Introduction to Exploratory Projects – Completed

In addition to deep research into high-risk, high-impact fundamental science and technology, GCEP also funds smaller exploratory efforts. These exploratory projects can be funded for up to one year, and have budget limits of up to $100,000 each. The goal of these projects is to quickly evaluate the feasibility of a novel concept. If such an investigation proves successful, the investigators may apply for regular GCEP funding.

Six exploratory projects have been completed this year of which four have updates from the previous technical report as discussed below.

Biondo Biondi and Sjoerd de Ridder investigated whether passive seismic imaging by interferometry is a reliable and feasible low-cost alternative to active seismic monitoring. The researchers have been analyzing two high-quality passive data sets. These data sets were recorded by using semi-permanent installations that had been deployed with the goal of developing and monitoring oil reservoirs, not CCS projects. Over the last year the researchers have shown that passive seismic monitoring might be feasible in diverse geographical settings, in addition to offshore (Valhall) or close to the ocean (Long Beach). Furthermore, careful processing shows that body-waves arrivals can be synthesized in addition to interface-waves arrivals. This observation opens the possibility that the method can provide information on processes taking place much deeper in the subsurface than the ones illuminated by interface waves.

Matthew Kanan and Thomas Veltman studied materials that catalyze efficient electrochemical N_2 fixation, which would open up the possibility of using an N_2/NH_3 cycle to store and utilize energy from diffuse renewable sources. In such a cycle, N_2 and H_2O would be electrolytically transformed to NH_3 and O_2 in an electrolyzer powered by a renewable electricity source. With existing technologies, NH_3 can be utilized in solid oxide fuel cells or combustion engines to generate electricity or work and regenerate N_2 and H_2O. In contrast to H_2, which has received the most attention for fuel-based renewable energy storage, NH_3 is easy to store in solid form by complexation with earth-abundant salts. Conventional spectrophotometric methods are cumbersome and prone to false positives from the presence of metal ions or other sample impurities. These researchers have successfully addressed this analytical problem by developing a device that quantifies NH_3 liberated from an aqueous solution. They have also constructed electrolysis cells suitable for evaluating catalysts in gas diffusion electrodes that provide much higher concentrations of N_2 at the catalyst surface. The information available from these studies will provide the foundation for the subsequent discovery and development of catalysts that are suitable for use in an electrolytic device.

The availability of effective and reliable monitoring is recognized as a requirement for the acceptance of geologic sequestration of CO_2. Peter Kitanidis and Eric Darve are developing ultra fast computational methods for the real-time monitoring of CO_2 plumes and the evaluation of risks of leakage. The ultimate objective is the development of computational tools for data assimilation and uncertainty quantification based on sound fundamentals and numerical methods but adapted to specific problems. Among the achievements is the development and implementation of a new fast direct solver (FDSPACK), which works for one-dimensional manifolds. This solver reduces the cost from order of magnitude N^3 to N log N where N is the number of unknowns. The researchers have also developed and implemented an algorithm for fast linear inversion (FLIPACK) which reduces the cost of inversion from order of magnitude M^2 to order of magnitude M, where M is the number of grid points and performed various numerical benchmarks to test FDSPACK and determine how to optimally choose the rank to have minimal numerical error.

Shanhui Fan and his team explored the feasibility of safe wireless power transfer directly to vehicles cruising at highway speed. They aim to use magnetically coupled resonating coils located in the roadbed and in the vehicles as the power transfer mechanism. Using large-scale electromagnetic simulations the researchers are examining the influence of the body of a vehicle, modeled as a metallic ground plane, on the efficiency of the resonant power transfer scheme in order to establish a preliminary experimental set up for the wireless power transfer system. This project has successfully demonstrated that numerically and experimentally the energy could be transferred efficiently between two magnetically coupled resonating coils in a complex electromagnetic environment.

Nick Melosh and James Harris explored photon-enhanced thermionic emission (PETE) for solar energy conversion. PETE operates at elevated temperatures (600 to 900 ºC) under high solar concentration (100s to 1000s of suns) appropriate for concentrated solar power. The process operates by thermionically emitting photo-excited electrons from a light absorbing p-type semiconductor cathode into vacuum, where they are collected by a lower temperature, low work function anode. Due to the combination of photovoltaic and thermal energy collection processes, PETE has the potential to achieve power conversion efficiencies above 47%, higher than the fundamental limits for single-junction PV. Furthermore, PETE devices integrated with solar thermal converters could achieve efficiencies over 55%. No updates are reported this year.

Jennifer Wilcox and Zhenan Bao investigated the potential for carbon capture using amine-modified carbon nanotubes. The purpose of this research project was to develop a robust, inexpensive solid sorbent for CO_2 capture from large point sources. Multi-walled carbon nanotubes (MWNTs) were chosen for functionalization using both primary and tertiary aminosilane compounds. The use of carbon nanotubes, which are essentially an activated carbon material that can be tuned to achieve desired properties, and aminosilane compounds creates a combination of materials that are well understood, and have been used widely in industry as individual components. Carbon nanotubes offer an advantage over other engineered materials, such as zeolites and metal-organic frameworks, which may preferably adsorb H_2O, making them difficult to work with in humid environments. The research objectives of this work included: 1) development of a method for successful functionalization of MWNTs; 2) characterization and testing of sorbents for CO_2 capture and release under relevant conditions; and 3) use of knowledge gained from these experiments to better tune the sorbents for enhanced CO_2 capture. No updates are reported this year.