FACT SHEET: Clean Coal University Research Awards and Project Descriptions

IMPROVED ALLOYS

By substantially increasing the pressure and temperature of the steam used to produce power, advanced ultrasupercritical (AUSC) coal-fired power plants improve generation efficiency, use less coal and release less carbon pollution. The implementation of AUSC boilers requires materials with high-temperature oxidation, corrosion and deformation resistance. These selected projects will develop new surface modification techniques or optimize existing techniques for the protection of high-temperature alloys used in AUSC coal-fired boilers and in advanced gas turbines.

Southern Illinois University *(Carbondale, Ill.)* **—** Southern Illinois University Carbondale (SIUC) will partner with the Gas Technology Institute to verify the novel use of titanium carbide and titanium diboride powders as coatings for enhanced corrosion protection on (AUSC) boiler and turbine components. If the proposed method is used to produce the powders in bulk, the partners predict at least a 50-percent reduction in their cost.
(DOE Share: $299,992; Recipient Share: $142,220)

Indiana University *(Indianapolis, Ind.)* — Indiana University will research a manufacturing process to produce a novel pyrochlore oxide-based double-layer coating that will have improved high-temperature corrosion resistance. Compared with current thermal barrier coatings, pyrochlore oxides have demonstrated lower thermal conductivity and better thermal stability - characteristics crucial to turbines in AUSC coal-fired power plants. Indiana University and partner Purdue University Indianapolis will collaborate with Praxair Surface Technologies, Indianapolis, to develop computational models to study the coatings.
(DOE Share: $293,519)

Brown University *(Providence, R.I.)* — Engines such as those found in integrated gasification combined cycle (IGCC) power plants and fueled by coal-derived syngas generally operate at higher temperatures than their natural-gas-fired counterparts. However, the efficiency and the power output of syngas-fired engines needs to be improved further so that they can be operated at even higher gas-inlet temperatures, beyond the 1375°C of current engines. Conventional ceramic thermal barrier coatings (TBCs) that insulate hot-section metallic engine parts from hot gases are not adequate to meet the needs of these future engines. Brown University will study the feasibility of two-layer air plasma-sprayed TBCs that will improve their durability, manufacturability and affordability.
(DOE Share: $300,000)

IMPROVED STRUCTURAL MATERIALS

Operating conditions for advanced boilers, steam turbines and gas turbines will be at temperatures and pressures far higher (760ºC and 5000 psi for boilers and steam turbines; 1700 ºC for gas turbines) than traditional coal-fired power plant equipment. New iron-based and stainless steel alloys are needed to increase the operating temperature limits of the currently used alloy families in AUSC boilers and steam turbines. New, improved methods are also necessary to design and predict the mechanical, oxidation, and corrosion behavior of structural materials in high-temperature, high-pressure fossil energy environments. These proposed projects will develop structural materials to address these issues in advanced power systems.

Texas Engineering Experiment Station (College Station, Texas) — This project will work to develop new austenitic stainless steels with ultrahigh strength, ductility, high temperature strength, and deformation and corrosion resistance. Austenitic stainless steel is an allotrope of iron with an alloying element or elements, such as chromium and nickel. Surgical stainless steel is an example of austenitic steel. For this project, Texas Engineering Experiment Station will combine state-of-the-art computational and experimental alloy and microstructural design approaches to improve the high-temperature properties of austenitic stainless steels. The development of advanced, next-generation high-temperature stainless steels will enable the deployment of significantly more efficient coal power generation plants.
(DOE Share: $300,000)

Ohio State University (Columbus, Ohio) — The study will research new steels capable of operating at 760°C in the aggressive environments of AUSC boilers and steam turbines. Ohio State will explore new compositions and new strengthening mechanisms, or microstructures, using high-throughput diffusion multiples—an assembly of different metals which are subjected to high temperature, creating intermetallic compounds—and computational thermodynamics. Steel compositions with high iron and chromium concentrations will be the focus of this exploration because high iron concentration—instead of expensive nickel-based super alloys—is important for cost reduction and high chromium concentration is essential for oxidation and hot-corrosion resistance.
(DOE Share: 299,934)

University of Tennessee (Knoxville, Tenn.) — High-entropy alloys (HEAs) have emerged as suitable materials for high-temperature applications in excess of 800ºC. HEAs have revolutionized alloy design by using several principal elements as opposed to traditional alloys which consist of one or two principal elements with small additions of alloying elements to achieve desired properties. For this project, the University of Tennessee will perform fundamental studies on the aluminum-chromium-copper-iron-manganese-nickel high-entropy alloy (HEA) system for use in boilers and steam and gas turbines at temperatures above 760ºC and stress of 35 MPa (megapascals). They will also develop an integrated approach coupling thermodynamic calculations and focused experiments to identify HEAs that outperform conventional alloys.
(DOE Share: $300,000)

Dartmouth College *(Hanover, N.H.)* — Materials that are strong and corrosion resistant are critical to the operation of AUSC power generation plants at high temperatures. However, the iron-based steels currently in use are not sufficient for temperatures greater than 700ºC that are required to operate advanced power plants. Dartmouth College will research strengthened iron-based austenitic steels alloyed with aluminum for improved oxidation resistance. The precipitation phenomena and deformation behavior of the specific alloys that will be studied and modeled will enable further systematic alloy development.
(DOE Share: $294,072; Recipient Share: $108,394)

University of North Texas *(Denton, Texas)* — The University of North Texas will team with the University of Idaho to develop a new computationally designed nickel-chromium alloy for use in the high temperatures of advanced coal-fired power plants. To accomplish this goal, the team will develop a methodology for microstructural optimization of the alloy, specifically a genetic algorithm approach using theoretical models based on fundamental micro-mechanisms. This new approach—development of materials by design rather than by discovery—has the potential to significantly reduce the cost and time for development of high-performance engineered materials.
(DOE Share: $300,000)

IMPROVED MATERIALS PROCESSING

The more severe operating environments (temperature, pressure and corrosivity) and performance specifications of advanced fossil energy systems require increasingly complex structural and functional materials. The research of novel and more robust ways to synthesize and process advanced materials and coatings for advanced fossil energy applications can reduce manufacturing costs, improve product recovery, reduce product variability, and allow the production of more precisely designed structural and functional materials and coatings.

University of Toledo *(Toledo, Ohio)* — Functional and safe oxygen carriers are considered keys to efficient and inexpensive CO_2 capture technologies and biofuel conversion for fossil-fuel-based industries. However, the availability of feasible oxygen carrier materials is one of the main challenges in the development of chemical-looping combustion. Oxygen carriers that do not suffer from limitations with respect to their thermal and chemical stability over a wide range of temperatures and pressures would be more suitable than the most commonly proposed oxygen carrier materials (oxides of copper, iron, manganese and nickel). The University of Toledo will devise material processing techniques for the development and evaluation of two new groups of oxygen carrier materials based on a crystal structure and will systematically investigate their carrier formulations.
(DOE Share: $300,000; Recipient Share: $170,674)