END USER FOCUS: Fuelled with expectation

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From rare earths to graphite, carbonates to zircon: components based on non-metallic minerals are the focus for fuel cell manufacturers as the industry strives to increase efficiency and drive down products costs in a world turning increasingly green Simon Moores, Deputy Editor

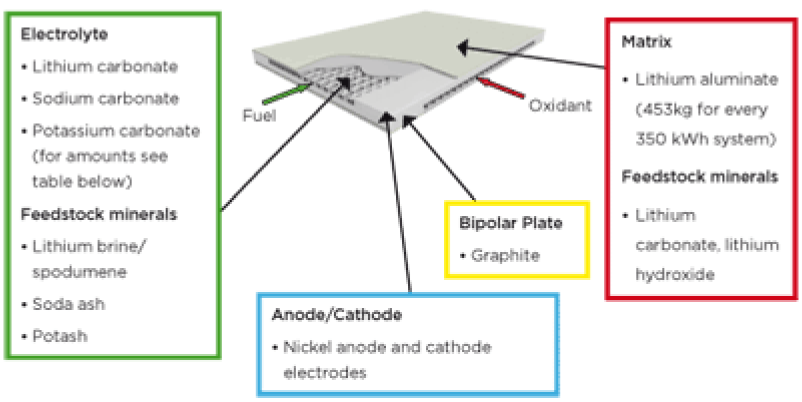
Fuel cells seem to be in perpetual development and never quite ready for commercialisation.

The idea of a system which can convert fuel and air into electricity, heat and water, without burning sounds too good to be true, but the technology have never matched the sound theory.

However, demand together with efficiency is on the slowly rise. Central to this is the wide range of minerals playing a critical role in the development of numerous fuel cell designs.

A focus on solid oxide and molten carbonate designs just scratches the surface of the potential for minerals in this emerging hi-tech market and highlights the wide variety needed for many complex and different parts that make up a fuel cell system.

Minerals consumed in a Molten Carbonate Fuel Cell



Solid oxide

Solid oxide fuel cells (SOFC) offers a technology most suitable for large scale energy storage systems and high pressure situations. This is owing to its make-up, the key is in the name every part of the SOFC is made from solid state materials, predominately a ceramic powder.

This allows the system to operate at temperatures of around 1,000¡C and the US department of energy has suggested it would be ideal for linking with a gas turbine in a hybrid configuration generating an additional source of electricity

Australia based Ceramic Fuel Cells Ltd is a company that specialises in production of SOFC.

A fuel cell powered car being filled with hydrogen at a station in Tokyo. Courtesy Shell

Its UK based mineral powder processing arm explained to **IM** how it uses yttria-stabilised zirconia (YSZ) for two key parts to each cell, the anode support structure and the electrolyte membrane.

“We use about two grams of YSZ per cell with four cells for each layer set and 48 layers to a stack,” explained Alan Chapman, Ceramic Fuel Cells’ powder plant technical manager, “all in all it is about two kilograms of material for each system.”

Chapman explained that nickel oxide is the other material used in the anode that catalyses the reaction in the cell with similar volumes to YSZ but different densities.

The company manufactures two cell types: anode supported, which is between 260-280 microns thick and electrolyte supported, 160-200 microns thickness.

Ceramic Fuel Cells sources yttria, derived from the rare earth yttrium, from China the world’s foremost source at the Batou mine of Inner Mongolia through a mineral processor. The zirconia begins as zircon sand in Australia.

Chapman said: “We chemically react both materials in two streams to create the product. This is the key technology for us.”

Amount of carbonate in a Molten Carbonate Fuel Cell

Power of system	Typical application	Carbonate electrolyte required* (kgs)
300kW	300 room hotel; average US supermarket	400
1.4MW	1,000 bed hotel; watewater treatment plant	630
2.8MW	Manufacturing plant, universities, 300 bed hospitals	1,087
10MW +	Electrical grid support	4530 +

* A blend of lithium carbonate, sodium carbonate and potassium carbonate
Source: Fuel Cell Energy Inc.

Molten carbonate

Molten carbonate fuel cells (MTFC) are also of increasing interest to applications requiring large scale electricity supply on a sub-megawatt scale and megawatt (MW) scale such as single site self generators and support to an electricity grid.

USA-based Fuel Cell Energy Inc. which constructs carbonate fuel cells explained how many components are based on lithium.

“Structurally, most of the power plant is carbon steel or stainless steel. The fuel cells themselves consist of a porous nickel anode and cathode electrodes separated by a matrix a ceramic filter paper-like wicking layer," Anthony Leo, the company's vice president, applications and OEM Engineering explained to **IM**.

Leo explained that the matrix, which houses the electrolyte, is a porous sheet of lithium aluminate which uses 1,000lbs (453kg) for every 350kw stack.

The electrolyte is a blend of lithium carbonate, sodium carbonate and potassium carbonate and also consumes 1,000lbs (453kg) for every 350kw stack.

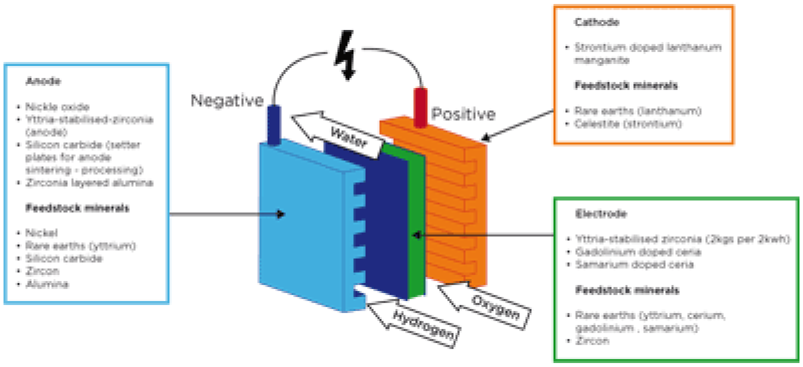
A 300kW application would be suitable for an average USA sized supermarket or a 300 room hotel while a 1.4MW fuel cell system would power a 1,000 room hotel or a wastewater treatment plant.

MTU Onsite Energy GmbH, a Munich, Germany based manufacturer of MTFCs , explained to **IM** further detail into lithium's application in the electrolyte.

"Ultrafine $LiAlO_2$ is the material forming the porous structure which is usually made from ultrafine alumina powder and lithium carbonate. Particle size and purity are the main requirements to the mineral material," explained the company.

MTU said that a 1kg each of lithium carbonate, potassium carbonate and alumina per kWh is require to make a MCFC, a slightly lower consumption figure than Fuel Cell Energy's.

Minerals consumed in a Solid Oxide Fuel Cell



Other mineral opportunities

The proton exchange membrane (PEM) fuel cell is a lower temperature design compared with solid oxide and carbonate and is aimed at the transport and portable electronics sectors.

PEM opens up prospects for **graphite** producers not in the primary battery components (anode, cathode, electrolyte), but the secondary components such as the flow field plates. Graphite's use in these secondary components is not only exclusive to PEM either and could open up opportunities for natural and synthetic producers.

Direct Borohydride Fuel Cells (DBFC) can use various chemicals based on **borates** for storage of hydrogen. Sodium borohydride has been widely touted as a key material for many years, but more recent research by US Borax Inc. has highlighted other boron based materials suitable for DBFC applications.

Lithium borohydride is attractive because it contains more hydrogen by weight of the metal borohydrides but is unstable in aqueous solution.

Ammonia borohydride has the largest "thermodynamically and kinetically accessible hydrogen content", according to US Borax but has a low decomposition temperature of around 50 ºC. Ammonia Borane has been highlighted as possible the leader at present as it is both stable in air and water.