Catalysis Center for Energy Innovation (CCEI)
EFRC Director: Dionisios G. Vlachos
Lead Institution: University of Delaware
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Mission Statement*: To develop innovative, transformational heterogeneous catalytic technologies for economically converting lignocellulosic (non-food-based) biomass into bioproducts and fuels.*

The Catalysis Center for Energy Innovation (CCEI) focuses on developing innovative, science-based heterogeneous catalytic technologies for transformation of lignocellulosic (non-food-based) biomass materials into fuels and bioproducts. Biomass offers a unique opportunity for a sustainable society with unprecedented impact on the US economy, energy security and independence. For this vision to be realized, we must overcome major scientific hurdles that are present due to the inherent complexity of biomass materials and associated processes.

The overall objectives of CCEI are to develop the enabling technologies for biomass conversion that lead to viable, economic operation of future biorefineries and to educate the workforce needed to further develop and implement these new technologies.

Since biomass feedstocks vary considerably by source and the number of candidate reactions is huge, the CCEI mainly focuses on developing a fundamental science base for controlling the scission and formation of C-H, O-H, C-C and C-O bonds by choosing a select number of reactions from a representative group of processes. Reactions typically take place in a complex, multiscale environment that renders the rational design of these processes and catalysts challenging. Our overarching goal is to develop methods and concepts that overcome this challenge and form the foundations of modern biorefineries. The cornerstone of the CCEI lies in advancing catalysis and its integration into processes that deliver innovative technologies for the conversion of building blocks of cellulose and hemi-cellulose, i.e., of sugars (produced from the hydrolysis of biomass). We have assembled an interdisciplinary team of principal investigators that brings together the necessary expertise and synergism to tackle these complex problems. We exploit various complementary catalytic technological platforms that are anticipated to play key roles in future biorefineries for energy, fuels, and chemical production. Examples include the production of renewable aromatics, of functionalized aliphatics, and other target bioproducts along with the production of fuels in the diesel and jet range. A unique trait of CCEI is the ability to carry out fundamental science in very complex problems, to introduce new inexpensive catalysts, and to integrate these catalysts into processes.

We have organized the following three crosscutting enablers as the backbone of the center's research to address the inherent complexities of the environment in which reactions take place: (1) synthesis of novel hierarchical multiscale materials with proper functional groups, (2) multiscale modeling, and (3) in situ characterization of materials. These enablers are integrated within all research thrusts to quickly advance scientific breakthroughs. We develop multiscale models to understand the chemistry and to design new materials. We synthesize hierarchical multiscale materials that are hydrothermally stable, possess tunable porosity with bio-inspired functionality grafted active sites, and minimize resistance to molecular motion while allowing shape selectivity. Furthermore, we design cutting-edge characterization methods to probe reactions, often under in situ environment.

The CCEI outcomes include a fundamental understanding of the reaction mechanisms of representative biomass thermochemical transformations, a rational framework for multiscale hierarchical catalytic materials and process design, science-based innovative technologies for biomass utilization, education of students and postdocs, and effective outreach/dissemination pathways to other scientists, students, and the public.

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