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Considerations of the high magnetic field tokamak path on the approach to fusion energy[1]

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This tutorial will review the physics basis, and its applications, for high magnetic field, compact visions of steady-state pilot plants and fusion reactors. This includes: energy and particle confinement; transport barriers; heating and current drive; scrape-off layer and divertor physics including implications for power handling, and ash/impurity control. The development of new technologies, particularly high-temperature, high critical magnetic field superconducting materials opens a new opportunity to consider the leverage of on-axis magnetic fields of 10T or more, enabling the feasibility of smaller sized devices on the path to fusion energy, including a pilot plant which could produce hundreds of megawatts of net electricity in a 10T tokamak with major radius of order 3 meter. Incorporating jointed magnetic coils, also made feasible by the high temperature superconductors, can dramatically improve flexibility of experimental superconducting facilities, and ultimately maintainability for reactor systems. Steady-state requires high bootstrap fraction, combined with efficient off-axis current drive, and existing and new approaches for RF sustainment will be covered, including Lower Hybrid Current Drive (both from the low- and high-field side), ECCD, and fast-wave techniques. External torque drive from neutral beams, routinely used in most present-day experiments to enhance confinement and suppress instabilities, will be weak or absent in reactors. Alternative, RF-based flow drive, using mode-converted ICRF waves will be discussed. All reactor concepts have extraordinary power handling requirements, combined with stringent limits on PFC erosion and impurity sources; the current state of the art in divertor configurations will be compared with emerging and new concepts, including snowflake, x-point, x-divertor and liquid metals, to meet these challenges.

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