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The role of the boundary plasma in defining the viability of a magnetic fusion reactor: A review[1]

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The boundary of magnetic confinement devices, from the pedestal through to the surrounding surfaces, encompasses an enormous range of plasma and material physics, and their integrated coupling. It is becoming clear that due to fundamental limits of plasma stability and material response the boundary will largely define the viability of an MFE reactor. However we face an enormous knowledge deficit in stepping from present devices and ITER towards a demonstration power plant. We review the boundary and plasma-material interaction (PMI) research required to address this deficit as well as related theoretical/scaling methods for extending present results to future devices. The research activities and gaps are reviewed and organized to three major axes of challenges: power density, plasma duration, and material temperature. The boundary can also be considered a multi-scale system of coupled plasma and material science regulated through the non-linear interface of the sheath. Measurement, theory and modeling across these scales are reviewed. Dimensionless parameters, often used to organized core plasma transport on similarity arguments, can be extended to the boundary plasma, plasma-surface interactions and material response. The scaling methodology suggests intriguing ways forward to prescribe and understand the boundary issues of an eventual reactor in intermediate size devices. Finally, proposed technology and science innovations towards solving the extreme PMI/boundary challenges of magnetic fusion energy will be reviewed.

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