Options for Chemical Storage of Renewable Energy

Thomas Aicher, Fraunhofer Institute for Solar Energy Systems, Freiburg, Germany

There are various renewable energy sources (RES) used in today's world, with the most important being sunlight, wind power, geothermal, hydropower, tidal, and biomass. Most of these RES can be converted into (renewable) electricity. Except for geothermal, hydropower, and biomass they all supply energy in a more or less fluctuating manner. Therefore, with increasing use of RES the storage of energy electric gains in importance.

The main focus of my presentation will be the storage of electric energy in form of chemical compounds. Approaches to directly use sunlight to produce hydrogen (e.g. via photocatalytic water splitting) or biomass conversion processes will not be covered.

Therefore, the starting point is (renewable) electric energy. There is one main way to convert electricity into a material energy carrier (i.e. chemical compound): water electrolysis. The presentation will briefly touch on the current status of technical development, hydrogen production costs, and the status of commercialization of the main electrolysis technologies. Even though one of the frontiers of engineering lies in this area lies, I will not go into more details.

The straight-forward method of storing hydrogen, i.e. in form of its molecules, is used for transportation (high pressure, metal hydrides, in liquid form) and for large storage in subterranean caverns (high pressure). However, a completely new world opens up when reacting hydrogen with other reactants thus creating molecules that are much easier to store. It is beneficial to use simple, small molecules, such as CO and CO_2, in order to keep the storage density high. I will look at the hydrogenation of CO and CO_2, which is currently one of the main routes investigated in academia and industry. The molecules that can be synthesized from H_2 and CO/CO_2 include but are not limited to formic acid, formaldehyde, methanol, ethanol, dimethylether (DME), methane and urea. In the presentation I will briefly talk about the various routes to synthesize them, the status of development, process chain efficiencies, and estimated costs. In addition, I will compare the energy balance and GHG emissions of all routes and will show why it is important to use renewable electricity, as supposed to 'conventional' electricity, for reduction in GHG emissions.

Finally, I will illustrate the increasing need to run chemical reactors not only under steady-state conditions (as it is currently done in industry) but to design chemical processes, reactors and production plants that allow to be operated in a fluctuating or intermittent manner. In my opinion, this topic is currently one of the frontiers of chemical engineering. Therefore, I will briefly show the work that is currently done in this area and address the open questions in this field.