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EDITORIAL

Preface

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The unique characteristics of the redox flow battery offer the promise of meeting specific needs of the "smart grid" and the continued incorporation of renewable power sources into the electricity distribution system.

There are two energy infrastructures at work in the world today: an electrical infrastructure that depends primarily on coal, nuclear, and hydroelectric power, and a transportation infrastructure that depends almost exclusively on petroleum. These two infrastructures exist almost completely independently of one another, with very little exchange of energy between the two. The scope of energy exploration, extraction, and conversion since the beginning of the industrial revolution has contributed to increasing life expectancies and standards of living across the world, but there are signs that the overall method of delivery and conversion is headed for change, marked by the limitations of the existing system and by the advent of new technologies: we are starting to see fundamental changes to the energy infrastructure. Chief among these changes is the addition of electrical energy storage to both systems.

The hybridization of our transportation infrastructure has begun, enabled by advances in the development of on-board electrical energy storage using lithium-ion batteries, in which energy is stored primarily in the solid active material and where weight and volume are key drivers of acceptance. In considering stationary power, however, a completely different set of requirements is driving development in complementary, but very different, technologies. After decades of development, renewable sources of electricity are becoming cost-competitive with incumbent technologies in an ever-expanding number of locations. As a result, renewables have seen significant year-over-year growth, even though they comprise a very small percentage of the overall generation of electricity. These renewable sources are intermittent and often unpredictable, which limits the degree to which utilities can rely upon them. These sources would be much more valuable if coupled with energy storage, so that the energy could be relied upon, whether or not it is generated in the same instant that the customer load demands it.

This energy storage requirement has stimulated a renaissance in redox-flow-battery technologies, wherein energy and power are decoupled, and efficiency more than weight and volume is the key metric. Redox flow batteries offer the ability to provide fluidity to the grid—to store electricity from places and times when generation is relatively cheap, and provide it to the consumer at times when demand is high and supply is relatively low. In fact, this kind of energy storage has been identified as sufficiently significant and enabling of renewables and the smart grid that it is specifically singled out for consideration in the Energy Independence and Security Act of 2007. Energy storage and redox flow batteries can be placed at the site of intermittent generators such as wind farms, at choke points in the distribution network, or at a substation to improve local power quality and reliability. Placing storage at these locations could allow deferment of some capital improvements, or make optimization of an improved transmission-and-distribution system considerably easier. Because of these factors, there has been substantial growth both in

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academic and industrial research and development of redox flow batteries, where there are various chemistries to be developed and new materials designed and optimized to yield highly efficient, low cost systems.

In this special issue, we seek to summarize the current state of flow battery technologies and to examine some of the key performance barriers that must be addressed to help realize the promise of battery technology to make our energy supply more robust, efficient, and sustainable. In particular, there is a review of redox flow batteries, focused on the issues common to all battery chemistries and the underlying phenomena that dictate the performance of flow cells. This review article is followed by research articles dedicated to both existing and novel chemistries, with focus on material component development, mathematical modeling, and reaction-rate studies.