

Introduction to Advanced Combustion

Combustion remains the primary way in which chemical energy is made available for use by humankind. As such, advances in the way that we perform energy conversions using combustion can have a significant impact on the greenhouse gas balance of the planet. Because of its ubiquitous nature, advances in combustion technologies can provide benefits in many areas from home heating, to transportation, to electrical power generation, to industrial processing.

One aspect of combustion that is critical in all arenas is efficiency—the balance between the energy invested to accomplish a task and the work actually required. Efficiency is linked to both how completely the process of combustion can be executed and how well the energy released by the combustion process can be coupled to the energy objective—turning a shaft, cooling a room, etc. In addition to efficiency, it is necessary to achieve combustion in an environmentally sound manner. The potential to produce toxic or photochemically active species during combustion always exists, and insuring that the process is completed within acceptable limits of emissions is critical. Because these two aspects are independent of the fuel used, they are ubiquitous to all combustion systems.

Other aspects of combustion are also generic. The need to understand reaction dynamics (chemical kinetics) and the need to sense chemical species both during combustion and in the post-combustor gases are also requirements of many combustion systems. There are also advanced combustion strategies—for example flameless oxidation—that are not fuel specific and that can be applied to a range of problems when brought to maturity.

Finally there are some fuel-specific combustion technologies that are also critical to success, particularly those that deal with special or exceedingly complex fuels. Hydrogen is an example of a special fuel—a fuel that can be used in unusual ways due to its simplicity. On the other end of the spectrum are biomass and coal. These fuels present significant challenges due to their variable composition, chemical and phase complexities, and potential for forming species that are deleterious to either combustor operation or human health.

In this area of research GCEP has five active projects targeted at specific topics in advanced combustion. The topics of chemical kinetics and sensing are addressed in the work of Profs. Golden and Hanson, respectively. The topic of efficient engine combustion is addressed in the work of Prof. Edwards. Prof. Bowman is pursuing advanced combustion strategies such as flameless oxidation—a form of kinetically controlled combustion. And Prof. Mitchell is pursuing research into the basic mechanisms of biomass and coal combustion—both important fuels for a low greenhouse gas future. Technical summaries of the activities in each of these areas are given below.