The World Market for Cathodes

The world market for cathode materials was in 2011 calculated at 59,470 tons with a total sales value of $600 million. Demand for lithium has been increasing at a rate of 30 percent per year and is expected to maintain that rhythm in the foreseeable future. As a result, prices for lithium in 2005, the main material for high density batteries, was limited to one dollar per kilogram have since increased tenfold to $10,000 per ton. Since the number of electric vehicles is expected to increase to 500,000 by 2015, the electric power base from batteries would have to increase to 15 billion kWh/year. This puts a tremendous pressure on the supply of materials. A small and existing 5 kWh lithium battery for a compact car requires 300 grams of lithium for each kWh storage capacity. However, a full sized SUV would use 3kg of pure lithium per power unit.

Due to its high energy density, the world is embracing lithium as the metal to power all mobile devices. Laptop computers and most hand-held mobile devices represent the greatest market segment in spite of their higher cost. However, the new emerging market is mobility and transportation. Latin America controls about 80 percent of the world’s lithium reserves with Chile (3 million tons), Argentina (2 million tons), Bolivia (5.4 million tons) and Brazil (<1 million tons). China is placed fourth with 1.1 million tons. If the world were to swap petroleum for lithium based propulsion, South America would become the new Middle east and Bolivia with its Uyuni salt pans - a unique and ancient ecosystem - would be richer and politically more powerful than Saudi Arabia ever was. The US, Europe and Japan would once again rely on external sources while China could guarantee self-sufficiency thanks to its own reserves.
The largest producer of lithium is SQM of Chile with a production of 27,000 tons per year. The main local competitor is SCL (controlled by Chemetall of Germany) with an annual output of 14,000 tons. FMC Lithium in Argentina competes with Admiralty Resources of Australia and Sterling Resources from China. The majority of the future supply of lithium will have to come from salt lakes located on 3,000 meter high mountain ranges where environmentally sensitive mining will be undertaken under harsh conditions risking precious resources. The total lack of infrastructure and the strict investment rules of Bolivia and Argentina limit the traditional schemes of investment by multinational corporations.

The Innovation

Today’s world automobile fleet of one billion vehicles is replaced at a rate of 60 million and if these were replaced by hybrids, plug in hybrid or battery-based electric vehicles (EV) then it is clear that there is insufficient lithium available in the Earth’s crust to sustain the EV roll-out based on lithium batteries. Worse, under this hypothesis of replacement, the depletion rates of the lithium ores will exceed the current oil depletion rates and therefore the switch of dependency from one non-renewable resource by another one is not solving the fuel for mobility challenge, even the carbon emissions balance with mining and processing as is the standard today remains questionable. The alternative battery technologies of ZnAir and NaNiCl are not as resource constrained but lack the performance the industry is aiming for.

Grzegorz Milczarek was born in Gostynin, outside Warsaw, the capital of Poland. His passion for science in general and chemistry in particular emerged already in primary school. He loved to play with pop guns and detonate squibs and wondered about the forces that created these noises. His desire to understand explosives brought him to become a major in chemistry at the Institute of Chemistry and Technical Electrochemistry at the Technical University of Poznan where he obtained his master degree in 1994. After an intensive research period Grzegorz superbly defended his thesis on modified electrodes and obtained a doctoral degree in 1999. Research also brought him for two years to Japan. A few months ago he was elected as the vice-dean of the faculty after he and his colleagues published a surprising article in Science Magazine (March 23, 2012) which - translated in simple terms - proposed batteries made from wood.

Grzegorz and Olle Inganäs, his colleague from Department of Physics, Chemistry and Biology at the University of Linköping (Sweden) studied the potential use of brown liquor, the waste product from paper processing. This chemical mix of sulfite chemicals, lignin and hemicellulose is often burned to generate steam. However, in view of the volumes and the residual waste streams after incineration, the team looked for higher value added applications beyond power and heat. Grzegorz was inspired by photosynthesis and studied with the team how lignin could be transformed into
electrically conductive molecules that transport electrons as do some molecules during photosynthesis.

By putting the sludge in a conductive polymer, they created an inexpensive cathode capable of holding a charge. It worked remarkably well. Olle and Grzegorz went on to create a prototype that continued to discharge when the battery was not in use. This needed to be corrected and they successfully found the pathway to resolve this challenge. The team believes it is capable of transforming lignin to create a low-cost, renewable battery thus creating a second revenue stream from the processing of wood into paper - a battery mainly made from wood residues that today is a waste in abundance. This sounds like a typical Blue Economy approach.

First Cash Flow
The inventors want to store renewable electricity where it is produced, without the expensive grid. Now that the solar technologies are reaching a competitive cost (Case 53) the key to success is to design new energy storage systems based on cheap and renewable raw materials, avoiding further needs for mining. The key to success was the design of this 0.5 micron thin film produced by the Polish-Swedish team from a mixture of lignin derivatives extracted from the brown liquor. Since lignin constitutes 20 to 30 percent of the biomass of a tree, and is at present discarded in the paper making process, it is a never-ending source therefore relieving pressure on the dwindling lithium resources. Olle and Grzegorz went on to patent their two square centimeter prototype.

However they realized early on that the design of the cathode is only half of the solution for a completely new battery concept. They also need to redesign the anode. A team composed of doctoral students has ideas on how to secure a complete concept. The vision is to have a hundred percent renewable battery. In the mean time they are experimenting with a fully recyclable polymer known as polypyrrole, a 100 percent recyclable petroleum derivative that has been known to the industry for over three decades.

The Opportunity
Grzegorz in not limiting his creative mind in the world of batteries. He sees multiple opportunities for the use of waste lignin, demonstrating multiple revenues and benefits from one discarded renewable material. He successfully designed a chemical sensor made from pure lignin extracted from the same black liquor. This cheap and quick sensor measures glucose in blood of diabetic patients. Their creative research also covers new insights into the immune system of plants opening a broad platform for multiple uses for one of the most abundant renewable resources on earth that is left without use in our industrialized society and that is not generating the value added, the
functionality or the jobs it could. Now that the first part of the product design has been completed successfully, it is time for some visionary entrepreneurs to embark on the development of a completely new concept of battery and engage in putting the sensors on the market. The paper and pulp industry could even be the first one to benefit in this time when consumption is decreasing and recycling of paper is reaching its limits.

Gunter Pauli is the author of the Report to the Club of Rome:
“Blue Economy: 100 Innovations - 10 years - 100 million jobs” published in 35 languages worldwide.

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