Introduction to Completed Project Reports

Eleven GCEP research projects have reached completion this May 2009 in the areas of Hydrogen Production, Distribution and Use, Renewable Energy-Solar, and Renewable Energy-Biomass, CO_2 Capture and Separation, CO_2 Storage, Advanced Combustion, Advanced Materials and Catalysts, and Integrated Assessment of Technology Options.

In the area of Renewables-Solar, three projects have reached completion. The first is by Pofessors Stacey Bent, James Harris, and Michael McGehee. They applied atomic layer deposition (ALD) techniques to the fabrication of thin-film photovoltaics using nanostructured inorganic semiconductor composites. This approach allows both an increase in photon absorption by increasing the optical path of light through the device and a decreased charge transport inefficiency through the control of the absorber morphology at the nanoscale. As ALD deposition is applicable to high-throughput fabrication, this technology could potentially lead to low cost photovoltaics with good energy conversion efficiencies. The second project in this area was carried out by Professors Mark Brongersma, Peter Peumans, and Shanhui Fan. They developed organic multijunction photovoltaic cells that use metal nanoscale features to enhance both photon absorption and charge transport. Transparent, high-sheet-conductivity, nano-patterned metal films were used as conductors, and metal nanostructures were embedded in the active layers to enhance the photon absorption and charge separation efficiency. The third project in the area of Renewables-Solar was led by Professors Martin Green and Gavin Conibeer of the University of New South Wales, Australia, who worked on an innovative photovoltaic device based on integrating low-cost polycrystalline silicon thin films with higher bandgap semiconducting materials. These materials were synthesized using silicon quantum dots embedded in a matrix of silicon oxide, nitride, or carbide to produce two- or three-cell tandem stacks. At the nanoscale, quantum confinement increases the effective bandgap of silicon and enhances absorptivity due to the formation of a quasi-direct bandgap. Providing that photo-generated charge transport can be optimized, such devices are anticipated to reach significant conversion efficiency compared to traditional silicon-based thin-films without adding appreciably to large-volume manufacturing costs per unit.

In the area of CO_2 Capture and Separation, researchers at the Energy Center of the Netherlands and Technical University of Delft (TU-Delft) completed their work on designing a combination of membranes, reactors and catalysts to form a membrane-reactor system for CO_2 separation. In this same area, Professor Yuichi Fujioka from the Research Institute of Innovate Technology for the Earth (RITE) led a ten-person chemical research group on the development of gas separation membranes through nanoscale material control. Their work on CO_2 separation will continue while the work on H_2 separation has been completed.

In the area of Advanced Combustion, Professor Tom Bowman and his colleagues completed research on the Optimization of Synthetic Oxygenated Fuels for Diesel

Engines. The work examined the combustion kinetics of oxygenated fuels such that the synthesis and design could be optimized for low-carbon feedstocks.

In the area of Carbon Storage, Professor Hamdi Tchelepi and his colleagues developed the General Purpose Research Simulator that efficiently simulates the flow of fluids in large-scale subsurface formations. With a few more incorporations and adjustments, the team expects the model to be an effective tool for modeling injection and CO_2 sequestration.

In the area of Advanced Materials and Catalysts, Professors Christopher Chidsey, Daniel Stack, and Robert Waymouth developed efficient catalysts for direct-hydrocarbon fuel cells. These catalysts are based on transition metal complexes immobilized on carbon electrodes. Specifically, various configurations of late-metal multi-metallic catalyst complexes were investigated for their role as electro-oxidation catalysts, and biologically inspired mono- and multi-metallic copper complexes were examined as electro-reduction catalysts.

In the area of Renewables-Biomass, Gavin Sherlock from Stanford University and Frank Rosenzweig from the University of Montana completed their project on the development of hybrid yeast strains by directed evolution for enhanced ethanol production from biomass. They successfully identified yeast species that are heat and ethanol tolerant and able to utilize the sugars from the cellulosic and hemicellulosic portions of biomass feedstocks.

In the area of Hydrogen Production Distribution and Use, Jim Swartz completed his project on Direct Solar Biohydrogen: part II. The overall objective of this research project was to develop a photosynthetic organism for the efficient conversion of sunlight and water into hydrogen fuel. The main focus was the evolution of an oxygen tolerant hydrogenase. In addition, the requirements for activation of these hydrogenases to ensure that the evolved hydrogenase could be efficiently activated during expression in the photosynthetic organism were investigated. Notable results were the discovery of a glycine to aspartic acid mutation adjacent to the active site that increased specific activity approximately three-fold and the establishment of a cell-free screening method for hydrogenase activity.