

CHEMICAL ENGINEERING

UNIVERSITY of WASHINGTON

# SEMINAR



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**Rational Design Strategies for redox flow batteries**

**Monday July 25<sup>th</sup>**

Lecture 4:00-5:00 p.m. | Physics/Astronomy

Auditorium (PAA) A118

Reception 5:00-6:00 p.m. | Benson Hall Lobby



## Bio

Bertrand is a National Science Foundation Graduate Research Fellow pursuing his Ph.D. in Chemical Engineering at MIT. His research in the Brushett Group centers on the design of redox flow batteries, applying chemical / electrochemical engineering principles to better understand design tradeoffs for constituent materials. He is also an Executive Editor for the MIT Science Policy Review, a fellow in the ChemE Communication Lab, and a representative to the Chemical Engineering Graduate Student Advisory Board. Prior to graduate school, Bertrand received his B.S. in Chemical Engineering from Ohio University. He is passionate about educating the next generation of chemical engineers and developing electrochemical technologies to address modern sustainability challenges.

**DYSS2022**

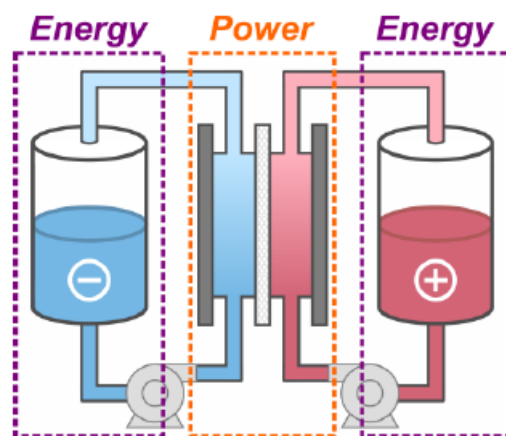
## Abstract

### Rational Design Strategies for Redox Flow Batteries

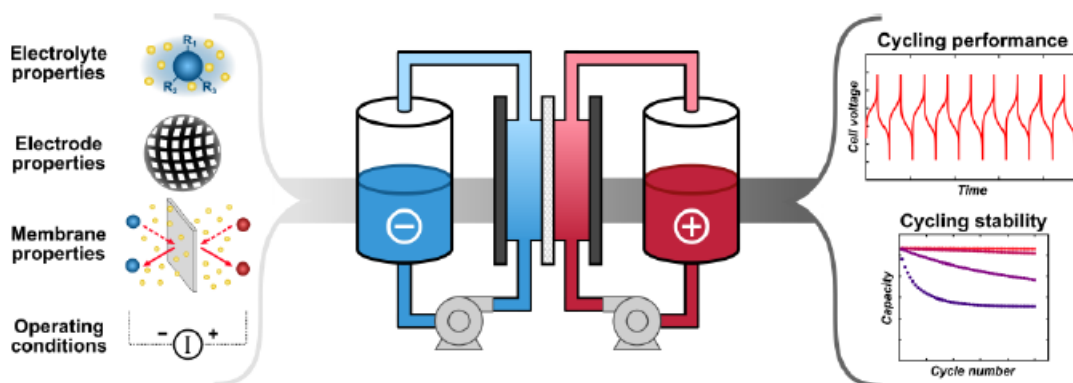
Global decarbonization of the energy sector necessitates development of storage technologies to mediate the inherent intermittency of renewable resources. Electrochemical systems are well-positioned to support this transition with redox flow batteries (RFBs) emerging as a promising platform; unlike solid-based batteries (e.g., lithium-ion) that store charge in their electrodes, RFBs store charge in electrolytes, which are held in external reservoirs and pumped through an electrochemical reactor during charge and discharge (Figure 1). This unique architecture offers decoupled energy / power scaling, simplified manufacturing, and long service life. Despite their favorable characteristics, current embodiments remain prohibitively expensive for broad adoption, motivating the development of new electrolyte formulations (e.g., redox molecules, supporting salts, solvents) and reactor materials (e.g., electrodes, membranes) to meet performance and cost targets for emerging applications.

While many next-generation materials offer performance improvements, they must carefully balance complex tradeoffs between power / energy density, cycling stability, energy efficiency, and capital costs. This multifaceted parameter space frustrates the articulation of unambiguous design criteria, as the relationships between constituent material properties and cell performance metrics are not yet well-understood. To this end, my research establishes rational design strategies for RFBs to enable robust, cost-competitive, and durable grid-scale energy storage.

In this talk, I will introduce a modeling framework for describing cell cycling behavior in RFBs (Figure 2), building on thermodynamic, kinetic, and transport descriptions for electrochemical processes. Using this generalized set of constitutive equations, I will then discuss analytical solutions for mass balances, charge / discharge behavior, and relevant performance metrics. Compared to previous numerical approaches, the discovery of analytical expressions reduces the required computation time by several orders of magnitude, enabling analyses that were previously unachievable for systematic RFB diagnostics (e.g., optimization, parameter estimation, techno-economics). To illustrate their utility, I will highlight applications which elucidate key design factors, including molecular engineering for redox species and membrane selectivity. Broadly, the methods developed in this work have potential to advance foundational understanding in RFB design, leading to more rigorous selection criteria for candidate materials.



**Figure 1.** Graphical depiction of RFBs, highlighting decoupled energy / power scaling.



**Figure 2.** Graphical representation of the constitutive relationships enabled by this modeling framework.