

# Chapter 13: Fuel Cells & Flow Batteries

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## Abstract

Modern society is founded on simple electric cells referred to as primary and secondary batteries which propel small scale electronics to electric cars and large scale storing of electrical energy systems. The need to use older forms of battery such as lead-acid and alkaline cells in the past, and still today, in some critical applications such as the dependability and low costs of this battery type is being supplanted by lithium-ion batteries because of its high energy densities, performance, and long cycle lives. The important concepts in determining the performance of the battery, its size and weight, and use in a specific application are energy density and energy efficiency. Batteries are fast becoming a part of electric mobility, portable electronics, medical devices, integration into renewable energy sources and are establishing enormous technological advancement and environmental sustainability. Nevertheless, safety and material availability, cost, and environmental effects imply that there must always be innovation. It is desired that, in the future, changes in battery chemistry, battery design and battery recycling will resolve these and be able to offer safer and greener methods of energy storage that will be more efficient. In conclusion, batteries will remain as one of the pillars of the present day energy systems and will be the determiners of the sustainable, electrified and a sustainable, energy efficient future.

**Keywords:** Fuel cells, Flow batteries, Hydrogen, Methanol, Renewable energy, Energy storage, Sustainable technology.

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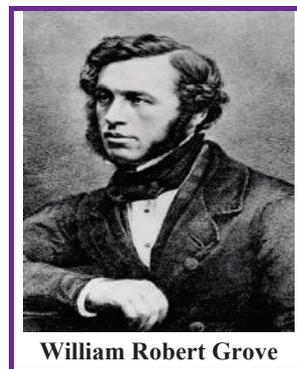
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## 13.1. Introduction

As the world demands continue to propel towards sustainable clean and efficient energy storage and conversion technology, it has emerged to be a valuable scientific and technological issue in response to the depletion of fossil energy, environmental pollution and climate changes. The conventional energy systems, which are based on combustion reaction, are typified by low efficiency and extensive greenhouse gaseous emissions and therefore alternative electrochemical technologies must be devised. In that respect, the flow batteries and the fuel cells have grown into developed energy systems that can come with a direct conversion of chemical energy into electrical energy at high efficiency, with lower environmental impact and carbon footprint.

### 13.1.1. Historical Development of Fuel Cells

The development of fuel cells can be traced back to 1839 when a British scientist (Sir William Robert Grove) demonstrated the gas voltaic battery that would combine hydrogen and oxygen to generate electricity and water. Nevertheless, fuel cell technology was mostly theoretical until the mid-twentieth century because of the shortage of materials and infrastructure. Major advancements were made in the 1960s, as NASA made successful attempts to use alkaline fuel cells in the Gemini and Apollo space missions as a source of electricity and drinking water in spacecrafts. Since that time, different types of fuel cell have been developed, such as proton exchange membrane and direct methanol fuel cells (PEMFCs and DMFCs), which are currently under intensive investigation as a source of transportation and portable power.



### 13.1.2. Evolution of Flow Batteries