuel Cycle: Processes, critical aspects and perspectives

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The growing awareness of the urgent need to reduce emissions of greenhouse gases and to increase the security of energy supply are changing significantly the energy scenarios of the world and low-carbon energy technologies in the next future will play a crucial role. To this end, although severe accidents occurred over the years, many countries are still considering nuclear energy as an important source for power generation - economically, environmentally and socially sustainable. Current technologies and the latest generation of nuclear plants offer better performance and reliability for all 60 years of their useful life (and beyond), increased efficiency in the use of the fuel, and advanced safety systems, with very high availability factors (over 90%) and less production of radioactive waste.

However, some critical points for a rapid expansion of nuclear energy remain. The whole nuclear power generation and the related fuel cycle is a very complex process, which requires large initial investments and considerable costs for a long period of operation and decommissioning.

Uranium resources are limited. At the current burn rate with the present technology, the conventional resources of uranium will ensure supply only for some hundred of years and the possibility that a strong expansion of nuclear energy could limit the availability of uranium on the market at competitive prices is in itself a limiting factor.

The enrichment process is another critical point. A large expansion of nuclear energy requires more efficient technologies and further enrichment facilities. To lose the control of these installations increases the risk of illicit trafficking of nuclear materials and the proliferation of nuclear weapons, including terrorist threats. The international system of safeguards on nuclear technology and materials in general ensures an adequate level of security, but it must be strengthened for some aspects, avoiding the spread of sensitive knowledge and technology and reinforcing the international co-operation.

Another important issue is the radioactive waste produced at each stage of the fuel cycle, which together with the plant safety is of greatest concern to the public. The management and disposal of radioactive wastes is an essential part of the fuel cycle. Progress needs to be made in building and operating facilities for the temporary storage and disposal of spent fuel and high-level wastes in geological formations.

Moreover, since the irradiated fuel discharged from the present reactor fleet, entirely made of light-water reactors, contains significant amounts of potentially recyclable combustible materials - mainly plutonium (about 1%) and slightly enriched uranium (about 95%), while only about 3.5% are fission products and 0.1% actinides –large scale reprocessing plants to extract uranium and plutonium from spent fuel are in operation and for the future it is expected an increasing of the current capacity, mainly related to the next-generation nuclear systems.

They will be able to burn the most part of uranium, as well as plutonium and actinides, which are the most responsible for the longevity of radioactive waste. At this point the problem of long-lived waste is strongly reduced, minimizing the need for geological repositories and current reserves of uranium will last for millennia.

To this aim, several technologies are under development, but their full commercial deployment will be reached not before of some decades.

The present work presents and discusses some critical points of current fuel cycle technologies and processes, providing also an overview on the perspectives for an increased sustainability - efficiency, safety and reliability, economics, waste reduction, proliferation resistance, etc - of nuclear energy in the future.

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