

# “Fuel-Generation-Limited Thorium Breeding System Driven by Fusion Neutrons”

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## Abstract

This project proposed a world-first reactor core concept based on fuel-generation-limited neutron dynamics, in which fissile material is not preloaded but is generated in situ from  $^{232}\text{Th}$  under an externally controlled fusion neutron source. Unlike conventional fission or fusion - fission hybrid systems, the proposed reactor operates on the principle that reactor power and neutron population are inherently limited by the rate of fissile fuel generation, rather than by mechanical control rods or prompt reactivity feedback. This intrinsic saturation behavior ensures subcritical operation at all times.

The core enabling technology is a thinly dispersed thorium oxide ( $\text{ThO}_2$ ) ceramic architecture, where micron-scale  $\text{ThO}_2$  particles are spatially diluted within a weakly absorbing, highly moderating ceramic matrix (e.g., SiC-based structures). This configuration suppresses parasitic neutron capture during the  $^{233}\text{Pa}$  decay period and enables net breeding of  $^{233}\text{U}$  under conditions where conventional dense thorium fuels fail.

The system is driven by a compact accelerator-based DD fusion neutron source, producing mono energetic 2.45 MeV neutrons without the use of thorium. This choice enables a small, low-cost, and intrinsically safe neutron driver that relies almost entirely on existing technologies.

The novelty of the proposal technology lies in the integration of three elements that have never been combined in a single reactor concept:

1. “Fuel-generation-limited reactor physics, exhibiting nonlinear neutron growth followed by self-stabilizing saturation below criticality.”
2. “Dispersed fertile fuel geometry, optimized to control neutron loss ( $L$ ) and maximize the effective breeding condition  $(\eta - 1) - L > 1$ .”
3. “External neutron-source-based control, allowing reactor startup, load following, and shutdown to be governed solely by source intensity and moderator conditions.”

This combination establishes a fundamentally new class of thorium reactor technology that is inherently subcritical, passively safe, free from plutonium, and suitable for small, modular, and transportable systems aligned with India’s long-term strategy.