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Fusion Energy: Prospects to the Future

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Fusion power is a proposed form of power generation that would generate electricity by using heat from nuclear fusion reactions. In a fusion process, two lighter atomic nuclei combine to form a heavier nucleus, while releasing energy. Devices designed to harness this energy are known as fusion reactors.
Nowaday, Fusion has the potential to provide a safe, cost-efficient and sustainable solution to global energy needs. Fusion energy has no difficult waste issues and is climate friendly.

Nuclear fusion presents a number of significant technological challenges, which must be solved before it can be made commercially available. A fusion reactor is a very complex device, and historical experimental systems have been chiefly physics experiments, designed for operational flexibility and, while experimental availability is a concern, the operating and maintenance regime required of a commercial power plant is very different to that of an experimental device.

Fusion materials have a twofold problem. The first is resisting radiation damage from fusion neutrons to maintain their properties over the design lifetime—as well as exposure to high temperatures and high stresses. The second is the avoidance of elements, which form long-lived radionuclides under neutron radiation, giving rise to long-term radioactive waste—or even changing the nature and properties of an alloy through the production of transmutation elements. Additionally, the functional demands on materials vary widely: plasma-facing materials must be resistant against very high heat and particle loads, without sputtering; in-vessel structural materials must be dimensionally stable and remain ductile while installed; elements of the breeder blanket must multiply neutrons for tritium production—tritium itself is prone to permeating through materials and cannot be allowed to leach into the environment; diagnostic and heating systems may be directly exposed to radiation and sputtered dust, which will fog lenses and mirrors and affect the conductivity of electronics. It is difficult to conceive that a commercial reactor will be licensable by regulatory authorities without qualification of these materials in a nuclear environment, which implies that a high-energy neutron source is required for materials development.

In this Paper we present the most relevant challenges of power generation by nuclear fusion reactors and the prospects for the future of this form of generation.

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