TS4E | 2026

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Computationally Guided EBCs for High Temperature, Fuel Flexible sCO$_2$ Turbine Cycles—A DOE Perspective

Abstract:
The U.S. Department of Energy's Advanced Turbine Systems effort targets step change efficiency and fuel flexibility (syngas blends and sCO$_2$ cycles), with temperature capability beyond today's limits—driving a materials challenge in turbine hot sections.

DOE's Advanced Energy Materials program addresses that challenge through integrated computational materials engineering, advanced manufacturing, and durability testing for extreme environments, with special emphasis on high temperature, corrosive service and hydrogen effects on materials.

To enable SiC/SiC CMC components, environmental barrier coatings (EBCs)—typically rare earth silicates over silicon bond coats—are essential to mitigate steam driven recession and oxide growth that limit lifetime. Recent DOE sponsored work refines phase field and lifetime modeling of thermally grown oxides (TGO) and demonstrates pathways to extend EBC durability in cyclic air steam environments toward industrial lifetime targets (≥25,000 h).

Parallel studies exploring bond coat free architectures illuminate failure modes at 1400–1600 °C and define requirements for next generation EBC chemistries and interfaces.

This contribution synthesizes DOE program insights with thermal spray process innovations—notably Suspension Plasma Spray (SPS) and Solution Precursor Plasma Spray (SPPS)—to achieve dense, phase stable Yb silicate EBCs while managing segmentation cracks and gas tightness, comparing oxidation kinetics versus conventional APS coatings.

We frame a computational to coating workflow (AEM/eXtremeMAT → spray process maps → microstructure → lifetime models) oriented to hydrogen ready and sCO$_2$ compatible turbine architectures, and we highlight Prague IPP lab capabilities (WSP/WSP H, RF/ICP torches, SPS facilities) as an ideal testbed for joint demonstrations.

Takeaway: a DOE informed, spray centric roadmap to accelerate EBC maturity for SiC/SiC CMCs, linking modeling, processing, and durability testing to meet next generation turbine performance goals with lower emissions and higher reliability.