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Batteries: an important piece in the puzzle of renewable energies for a better world

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Along with the rapid growth in the world population, the concerns regarding the production and consumption of energy originating from fossil fuels have been increasing in recent years. Therefore, there is higher demand to develop “clean” renewable energies to reduce the use of fossil fuel.

ENVIRONMENTAL PERSPECTIVE

Most people today are aware of environmental issues related to consumption of fossil fuels. Global warming and consequent unwanted changes in the chemistry of our planet, as a result of greenhouse gas emissions, is a chief concern, which motivates investments to replace fossil fuels by renewable energies. In the year 2000, the annual CO₂ emission from the combustion of fossil fuels surpassed 6.7 Gt C (gigaton of carbon) (Smil, 2003), and further increased to 9 Gt in the year 2010 (Peters et al., 2011). Therefore, to protect the Earth’s atmosphere and minimize global warming many countries have presented plans to reduce greenhouse gas emissions. For example, the European Union has planned for an 80% reduction in its 1990 greenhouse gas emissions by the year 2050 (Swedish Energy Agency, 2013).

POLITICAL PERSPECTIVE

The instability of oil prices and resources is another major factor in the drive for renewable energy. The dependency on oil, which is distributed in limited areas in the world’s so-called “energy strategic ellipse” (Armaroli and Balzani, 2007), is potentially a threat to the world economy as well as to world peace. The US, China, and EU are the largest importers of crude oil, while Saudi

Arabia, Russia, Nigeria, and Iran are among the largest exporters of crude oil (International Energy Agency, 2012). Though recent advances in the production of shale gas, as an alternative to oil, might change the map of oil importers/exporters, oil is still very important source of energy and/or political power for many countries. The “oil business” often has indirectly resulted in abuse of human rights in different countries. For example, the clerical regime in Iran with the highest number of executions per capita in the world is widely viewed as one of the worst countries regarding the violation of human right conventions (Amnesty International, 2013). However, the regime has had such a big oil-originated power to oppress people in the country and often threaten global peace and security. Therefore, the liberation of people from oppression and ensuring global security is another often seldom considered motivation for finding an alternative to an oil-driven energy economy. Furthermore, the dependency of the US economy on oil has in many occasions played an important factor in its military involvement in several controversial incidents over the years (Klare, 2005). A sentence by former US President Jimmy Carter is an example indicating how US economic and foreign policy are inextricably linked to the consumption of oil:

“The US would use any means necessary, including military forces, to keep the oil flowing” (Klare, 2005).

Thus, considering the environmental and political troubles originating from the huge consumption of fossil fuels, further developments of renewable energies can lead to a

better life situation for everyone around the world. In such a development, advanced energy storage technologies such as batteries, supercapacitors, flywheels, etc. play key roles, especially as they can be combined with sustainable energy systems such as wind, solar, and hydropower. Key to the realization of this future is efficient energy storage systems, and in this respect “batteries” have potentials to provide the most realistic solution.

BATTERIES

A battery can store chemical energy and convert it into electrical energy when it is needed. The history of batteries dates to ~200 BC when a battery called the “Baghdad Battery” was used in the Parthian era. This battery was made up of a copper cylinder and iron rod, but it is not clear in what capacity it was used (Flood, 2003; Palacin, 2009). However, the real birth of battery technology is attributed to Alessandro Volta of the voltaic pile in 1800 (Palacin, 2009). Since then, hundreds of different chemical reactions have been utilized to create battery systems including the development of lead–acid, nickel–metal hydride (Ni–MH), nickel–cadmium (Ni–Cd), sodium–sulfur (Na–S), flow batteries, lithium-ion, sodium-ion, and metal–air batteries (Linden and Reddy, 2001; Goodenough and Kim, 2009).

In the path to the resplendence of fossil fuels by advanced renewable energy systems, batteries can be valuable to overcome two main sources of dependency to fossil fuels: transportation and grid applications (Vazquez et al., 2010; Zhang, 2013). An enormous amount of research is now being conducted around the world to fulfil

the challenging requirements for these two applications.

According to the European energy policy, 10% of the energy required in the transport sector shall be provided by renewable energies by the year 2020. To achieve this goal, several targets have been defined such as:

“No more conventionally-fueled cars in cities by 2050” (European Commission, 2011).

Though batteries have been utilized in vehicles for more than a century, recent progresses especially in lithium batteries has raised hopes to produce all-electric-vehicles (EV) that can be used for longer driving ranges and longer life span. In this context, the US department of energy has set goals of specific energy of 40 kWh, 1000 cycle life in 10 years of life, and system price of \$6000 for batteries in EVs (Cairns and Albertus, 2010). System costs and life span remain major challenges for today's lithium battery technology for EVs. It is well-known that the performance of lithium batteries diminishes during operation in long spanning applications, e.g., due to operation at high temperature or high power. Thus, it is still uncertain how lithium batteries can perform in EVs in 10 years of operation in different temperatures. The cost of lithium batteries is mainly from “materials” used in the batteries, particularly “cathode materials” contribute significantly to the cost of lithium batteries (Cairns and Albertus, 2010). New generation of advanced lithium batteries such as lithium–air (Li–O₂) and lithium–sulfur (Li–S) batteries have potential to increase practical specific energy of lithium batteries at least two to three times (Bruce et al., 2012; Younesi, 2012; Younesi et al., 2014). This can, consequently, lead to a decrease in the cost of lithium batteries – however, these new battery technologies have not yet been commercialized. Further research should be performed to improve rechargeability, life cycle, specific power, safety, and other issues of Li–O₂ and Li–S batteries in order to utilize them in EVs.

For the stationary grid application, the Na–S battery technology is today commercially available with approximately 200 installations in the world providing 315 MW of discharge power capacity (Dunn et al., 2011). The Na–S battery, however, works at a high temperature (270°C) and still suffers from safety issues, especially after the fire at the Tsukuba Plant (Joso City, Ibaraki Prefecture) power plant in September 2011 due to the malfunction of one of the Na/S cells (NGK Insulators, 2012). Alternative battery technologies like lithium-ion and redox-flow batteries are now considered for the grid application.

Further developments of different battery systems enable them to meet prerequisites – for example: lower cost, higher energy density, higher power density, higher safety, and cycle life for larger application in EVs as well as for the stationary energy storage.

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