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Toward Technical Readiness: Private-Sector Pathways for Fusion Fuel Cycle and Power Integration

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The landscape of fusion energy development is undergoing a fundamental transformation, increasingly driven by private sector initiatives. While both public and private entities target First-Of-A-Kind fusion energy systems such as DEMOs and Pilot Plants, their technical approaches and timelines differ significantly. Private sector actors emphasize accelerated deployment, productization, and market integration, often prioritizing rapid development cycles over long-term public-sector schedules. As a result, industrialization—including supply chain development and technology integration to achieve commercial-level Technical Readiness—is becoming a core focus of fusion system design.

One of the most striking changes is the early engagement of private companies in deuterium-tritium (DT) burning experiments and tritium system development, well ahead of ITER's planned tritium operations in the late 2030s. Several private projects are expected to handle and burn tritium at significant levels from before 2030 through 2040, with the aim of demonstrating key fusion nuclear technologies such as breeding blankets, tritium extraction, and thermal energy conversion on compact platforms. These efforts mark a departure from traditional DEMO-scale programs by proposing smaller-scale, fast-track systems designed to demonstrate reliability, safety, and integration at commercially relevant scales.

This talk will overview these paradigm shifts and highlight the emerging role of public-private partnerships, focusing on the fusion tritium economy, safety protocols, regulatory frameworks, and the critical importance of societal engagement. Emphasis will be placed on the challenges of integrating nuclear and plant technologies—often identified as bottlenecks in fusion commercialization—such as materials, fuel cycles, energy conversion systems, and tritium breeding and handling.

As a case, the Japanese private-led FAST (Fusion by Advanced Superconducting Tokamak) project will be introduced. With a target start date in the mid-2030s, FAST will use a low aspect ratio tokamak with high-temperature superconducting magnets to sustain DT plasma burning for durations exceeding 1000 seconds. It will incorporate a full tritium breeding and extraction system, closed-loop thermal energy conversion, and co-generation capabilities including hydrogen production. Designed to operate at 100 MW thermal power, FAST is expected to serve as a testbed for maturing critical technologies for future fusion power plants, bridging the gap between plasma physics and energy systems engineering.

This presentation will explore how private sector innovation is reshaping fusion development timelines and technical priorities, ultimately accelerating the pathway to commercial fusion energy.

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