Appendix A Solid Oxide Fuel Cell Primer

This section is not a comprehensive discussion of all potential components and applications of SOFCs; rather, it is intended to provide a conceptual overview of the basic components and functions of a SOFC supporting a vocabulary within which policymakers can debate and formulate policy decisions. A SOFC is an electrochemical device that generates electricity by oxidizing fuel such as natural gas or synthetic gas produced from coal. When commercialization of SOFCs is achieved, they can become a desirable and significant source of electricity in the United States and the world because they are efficient, reliable, adaptable, and produce low levels of emissions. When the fuel is hydrogen the only byproducts are water and heat, which can be used to support heat and power systems.

In a SOFC, electricity is generated through an electrochemical reaction and not through a combustion process. The operating principles of fuel cells are similar to those of batteries, given they produce electricity without combustion or emissions. Unlike batteries, SOFCs do not run down or need to recharge; they only require a constant source of fuel and oxygen.

A single fuel cell consists of three basic components[1]: (1) an anode, (2) a cathode, and (3) an electrolyte that separates them (see Figure 1). Bipolar plates on either side of the cell distribute gases and serve as current conductors. The **Anode** is the negative electrode that releases electrons to the external circuit and oxidizes fuel during the electrochemical reaction. The **Cathode** is the positive electrode that acquires electrons from the external circuit and is reduced during the electrochemical reaction. The **Electrolyte** is the medium that provides the ion transport mechanism between the cathode and anode of the cell.

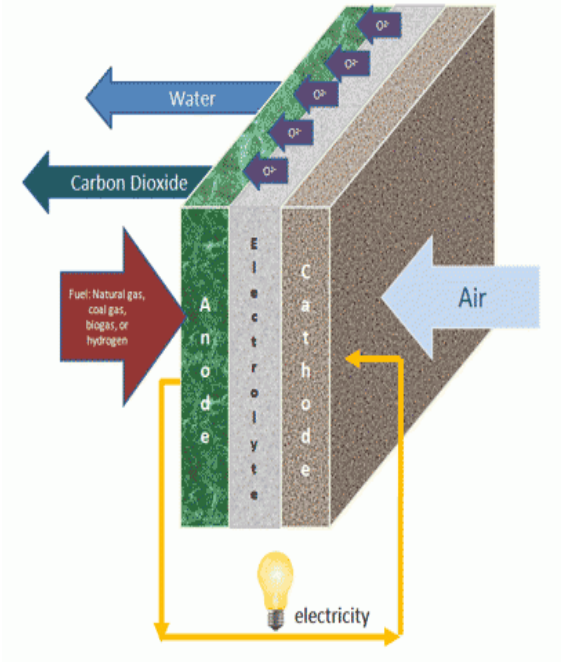

Figure 1 Three ceramic layers of an SOFC

In general, a fuel source is fed into the anode of the fuel cell and oxygen, from the air, enters the cell through the cathode. By reacting fuel on the anode side of the electrolyte, the concentration of oxygen

[1] https://depts.washington.edu/matseed/batteries/MSE/components.html

is dramatically reduced. The electrode on this surface will allow oxygen ions to leave the electrolyte and react with the fuel which is oxidized, thereby releasing electrons. Exposing the cathode side of the electrolyte plate to air creates an oxygen concentration gradient across the electrolyte, which attracts oxygen ions from the cathode to the anode. If there is an electrical connection between the cathode and the anode, this allows electrons to flow from the anode to the cathode, where a continuous supply of oxygen ions for the electrolyte is maintained, and oxygen ions from cathode to anode, maintaining overall electrical charge balance, and thereby generating useful electrical power from the reaction of the fuel.[2]

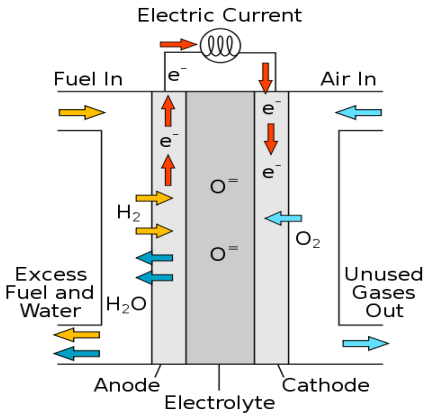

Figure 2 A Solid Oxide Fuel Cell

The power of a single cell produces a small amount of voltage. In order to increase the voltage, a group of individual fuel cells may be networked via various geometric configurations (such as tubular or planar designs) to form a stack of fuel cells, or "stack." Even though an individual fuel cell is technically just one component of a stack of fuel cells, it is not uncommon for "stack" and "cell" to be used interchangeably in conversation or even in technical literature.

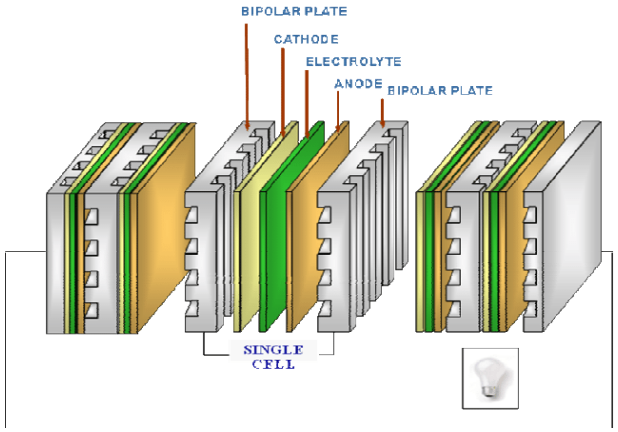

Figure 3 Stacked Fuel Cells

[2] Stambouli and Traversa, 2002.

Advantages and Challenges[3]

Advantages	Challenges
• High efficiency • Fuel flexibility • Solid electrolyte • Suitable for Combined Heat and Power • Hybrid/gas turbine cycle	• High temperature corrosion and breakdown of cell components • Long start-up time • Limited number of shutdowns

[3] https://www.energy.gov/sites/prod/files/2015/11/f27/fcto_fuel_cells_fact_sheet.pdf