Introduction

The 2013-2014 portfolio marks 11 years of GCEP activities with new, completed, and ongoing programs spanning ten topic areas. This technical report contains updates from approximately 33 currently funded research activities and three completed programs. The progress and results from six exploratory programs are provided, as well as descriptions from two cost-shared research programs.

Progress reports from current GCEP funded research activities are described by topic area in Chapter 2 and final reports of projects that have reached completion during the past year are presented in Chapter 5. Investigators provide updates that include an abstract, introduction, results and progress, publications, and future directions.

Interest in exploratory research programs continues as GCEP receives proposals from investigators new to the energy field but wanting to explore ideas with relevance. The purpose of this program is to allow exploration of new ideas by supporting preliminary research or analysis. These scoping research activities are limited to $100K and a one-year performance period. Chapter 3 provides the reports from the active programs and Chapter 6 contains reports from completed programs for 2013-2014. The topic areas span the portfolio in topics including Hydrogen, Solar, CO_2 Storage, Advanced Combustion, and Advanced Materials and Catalysts. On average, around one-third of the programs which receive exploratory funds are successful at becoming fully funded, three year programs.

The updates and activities from cost-shared research are presented in Chapter 4. Participation in cost-shared research provides funding that leverages other third party contributions and continues the research interests of GCEP-related work. Currently GCEP is affiliated with two membership organizations, the Bay Area Photovoltaic Consortium and the Stanford Center for Carbon Storage.

In the past year, GCEP continued to receive large numbers of proposals in response to the solicitation for proposals. As a result, multiple subcontracts are being negotiated with external institutions in new targeted areas for GCEP. This work is expected to begin later in 2014. GCEP has now funded research across the following twelve topic areas of its portfolio:

1. Hydrogen Production, Distribution, and Use
2. Renewable Energy - Solar
3. Renewable Energy - Biomass
4. Carbon Dioxide Capture and Separation
5. Carbon Dioxide Storage
6. Advanced Combustion
7. Advanced Materials and Catalysts
8. Advanced Electric Infrastructure
9. Advanced Coal
10. Grid Storage

11. Advanced Transportation Systems
12. Energy Systems Analysis

The distribution of approved funds across the current research portfolio is shown in Figure 1. There is strong support for research in renewable energy sources comprising almost half of the currently funded projects. The broad categories of carbon-based energy systems, and electrochemistry and electric grid each are almost a quarter of the distribution. The single largest category of current funding is allocated to solar photovolatics followed by bioenergy then carbon capture. The allocation of funds is expected to expand and change over time as major projects are completed and targeted funds address specific topic areas.

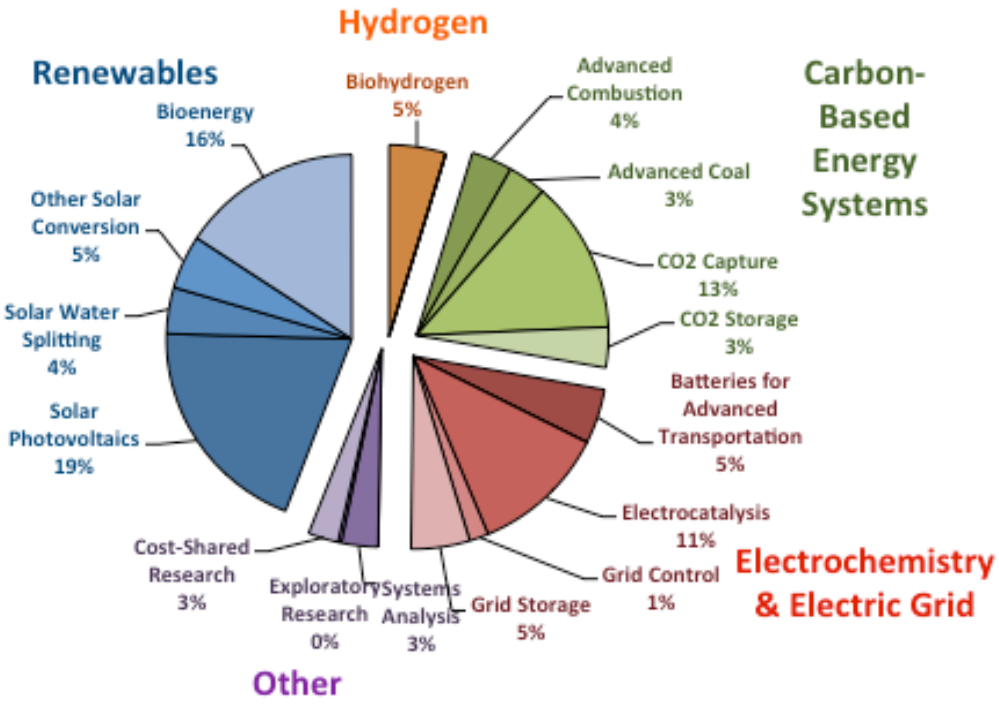

Figure 1. GCEP Portfolio 2013-2014

While not an exhaustive list, each of these areas is expected to play an important and interconnected role in future energy systems and the reduction of greenhouse gas emissions (GHG). For example, hydrogen has been identified as a potential energy carrier in some energy scenarios. The research portfolio described here includes programs where the hydrogen is produced by microbes. Currently hydrogen is produced primarily from fossil fuels. Reduction of GHG emissions from that method of producing hydrogen would also require CO_2 capture and storage, another topic considered in this report.

One option for carbon mitigation is through carbon capture and storage (CCS). While there are many elements to the CCS chain, capture and separation technologies dominate upwards of 80% of the total CCS costs. There is significant opportunity to exploit

fundamental advances in chemistry, materials science and engineering to drive down the penalties that CO_2 capture and separation technologies imposes. There are also opportunities that reduce the CO_2 generated or emitted through overall system optimization and process alternatives. For carbon storage, better understanding of the subsurface reactions is needed to gain confidence in full-scale technology and system deployment.

Solar radiation is the largest energy flow entering the ecosystem, representing an enormous resource of renewable energy that could potentially meet a large fraction of global energy needs. Several solar programs are focused on developing innovative materials for high-performance photovoltaic solar cells to improve efficiency, reduce cost, and increase durability. This field has many researchers pursuing similar means, and the focus for GCEP is beginning to evolve toward solar technologies that are not only efficient and inexpensive at the cell or module level, but also those which can be durable in the field, easily manufactured, and cost-effectively integrated at scale at the system level.

Biomass energy is another renewable energy option that has the potential of low net emissions of CO_2. Biomass resources are being considered as a potential alternative to transportation fuels. Biomass research, like other renewable energy technologies, still needs to address issues of cost, conversion efficiency, energy density, and sustainability.

Combustion is currently, by far, the most common first step in converting the energy stored in chemical bonds to energy services for humankind. Because of its ubiquitous nature and its intimate coupling with carbon-based fuels, even small improvements to combustion technology can have significant impact on total greenhouse gas emissions whether they are from biomass or fossil resources.

The development and advancement of materials is an encompassing need in systems that extract, distribute, store or use energy. The performance of these systems depends on the materials. Plastics, coatings, alloys and catalysts are some of the broad classes of materials used in current energy products. Advancements in these materials improve system efficiency and energy conversion processes, extend lifetime, and reduce CO_2 emissions.

To allow integration of renewable sources of electricity onto the electric grid and to achieve displacement of base load electricity supplied from fossil fuel sources, research aimed at understanding the grid operation and needs for storage is essential. The GCEP portfolio now includes studies on grid controls and large-scale storage to examine the control of the electricity network in a condition where there is a high penetration of renewables and to develop technology so that supply does not have to equal demand at all times.

Energy systems analysis involving net energy analysis and life-cycle assessment is emerging as an important research area for long-term, energy economic and policy planning. Fundamental analysis of energy and material flows in technology development

and deployment provides a perspective grounded in first-order laws of physics and thermodynamics. Over the past year the energy systems work has looked at renewable energy, particularly wind and solar, coupled with storage. In the upcoming year, the team will examine the regenerative hydrogen fuel cell as energy storage and natural gas combustion turbines coupled with storage.