

Novel Reactor Designs To Burn Non-Fissile Fuels

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Abstract

Intellectual Ventures is leading a privately sponsored study to explore new approaches to nuclear power. We have used advanced computational tools and modeling technology to reexamine some of the fundamental assumptions—such as the requirement for a continuous supply of enriched fuel—that have long driven the design of fission reactor cores. Our highest goal is to simplify nuclear infrastructure in multiple ways that will help fission power meet the world's growing need for affordable and sustainable energy by directly addressing the issues of emissions, proliferation resistance, safety, and long-term fuel disposal.

Our concepts build on the “traveling wave” reactor idea first presented by Edward Teller et al. in the early 1990s. Initial work on the traveling wave reactor (TWR) suggested that this design could have several important advantages over other current and proposed fission reactor designs. After startup, for example, a TWR could run for its entire design life without refueling with fissile material; alternative TWR designs might allow for refueling without pause in operation. A TWR plant would also require little or no enriched uranium after an initial “ignition” phase. For the great majority of its operating life, the reactor could instead burn natural uranium, depleted uranium (a low-cost byproduct of uranium enrichment), or possibly even thorium.

A TWR derives these advantages from the unique way in which the reactor burns its fuel. A deflagration wave is first formed using enriched uranium or some other fissile material. Once ignited, the wave front is allowed to expand into adjacent sections of the core that contain only fertile material. Here the slow-moving wave is sustained and passively controlled by its own breed and burn dynamics. Preliminary analysis suggests that practical designs could emplace enough fertile material in the core to sustain reactor operation for decades.

For the LWRs now in operation, the rapidly rising cost of enriched uranium fuel is becoming a major driver of the total cost of delivered energy. Mass deployment of TWRs, fueled instead primarily by natural uranium or depleted uranium (huge stockpiles of which exist), could extend the remaining economic resources of uranium from a century or less to several millennia. TWRs that burn thorium fuel would tap into an essentially unlimited resource: By some estimates, thorium reserves are sufficient to support the energy consumption of the entire world population at current US per-capita levels for over 100,000 years.

A technology that effectively eliminates the expensive necessity of significant enrichment facilities, reprocessing plants, actinide “burner” reactors, and the transport of fissile material would greatly improve the economics of nuclear energy, aiding its adoption as the natural “carbon-free” alternative to coal. If TWR technology lives up to its early promise, it may also ameliorate public concerns about proliferation, terrorism, safety, and environmental risks associated with nuclear power.

The TWR design team at Intellectual Ventures has performed integrated physics and engineering analysis of several TWR reactor designs, including those fueled by natural uranium, depleted uranium, thorium, and various combinations of these materials. Each of these distinct reactor concepts addresses different markets and applications, and also

raises a number of interesting engineering challenges. This paper includes illustrations and numeric examples of our progress to date and highlights some the questions still to be answered about this fundamentally new approach to nuclear energy.