Lunch, Bocce, and Electrochemical Systems for Large-Scale Energy Storage

September was a busy month for the California Section, starting with a full day of public outreach at the Solano Stroll in Berkeley on Sunday, September 8th, continuing with the WCC Zoom presentation on sustainability by Professor Julie Zimmerman ("Designing Tomorrow") on Saturday, September 14th, and the Diversity in Science event on Saturday, September 21st, hosted by the Lawrence Hall of Science in Berkeley and featuring a film ("Surviving Voices – Quilt Panel Makers") documenting the history of the AIDS epidemic, followed by an exciting update on HIV treatment and prevention by Dr. Christoph Carter, Senior Director of Clinical Development at Gilead Sciences.

The last Saturday in September found us in Fremont, CA, where a dozen Cal ACS members and friends gathered at the Mission Peak Sportplex for networking, an excellent Mexican-themed buffet, and a talk by Dr. Nicholas Cross, postdoctoral researcher at Lawrence Livermore National Laboratory. His talk, "Electrochemical Systems for Large-Scale Energy Storage" attracted another half-dozen online viewers from across the Bay Area and as far away as Penn State University (where Dr. Cross completed his doctoral studies). He set the stage by reviewing current U.S. energy consumption (approximately 100 quadrillion BTU's in 2022). Just considering electricity generation (about 38 Quads), about 40% comes from renewable or nuclear sources (non-fossil fuel), and the challenge is to decarbonize the remaining 22 Quads by 2035 to meet U.S. commitments to reduce carbon dioxide emissions. Including transportation and, manufacturing, and space heating, the longer term goal is to decarbonize 56.5 Quads of energy use. It's a huge challenge.

The growth of solar PV electrical generation has reduced the consumption of natural gas during daylight hours, but energy storage is crucial to provide power at night. Pumped hydropower is the best established storage method, but it is restricted to specific sites and cannot be expanded. Other mechanical and thermal storage methods are still at the prototype stage. Electrochemical storage (batteries) is growing rapidly; in fact, California utilities currently have the equivalent of 10 gigawatts of battery storage, primarily lithium-ion batteries, and this capacity is projected to grow tenfold by 2050. Battery storage is already reducing the risk of blackouts in California.

Dr. Cross reviewed the principles of electrochemical energy storage, which requires a coupled pair of reversible reactions that can be used to charge and discharge a battery. The reaction pair defines the available potential, but efficient storage also requires stable materials with high conductivity and rapid ion transport. The current generation of lithium ion batteries rely on multiple materials that face short-term or long-term supply risks, including lithium, nickel, cobalt, and graphite. Lithium-ion batteries are also susceptible to thermal runaway and fires, initiated by defects, overcharging, mechanical damage, or chemical breakdown.

Could earth-abundant sodium replace lithium? The sodium ion is substantially larger, increasing weight while slowing ion transport. Nonetheless, sodium ion electrolytes have conductivity that is close to their lithium equivalents. Sodium ion anodes use graphene or amorphous carbon rather than graphite to stabilize the metal atoms. Various abundant metal oxides can be used as the cathode that accumulates sodium ions during battery discharge. These batteries resist thermal runaway and thus promise improved safety.

Solid-electrode batteries offer high power and energy density that is essential for transportation, but size and weight are not critical for grid scale energy storage. Flow batteries offer reduced cost and easy scale-up, since the electrolytes are stored in tanks that can be as large as needed. The electrolytes are pumped through electrode cells where the electrochemical reactions take place during charging or discharging. Both inorganic and organic electrolytes have been used in prototype batteries, and several types are currently in small-scale production. Most use some combination of strong acids, expensive membrane separators, and are limited to relatively low voltages to avoid electrolysis of the water in the electrolytes.

The Department of Energy has set a target of five cents per kilowatt hour, and all of the technologies discussed here (except sodium ion batteries) are expected to reach this target by 2030.