

Fusion Challenges and Opportunities: The BRIGHT Pilot Plant

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Fusion energy is entering a decisive transition from scientific demonstration toward integrated pilot-plant development. Recent progress in deuterium–tritium performance, inertial-fusion gain, high-temperature superconducting magnets, long-pulse superconducting devices, and rapidly increasing private investment has brought commercial fusion closer to reality. However, the path to a fusion power plant is no longer defined by plasma performance alone. International roadmaps from converge on a common conclusion: the central challenge is integrated pilot-plant readiness, including tritium breeding and fuel-cycle closure, neutron-resistant materials, first-wall and blanket qualification, plasma exhaust, magnets and cryogenics, diagnostics and control, remote maintenance, RAMI, regulation, supply chains and economics.

This talk reviews the main cross-cutting and confinement-specific challenges on the path to commercial fusion, with emphasis on the deuterium–tritium reaction as the origin of both fusion’s opportunity and its most demanding engineering constraints: 14.1 MeV neutron production, alpha-particle self-heating, tritium management, safety, balance-of-plant integration and capacity factor. It then discusses the need for multidisciplinary infrastructures, including burning-plasma pilot plants, volumetric neutron sources and materials qualification facilities such as IFMIF-DONES, as essential elements of a credible European fusion strategy.

Finally, the talk introduces the BRIGHT Pilot Plant concept as a proposed fast-learning platform to address these challenges through integrated systems engineering, HTS magnets in relevant environments, blanket and tritium-cycle development, burning-plasma physics and fusion power-plant economics. The SMART tokamak at the University of Seville is presented as the experimental foundation for this vision: a unique spherical tokamak optimized for negative triangularity, providing a proof-of-concept and technology testbed for the development of compact, maintainable and commercially relevant fusion pilot plants.