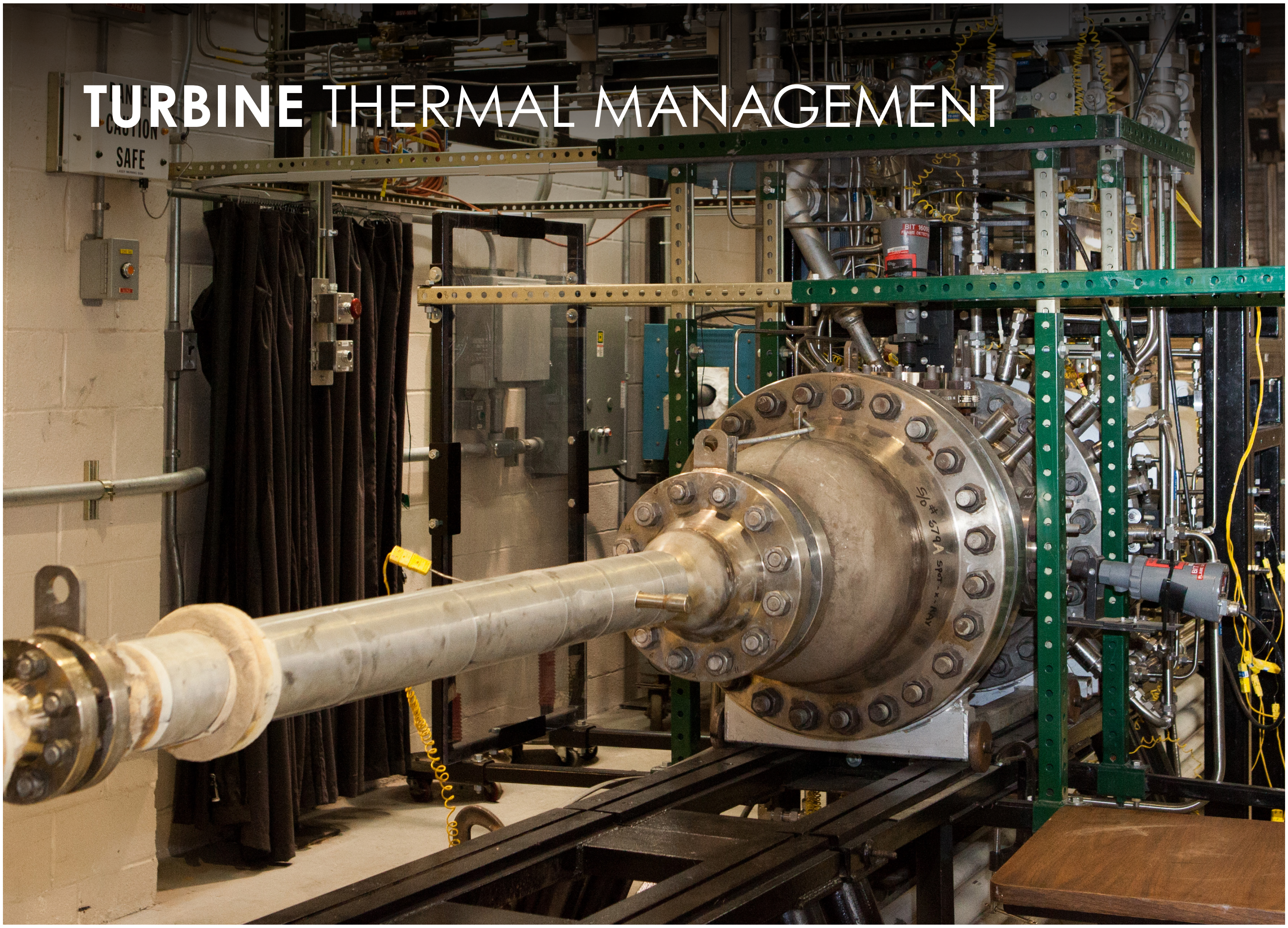
# TURBINE THERMAL MANAGEMENT

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NATIONAL ENERGY TECHNOLOGY LABORATORY

The gas turbine is the workhorse of power generation, and technology advances to current land-based turbines are directly linked to our country's economic and energy security. Technical advancement for any type of gas turbine generally implies better performance, greater efficiency, and extended component life. From the standpoint of cycle efficiency and durability, this suggests that a continual goal for higher gas turbine-inlet temperatures and pressures with reduced coolant levels is desirable.

The realization of future high-efficiency, near-zero-emission turbine power systems depends on the advancement of thermal protection of hot section components such as first-stage vanes and blades. Current technology relies primarily on the combined effects of a thermal barrier coating (TBC) and convective cooling, but the current state-of-the-art is insufficient to meet the thermal-mechanical demands imposed by hot gases with elevated turbine-inlet temperatures. Advanced internal and external (film) cooling technologies are a feasible pathway to more efficient, cost effective, and sustainable power generation. This research effort aims to significantly advance cooling technologies for gas turbine applications.

In addition to addressing technology advancements that improve gas turbine airfoil performance, pressure gain combustion has been identified as a possible means for improving plant operating efficiency. Unlike the Brayton Cycle of a conventional gas turbine engine (which experiences a pressure drop across the combustor), the combustion process in a Humphrey (or Atkinson) Cycle produces a pressure gain that even under conservative estimates could result in up to a 6% increase in overall system efficiency. Rotating Detonation Combustion (RDC) capitalizes on this cycle and offers potential as a drop in replacement for conventional gas turbine combustors. In addition to the potential gain in efficiency due to minimal time spent at peak combustion temperatures, NOx may also be reduced. This research effort is also addressing the technical challenges associated with RDC for gas turbine power generation.

## ADVANCED TURBNIE RESEARCH AT NETL

The U.S. DOE NETL Advanced Turbines team is taking an integrated, systematic approach to addressing state-of-the-art gas turbine needs. The primary objective of this research is to support the hydrogen turbine technology area in meeting the Department of Energy's (DOE) advanced turbine development goals, which include; 1) an efficiency target of 70% LHV for natural gas combined cycle and 2) net-zero carbon emissions by 2050.

Research projects utilize the extensive expertise and facilities readily available at NETL and participating universities. The research approach includes explorative studies based on scaled models and prototype testing.

Technical goals for the advanced turbines research include:

- Development of novel, manufacturable internal airfoil cooling technology concepts with cooling effectiveness improvements that are comparable to 2 percentage points for small gas turbine applications.
- Development of advanced, concepts to achieve film effectiveness values greater than 0.4 using the same coolant flow as the current state-of-the-art.
- Development of advanced material system architectures that permit operation of turbine airfoils at temperatures approximately 100 ºC higher than current state-of-the-art components.
- Demonstrate reliable deflagration-to-detonation transition and detonation initiation and sustained operation in a hydrogen-fueled RDC.
- Explore optimal operating conditions to reduce non-detonative combustion that adversely impacts potential efficiency improvements.
- Examine combustor configurations to achieve quasi-steady exit flow and low NOx emissions.
- Produce high-fidelity experimental data and validate Computational Fluid Dynamics models.
- Develop computational tools for RDC development.
- Conduct techno-economic analyses of gas turbine systems for R&D decision making.
- Develop combustion strategies and materials for hydrogen-fueled gas turbine combustors.
- Evaluate the combustion characteristics of ammonia ($NH_3$) as a carbon-free fuel source in gas turbine engines.

## IMPACT AND BENEFITS

Research results obtained through these projects can directly benefit the U.S. power and utility turbine industries by improving product development and meeting DOE's advanced turbine program goals for higher efficiencies and reduced emissions. Higher efficiencies implies alleviating dependence on foreign resources and improving preservation of domestic natural resources as we transition to greater reliance on renewable energy. Reduced emissions implies better environmental conditions and lower costs for pollution controls, including carbon capture and sequestration. These factors will eventually lead to greater energy security and economy for our country as we work toward net-zero carbon emissions in the power sector by 2035 and in the broader economy by 2050.

NETL is a U.S. Department of Energy (DOE) national laboratory dedicated to advancing the nation's energy future by creating innovative solutions that strengthen the security, affordability and reliability of energy systems and natural resources. With laboratories and computational capabilities at research facilities in Albany, Oregon; Morgantown, West Virginia; and Pittsburgh, Pennsylvania, NETL addresses energy challenges through implementing DOE programs across the nation and advancing energy technologies related to fossil fuels. By fostering collaborations and conducting world-class research, NETL strives to strengthen national energy security through energy technology development.

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