Comparison of the Overall Environmental Footprint between Current and Future Nuclear Fuel Cycles

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Abstract

Nuclear energy is anticipated to be one of the possible energy sources which can allow the production of energy at high load with a high level of reliability without significant impact on the environment. Nowadays, most of the countries have chosen an open fuel cycle which basically considers spent nuclear fuel as a waste, whereas others like France, the United Kingdom, Japan and soon China reprocess their spent fuel to recover the plutonium (and partially U) to produce mixed oxide fuel to be irradiated in a second cycle. In a second step, considering the possibility of fertilising ^{238}U to ^{239}Pu in fast reactors, recycling major actinides is thought to be a major improvement towards the global sustainability of the nuclear energy: It will indeed allow the natural resource efficiency to be increased by orders of magnitude by consuming quantitatively the natural uranium resource involved. Driven by the Fukushima accident, nuclear energy is currently questioned about its overall environmental impact and footprint. However, very little information is available on the actual footprint of current and future nuclear systems. In order to bring insights on this issue, a life cycle assessment simulation tool NELCAS was developed based on the French nuclear closed fuel cycle. It allows the calculation of representative key environmental indicators and potential impact indicators for the whole nuclear systems. The very good consistency of the results with the literature data confirms the relevance and robustness of NELCAS. It was subsequently used to derive representative indicators for open and future potential fuel cycles, i.e. mixed GEN3 and GEN4 reactors fleet and full GEN4 reactors fleet. The results demonstrate the very significant improvement brought by the actinides recycling and the future fuel cycle. Most of the indicators are very significantly decreased with the implementation of long-term recycling strategies. This paper will present in the details the figures of merit of the different fuel cycles options and assess their respective sustainability.