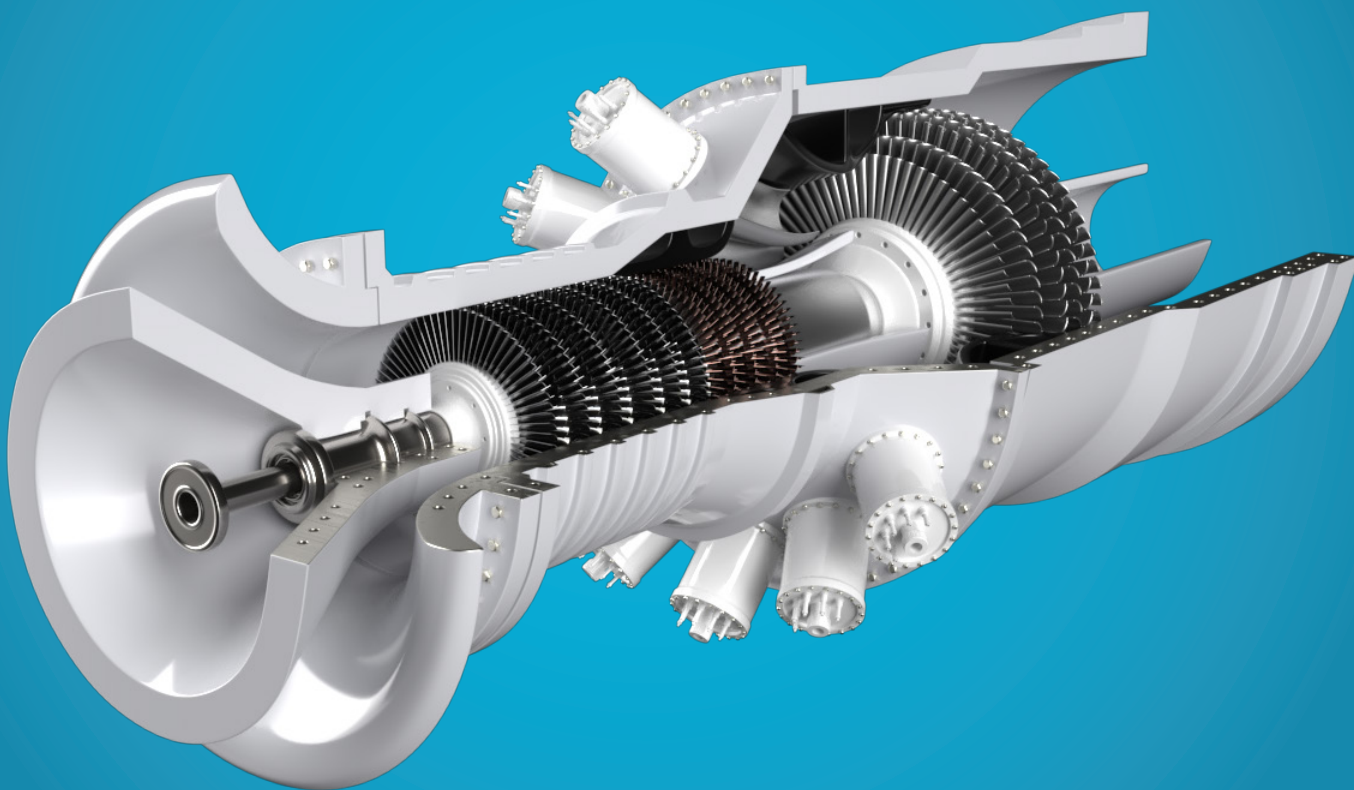
ADVANCED TURBINES



NATIONAL ENERGY TECHNOLOGY LABORATORY

BACKGROUND

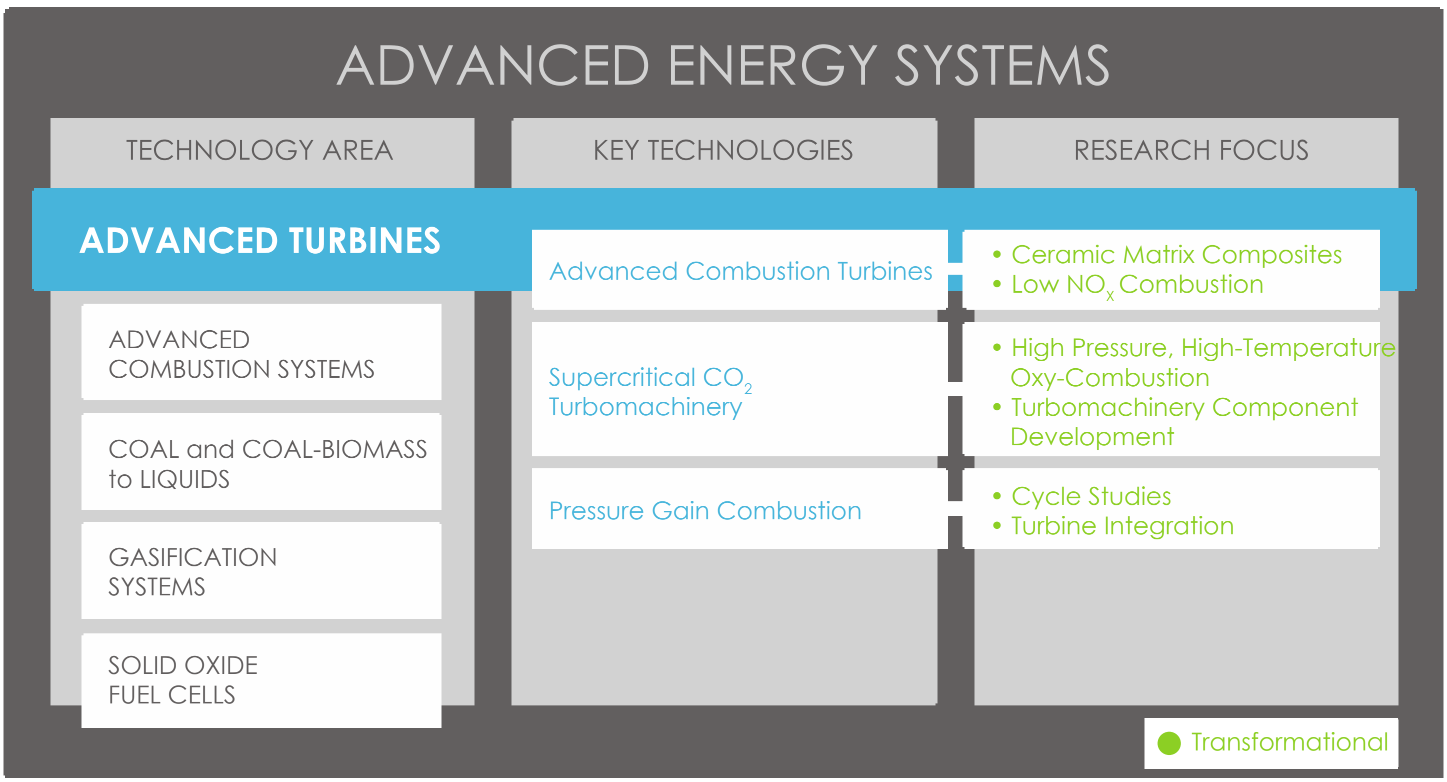
The National Energy Technology Laboratory (NETL) is a U.S. Department of Energy (DOE) national laboratory that drives innovation and delivers technological solutions for an environmentally sustainable and prosperous energy future. By leveraging its world-class talent and research facilities, NETL is ensuring affordable, abundant and reliable energy that drives a robust economy and national security, while developing technologies to manage carbon across the full life cycle, enabling environmental sustainability for all Americans. Our Advanced Turbines Program is conducted under the Clean Coal and Carbon Management Research Program (CCCMRP). Fossil fuels account for a large percentage of total U.S. primary energy use due to their abundance, high energy density, and the relatively low costs associated with production, safe transport, and use. However, the combustion of fossil fuels for electricity generation is the largest single source of carbon dioxide (CO^2) emission in the nation, accounting for one third of total U.S. CO^2 emissions. Control and mitigation of such greenhouse gases is a national focus.

ADVANCED TURBINES

The Advanced Turbines Program is just one of NETL's critical domestic energy initiatives that touch the lives of virtually all Americans. Our innovations support decarbonization and responsible stewardship of our environment; create valuable products from domestic resources; and inform energy strategies that work toward achieving net-zero CO_2 emissions by mid-century while supporting a clean energy economy that creates good-paying jobs, spurs economic revitalization, advances environmental justice, and supports energy workers in communities across the country.

ADVANCED TURBINES PROGRAM

The Advanced Turbines program is focused on the development of advanced turbine technologies that will accelerate turbine performance, efficiency, and cost effectiveness beyond current state-of-the-art and provide tangible benefits to the public in the form of lower cost of electricity (COE), reduced emissions of criteria pollutants, and carbon capture options. The efficiency of combustion turbines has steadily increased as advanced technologies have provided manufacturers with the ability to produce highly advanced turbines that operate at very high temperatures. Further increases in efficiency are possible through the continued development of advanced components, combustion technologies, material systems, thermal management, and novel turbine-based cycles.



KEY TECHNOLOGIES

The Advanced Turbines Program supports three key technologies that will advance clean, low-cost, coal-based power production—and at the same time—take advantage of all fossil fuel opportunities: (1) Advanced Combustion Turbines, (2) Pressure Gain Combustion, and (3) Turbomachinery for Supercritical Carbon Dioxide (SCO_2) Power Cycles.

ADVANCED COMBUSTION TURBINES

Advanced turbine research addresses component development for turbine systems fueled with coal-derived fuels (including hydrogen and syngas) and natural gas in combined cycle applications with pre- or post-combustion carbon capture that can achieve greater than 65 percent combined cycle efficiency (LHV, natural gas benchmark) and support load following capabilities to meet the demand of a modern grid. To achieve this target, emphasis will be placed on advanced turbine concepts that are fueled with natural gas and coal derived fuels, including hydrogen and syngas, and higher firing temperatures (3,100 °F). Components from this program can be easily applied to existing and future gas turbine product lines for natural gas applications; leveraging existing equipment and products for component demonstration.

Component R&D is being conducted that will allow higher turbine inlet temperatures, manage cooling requirements, minimize leakage, advance compressor and expander aerodynamics, advance the performance of high temperature load following combustion systems with low emissions of criteria pollutants including oxides of nitrogen (NO_X), and overall lead to improved efficiency of the gas turbine machine in a combined cycle application.

Advanced Combustion Turbine
Courtesy Siemens Energy Inc.

PRESSURE GAIN COMBUSTION

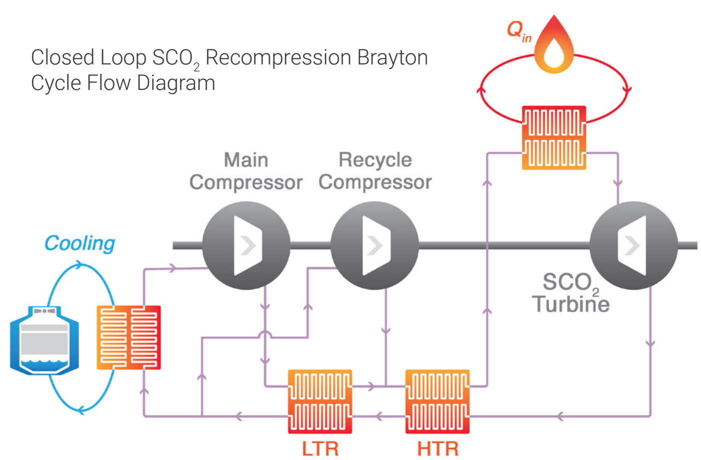
Pressure gain combustion (PGC) has the potential to significantly improve combined cycle performance when integrated with combustion gas turbines by realizing a pressure increase versus a pressure loss through the combustor of the turbine. Approximately half of the work produced by the turbine expander is used to drive the compressor and increase the pressure of the working fluid, air in this case. This compressed air is conveyed to the turbine combustor where a nominal five percent loss in pressure (pressure drop) is realized. Concepts for PGC utilizes multiple physical phenomena, including resonant pulsed combustion, constant volume combustion, or detonation, to affect a rise in effective pressure across the combustor, while consuming the same amount of fuel as the constant pressure combustor.

Pressure gain combustion projects focus on assessing the potential benefit of PGC system technology for combined-cycle gas turbines. Researchers are focused on combustion control strategies and fundamental understanding of pressure wave-flame interaction that will lead to lab-scale testing and component prototyping for turbine integration with PGC. Project participants are developing systems models for combined cycle turbine systems in order to define the path to configurations that exceed 65 percent combined-cycle efficiency. These models will be validated against experimental data. In addition, these projects will document the technical gaps for PGC development and turbine integration in order to focus continued R&D.

TURBOMACHINERY FOR SCO^2 POWER CYCLES

Projects for this key technology are focused on developing technology for supercritical CO_2 (SCO_2) based power cycles that are applicable to fossil fuel applications. This includes developing high pressure and high temperature oxygen and fuel (oxy-fuel) combustion systems with CO_2 as the diluent that can be incorporated into turbines designed for directly heated SCO_2 based power cycles. As well as advancing the technical capabilities and understanding in the areas of SCO_2 gas turbine - turbomachinery interactions, influences of high fluid densities on turbomachinery design, and/or commissioning components within the high operating pressures and temperatures anticipated for SCO_2 service.

Closed Loop SCO_2 Recompression Brayton Cycle Flow Diagram



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