Electro- and Photo-Chemical Energy System

Theme leader

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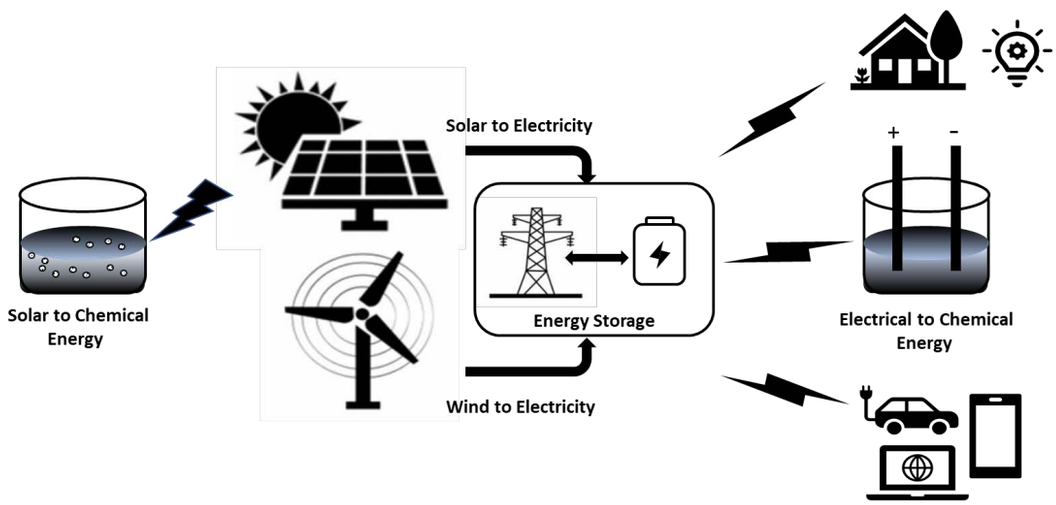
At CERC, we aimed at addressing the universal problems related to the environment change by providing clean and sustainable energy solutions. The electro and photo chemical energy systems provide efficient ways of harvesting the energy from the renewables (sun and wind), storing the energy to resolve intermittency supply issues (batteries) and transforming the energy for household and portable energy application, and for generating useful chemicals or fuels (green H2 etc.). From computational to experimental tools, our research team is involved in discovering advanced photo and electro active materials, designing new devices and systems, and developing mathematical models to predict the real time scenarios.



PHOTOCHEMICAL SYSTEM

Direct conversion of solar energy to chemical energy such as green hydrogen.
Wastewater treatment using sun light.
Design of photo catalytic reactor for the degradation of organics in drinking water.

ENERGY STORAGE SYSTEM

- Harvesting energy from renewables (solar and wind).
- Battery development for small- and large-scale energy storage.
- Performance optimization of Li-ion and flow batteries using experimental and computational tools.

ELECTROCHEMICAL SYSTEM

- Clean electricity for utilities, zero carbon emission vehicles and portable electronics applications.
- Electrolysis to generate new green and value-added chemicals.

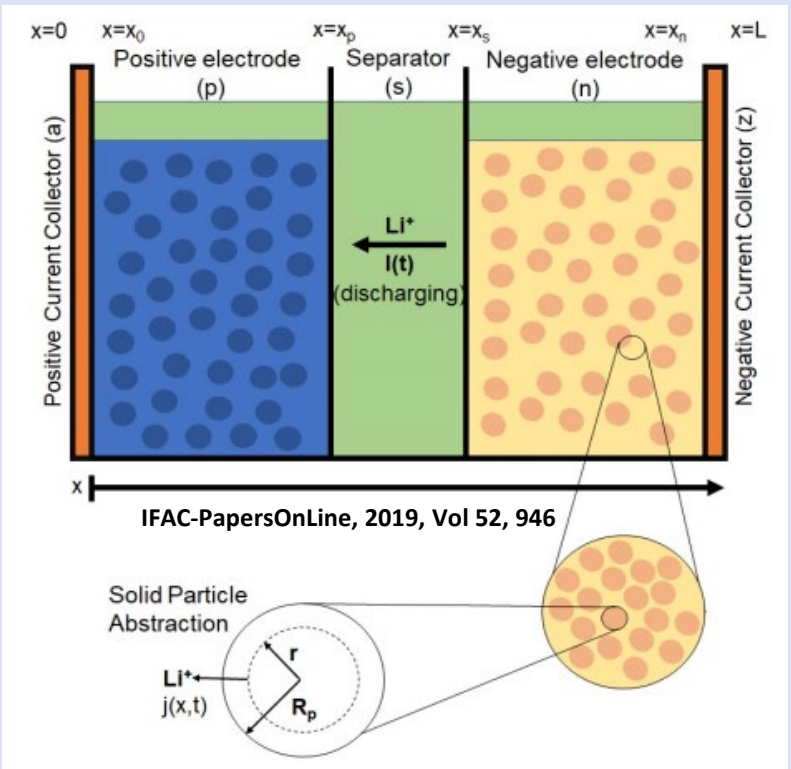
Challenges and Opportunities

Although photo and electrochemical systems can provide cleaner and sustainable energy solutions, the engineering challenges and the cost associated with these systems prevent them from entering the profitable market. However, with the recent development in the cost-effective production of solar cells technology as well as in the optimization of battery and electrolyzer operations, it is possible that these systems will replace conventional fossil fuel-based energy system soon. With strong support from the Canadian government and industrial sector, CERC team is committed to overcome short- and long-term challenges associated with these systems.

FEATURE PROJECT

Li-ion battery electrochemical modeling

Li-ion batteries are ubiquitous in portable electronics, automotive applications, and stationary power storage. Accurate mathematical models of their behavior and corresponding computational tools are necessary for battery cell development. Our team is focused on improving the efficiency of these systems, using scientific computing and machine learning techniques, to allow their use in real time control.

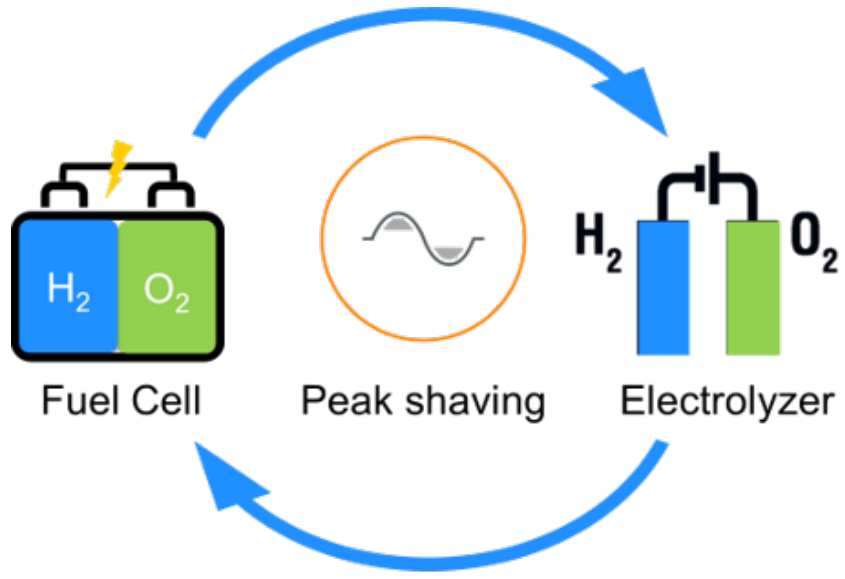


$$\frac{\partial c_s(r,t)}{\partial t} = \frac{1}{r^2}\frac{\partial}{\partial r}\left[r^2 D_p^s \frac{\partial c_s(r,t)}{\partial r}\right]$$

FEATURE PROJECT

Reversible oxygen electrodes for fuel cell and metal-air battery applications

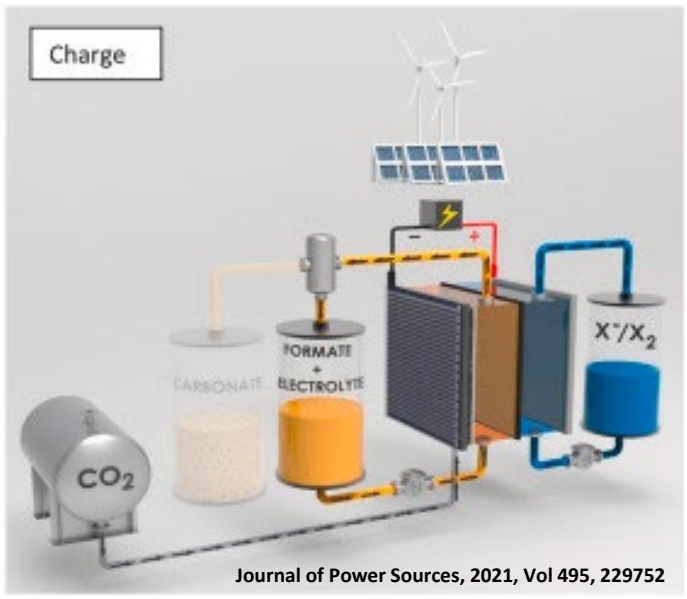
Owing to the increasing demand on reversible energy storage/conversion system, regenerative fuel cell and rechargeable metal-air batteries are in demand. However, the sluggish oxygen reactions, scarcity of noble metal catalysts, and catalyst degradation become the main obstacle for their wide implementation. To address these challenges, our team at CERC is pursuing the advancement of transition-metal-oxide-based catalysts by exploring the catalyst architectures, electrochemical interface environment, and electrode break-in protocols in oxygen reduction reaction /oxygen evolution reaction applications.



FEATURE PROJECT

Metal free CO_2 redox flow battery

Due to unprecedented growth in battery demand, there are challenges regarding the supply of diverse minerals coupled with the high energy intensity and carbon footprint of metal production. In collaboration with the industrial partner, our team at CERC is developing a novel class of non-metal flow battery namely the CO_2 redox flow battery that utilizes CO_2 as an active species. The price of CO_2 captured from industrial emission sources and purified is between 50 and 150 USD t^{-1}, which is two orders of magnitude cheaper than lithium or vanadium and one order of magnitude cheaper than zinc.



FEATURE PROJECT

Electrolysis of air capture solutions

Unlike the power generated from the conventional fossil fuel-based systems, the electricity from the renewables is clean and sustainable in nature. This clean electricity allows the conversion of waste CO_2 into carbon-based fuels and other valuable chemicals. Our team at CERC is involved in advancing the science and engineering of deploying electrocatalysts, membranes, and flow chemistry in electrolyzer that will contribute to a carbon-neutral environment. This electrochemical process has a potential to replace the thermochemical-based system for the greener environment.