

Is Nuclear Fission a Sustainable Source of Energy?

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Nuclear power could ease the transition to a more sustainable energy economy, if it can substitute for enough fossil fuel. Key to evaluating the potential of nuclear energy to meet future demands are the amounts of uranium and thorium economically available. Estimates are necessarily speculative, as they require knowledge of the abundance, quality, and distribution of metals in ore deposits, as well as the costs of extraction (mining and milling).

However, the amount energy production by a nuclear power plant is profoundly affected by the choice of the type of nuclear fuel cycle. The open fuel cycle, which entails direct disposal of used nuclear fuel, depends directly on the amounts of uranium and thorium available. Today's estimates of uranium resources have identified 7,640 kilotonnes (at a price of up to US\$260/kg of uranium), which would sustain the current demand of roughly 68 kt/yr beyond the end of this century. If nuclear power generation were to double or triple by the end of the century, the currently estimated 7,400 kt of undiscovered resources would need to be brought into production as well. Today, world uranium production provides about 99% of world reactor requirements, as the use of enriched uranium from dismantled nuclear weapons ended in 2013.

The open fuel cycle, without reprocessing, uses less than 1% of the energy content of the uranium fuel. In contrast, the *closed fuel cycle*, with reprocessing to reclaim fissile nuclides, such as plutonium, can extend the uranium resource by breeding fissile ^{239}Pu from the much more abundant ^{238}U or fissile ^{233}U from ^{232}Th . The fully closed fuel cycle requires an advanced processing technology, as well as the development of fast reactors that employ higher-energy neutrons that fission actinides more efficiently. Such fully closed systems could use as much as 70% of the energy content of the nuclear fuel, thus extending the uranium resource.

The energy efficiency of each type of fuel cycle is not the only issue, a complete analysis requires a consideration the environmental impact (*e.g.*, nuclear waste), as well as the risk of nuclear proliferation.