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Back-End fuel cycle strategies in uncertain 'Gen-IV' futures: effective scenarios towards sustainable nuclear energy futures

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Various roadmap exercises have been undertaken during the past 2 decades relating to the development and deployment of 'advanced' nuclear energy systems, particularly so-called "Generation-IV", to improve the sustainability of nuclear energy. While nuclear energy is already among the most sustainable energy conversion technologies, the spent fuel (SF) management particularly remains a major socio-political challenge to further the use of nuclear energy in sustainable energy mixes. The availability of natural resources being, for the time being, less a driver towards such 'advanced' sustainable nuclear energy systems.
Though, such advanced nuclear energy systems require competitive technical-economic performance while addressing the socio-polical challenge for improved SF-management and, in today's energy market and socio-political environment, there's (very) limited willingness by private sector and even by most governments to embark on the effective deployment of such advanced nuclear energy systems.
Three categories of 'advanced' nuclear energy systems are considered and analysis in this paper:
a. nuclear energy systems using more advanced synergies between existing or near-term deployable nuclear technologies and where the development effort as such is limited but where especially international win-win situations need ot be recognised and deployed by mostly the private sector though considerable for deployment during the next 2 decades;
b. "Generation-IV'-systems, mainly HTGR and FRs, under development internationally and providing essentially multi-recycling options of separated materials in addressing SF-management challenges. These systems potentially seeing market deployment from the 2040s on in synergy with the LWR/PHWR-park worldwide;
c. "Generation-X"-systems focusing on very advanced nuclear energy systems and particularly seeking transmutation avenues aimed at furthering the reduction of transuranics amounts to be disposed of. These systems, from a technical-economic perspective, only deployable well after mid-century.

This paper presents an analysis of the technical-economic effectiveness of these three categories of advanced nuclear systems in transitioning towards more sustainable nuclear energy systems. A multi-regional analysis, reflecting real data on nuclear energy systems evolution in these regions, mapping the time-lines to address the socio-political challenges for the (regional) transition towards more sustainable nuclear versus the (regional) technical-economic performance challenges is presented accordingly.

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