Hydrogen and Beyond: the Role of Chemistry in Future Energy Systems

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CO_2-emissions from the energy sector, caused by the combustion of fossil fuels, are one of the main drivers of global warming. In order to restrict the increase of the Earth's temperature to acceptable levels, our energy systems have to change and need to be based on renewable energy. The sun supplies energy in amounts vastly exceeding the demand of our civilization, and it can be harvested in the form of radiation or wind. Other than expected only decades ago, the cost of renewable energy has come down so much that it is competitive with fossil energy, in favourable locations already even cheaper.

Renewable energy is predominantly harvested in form of electricity. For some applications, such as in electromobility, this is advantageous, since conversion losses are minimized by staying fully electric. Advances in battery technology, especially in battery chemistry, would help this transition from internal combustion engines to battery electromobility tremendously. In addition, if cheap large-scale batteries were available, the intermittent nature of wind or solar irradiation could be mitigated. For the chemical industry the change could mean that heat, currently supplied by the combustion of fossil fuels, might be replaced by electric heating, as in a recently announced steam cracker project by BASF, Linde, and SABIC. Also electrosynthetic production of chemicals could become increasingly interesting in the future, especially for the anode side of hydrogen-producing electrolyzers, where currently the oxygen is just emitted into the atmosphere.

The hydrogen produced by electrolysis seems to be the most straightforward solution for grid-scale storage of energy in form of chemical compounds. Direct photocatalytic water splitting is an alternative, but currently and for the next years, this is not a mature technology. The hydrogen could not only be a suitable storage form, but it could provide the second backbone of a predominantly electrified economy. With respect to reducing the CO_2 footprint, hydrogen produced from renewable electricity should – at highest priority - be used to substitute fossil hydrogen made by steam reforming, for instance for use in refineries or in hydrogen metallurgy. Another option is to complement battery electromobility by hydrogen fuel cell vehicles, which, however, overall have a lower energy efficiency than battery cars. Reconversion of the hydrogen to grid-electricity should only be a last use option, since the cycle efficiency is rather low.

A substantial challenge is also the transport of renewable energy from sun-rich parts of the world to the consumption centers. Since power lines are often not viable for various reasons, chemical compounds are the best option in many cases. The transport form could be hydrogen, but also methanol, hydrocarbons, ammonia, or liquid organic hydrogen carriers. In this and all the other fields relevant for future energy systems mentioned above, chemistry has a key role to play – both for providing novel solutions, but also for bringing the cost of existing technologies down to acceptable levels.