# Introduction to Grid Storage

Grid-scale storage can help integrate electricity generation from intermittent renewable energy technologies, particularly solar and wind, to help meet the increasing global electricity demand while simultaneously reducing $CO_2$ emissions. A scenario where renewable resources comprise 50% of energy generation is likely to require the integration of large-scale energy storage to support, balance, and stabilize the power system.

Energy storage options apply to different niches in the power system and are often categorized by their power ratings (kW to GW) and discharge rates (seconds to hours). They can be based on different fundamental processes including mechanical, electrical and electromagnetic, and electrochemical. Existing technologies, however, suffer from a number of drawbacks that inhibit widespread adoption and deployment such as low cycle life, high cost, and poor performance, durability, and scalability.

GCEP currently funds four programs to address grid-scale storage all of which began in 2012. Professor Scott Barnett at Northwestern University is collaborating with Professor Robert Kee at the Colorado School of Mines to develop “A Novel Solid Oxide Flow Battery Using H-C-O Chemistry”. The program performs fundamental studies of the materials, cells, stacks, and system designs to validate and improve upon the device. Progress over the past year includes electrochemical cell fabrication, setup and operation of the pressure testing vessel and system-level simulations.

A team at the University of Texas, Austin led by Professor Allan Bard conducts research on “Novel Electrolyte Energy Storage Systems”. This program is rooted firmly in re-examining the fundamentals of flow battery technology and engaging in an effort in which the active redox couples, the materials that separate the couples, and the flow characteristics that dictate the rate of delivery are optimized. This work allows system-level solutions with high efficiency and capital costs that are much lower than if each aspect of the system were optimized individually. To date, the group has developed and deployed a series of experimental methods to study the needed composition and transport properties of membranes under conditions used in vanadium redox batteries and tin-bromine RFB systems and have future plans to focus more on the vanadium and expand the testing of electrodes.

Professor Robert Hebner at the University of Texas, Austin and Professor Ray Baughman at the University of Texas, Dallas, are researching “A Low-Cost Flywheel Design and Flywheel Materials”. The group at UT Dallas has been working with CNT fibers and composites to create multifunctional materials that combine high strength with the magnetic and superconducting properties needed to levitate rotors for flywheel batteries. Meanwhile the UT Austin group has been designing codes and methods for incorporating the materials into the flywheel bearing designs. Promising results show that flywheel storage may have potential applications for diurnal energy storage.

Professors Yi Cui and Robert Huggins from the Department of Material Science and Engineering at Stanford University are leading a program to develop inexpensive, safe, high power lithium batteries using aqueous electrolytes. The team is exploring aqueous electrolytes to extend voltage ranges and a new group of electrode materials based on Prussian Blue (PB) which is made up of common, earth-abundant materials and has a zeolitic open framework type of crystal structure. Over the past year, the group has successfully demonstrated the ability of the PB family to intercalate monovalent and divalent ions that would create a pathway towards low-cost grid-scale batteries. The remainder of the project will be to study the PB materials in organic electrolytes and to develop anodes to match the cathodes.