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The Science and Technology Case for High-Field Fusion.

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This review will focus on the origin, development and new opportunities of a strategy for fusion energy based on the *high-field approach*. In this approach confinement devices are designed at the maximum possible value of vacuum magnetic field strength, B. The integrated electrical, mechanical and cooling engineering challenges of high-field on coil (B_{coil}), large-bore electromagnets are examined for both copper and superconductor materials. These engineering challenges are confronted because of the profound science advantages provided by high-B, which are derived and reviewed: high fusion power density, ˜B^4, in compact devices, thermonuclear plasmas with significant stability margin, and, in tokamaks, access to higher plasma density. Two distinct high-field strategies emerged in the 1980's. The first was compact, cryogenically-cooled copper devices (BPX, IGNITOR, FIRE) with B_{coil}>20 T, while the second was a large-volume, Nb_3Sn superconductor device with B_{coil} <12 T; with the second path exclusively chosen ca. 2000 with the ITER construction decision. The reasoning, advantages and challenges of that decision are discussed. Yet since that decision, a new opportunity has arisen: compact, Rare Earth Barium Copper Oxide (REBCO) superconductor-based devices with B_{coil} >20 T; a strategy that essentially combines the best components of the two previous strategies. Recent activities examining the technology and science implications of this new strategy are reviewed. On the technology side, REBCO superconductors have now been used to produce B_{coil}>40 T in small-bore electromagnets, enabled by rapid progress in manufactured REBCO conductor quality, coil modularity and flexible operating temperature range. Specific tokamak designs, over a range of aspect ratios, have been developed to take scientific advantage of these features in various ways, and will be described.