



Roles of electrochemistry in a fully renewable energy society

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Roles of electrochemistry in a fully renewable energy society

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Abstract

Denmark has the ambition to reduce CO₂ emission by 70% by 2030 and become free of fossil energy by 2050. Today approximately 50% of Denmark's electricity supply is produced by wind power with a fast pace of construction of further wind power capacity, and electricity production from solar photovoltaics is likewise increasing. Large parts of the world and in particular of Western Europe have similar ambitions for implementing large amounts of wind and solar power. However, until now only relatively minor efforts in conversion and storage technology development and implementation have taken place. During the recent year politicians have finally realized that electrochemical technologies in the form of batteries, electrolyzers and fuel cells will be absolutely necessary in order to secure 100% renewable energy and an electricity supply that matches the customers' needs.

In spite of an increasing agreement on the necessity of electrochemistry in conversion and storage of renewable electricity, there is still an ongoing debate about what the main role and share of various electrochemical devices in the conversion and storage should be. This presentation is an overview of the main types of electrochemical devices for conversion and storage, and it will discuss the most rational application of the various options based on simple technical criteria such as energy density, power density, and flexibility. For instance Li-batteries can convert electricity to chemical energy in the battery, but this chemical energy can only be converted back into electricity, whereas e.g. reversible solid oxide cells (RSOCs) can use electricity to convert steam and carbon dioxide into syngas, which - apart from possible conversion back into electricity - may be converted chemically into methane, methanol or other useful hydrocarbon or oxygenates. Nowadays such fuels are often called e-fuels, which is short for "electrochemically synthesized fuel". Short terms of the processes are "power to fuel" (P2F), or "power to X" (P2X), where X stands for any chemical compound, which has been synthesized - partly or fully - by electrochemical processes.

Cost-effectiveness will naturally be most decisive for how the different technologies will be applied and to which extent. This will be discussed qualitatively based on aspects such as the abundance of the raw materials in the crust of the earth and the properties of the chemical compounds used for the energy storage. Another aspect is the demand of properties to the storage media depending on the application. Storage of energy in a zinc-bromine flow battery will probably become much cheaper per kWh than storage in a lithium battery, but as the gravimetric power density of the lithium battery is many times higher than that of the flow battery, the lithium battery will be preferred in a car while the flow battery may be preferred for stationary energy storage. The size of the energy system may also be determining for the choice of type of electrochemical technology. It is expected that in most renewable energy systems, seasonal storage will be necessary, i.e. storage of large amounts of energy through several months. For such a case it will be feasible to store the energy in form of hydrocarbons or ammonia using already existing infrastructure. If this further can be done using suitable reversible electrochemistry with formation of methane inside an RSOC in electrolysis mode then the round trip efficiency may become very high. Such a system is sketched in the Figure, which is taken from G. Butera, S.H. Jensen, L.R. Clausen, *Energy*, **166** (2019) 738. It illustrates an idea of using the natural gas grid for storage of CH₄, and storage of CO₂ in a salt cavern. The oxidant would come from the air, and the electrical source should be renewable energy and the recipient the power grid - all coupled together with a huge RSOC system.

Other examples, like using solid oxide electrolysis cells and electricity for manufacturing of ammonia without any use of fossil fuel, and for direct conversion of CO_2 into CO , will also be presented.

