Production and Utilization of Green Hydrogen

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The growing scarcity of fossil fuels and the rising threat of climate change are forcing society the world over to rethink its energy policy. In the foreseeable future, energy supplies and industrial production processes will have to increasingly rely on regenerative raw materials, replacing crude based material flows with green chains. We have already reached the biotech watershed –thanks in part to innovative plants and gas technologies from Linde.

Green Mobility is an important megatrend for our century. However – at least for private transport – there are still a multitude of concepts competing for dominance: battery- or fuel cell powered cars, combustion engines that run on bio-, synthetic fuels, biogas, various hybrid drive trains and even cars that run on compressed air. It is not yet clear what the future will hold. The automotive industry is at a crossroads similar to that of a hundred years ago, when steam engines fought against electric motors, petrol and diesel engines for recognition as the most successful propulsion technology – we all know the results. This time, according to many experts, it is unlikely that one single technology will be seen as the solution to the challenge. Indeed, it seems likely that the differing designs will each find their niche in a separate application field. City buses require a different design than heavy duty long distance vehicles, or vehicles designed for individual recreational mobility in the city or country.

Linde is working with industrial partners and is active in national and international public-private-partnerships to put a comprehensive hydrogen (H2) infrastructure in place and lay the foundation for the success of this sustainable fuel. H2-powered fuel cells have a key role to play in advancing electro mobility. In addition to developing innovative hydrogen production and storage technologies, industry leaders are also focusing on expanding the infrastructure for hydrogen powered fuel-cell vehicles. Together with Daimler, for instance, Linde intends to set up a further 20 hydrogen refuelling stations in Germany over the next three years, ensuring that the steadily growing number of fuel-cell vehicles can be supplied with H2 generated solely from renewable resources. This project forms a bridge between the established CEP infrastructure project and the longterm H2 Mobility Initiative, which are supported by the German National Innovation Programme for Hydrogen and Fuel Cell Technology (NIP). The Linde and Daimler initiative, involving an investment in the double-

digit million euro range, will more than double the current number of public hydrogen refueling stations in Germany. The new facilities are planned for the existing hydrogen hubs of Stuttgart, Berlin and Hamburg, as well as along new, end-to-end north-south and east-west corridors (see below). The aim is to make use of existing, easily accessible locations belonging to various petroleum companies. These corridors will then make it possible to travel anywhere in Germany with a fuel-cell vehicle.

Hydrogen from biomass is a key element of the production portfolio of green hydrogen for the future zero-emission mobility. The Linde Group is investigating several innovative routes for the sustainable production of hydrogen based on biomass, for example: glycerol pyroreforming, biomethane steam reforming and gasification of solid biomass.

One possible pathway is Linde's recent successful development - Pyroreforming of liquid biobased feedstocks. As an example, raw glycerol as a by-product of the biodiesel production was chosen since it is available all year round and easy to handle. A Pyroreforming pilot plant was built and is currently in operation at Linde's hydrogen production site in Leuna, Germany. This plant produces a hydrogen-rich gas, which is CO-shifted, purified and - if required - liquefied for transport. In addition to raw glycerol from the biodiesel production, this process also allows the conversion of other similar products, such as waste streams of the propylene glycol (PG) production.

The second pathway is the gasification of the solid biomass. The focus of this development is the generation of "green" hydrogen and "green" electricity from a wide range of biogenic, non-food feedstocks using a thermo-chemical conversion route.

Both technologies have been successfully demonstrated on pilot-scale level and are currently under implementation into demonstration facilities.

The third pathway is the production of green hydrogen via biomethane steam reforming. In this case the biomethane is derived from cleaned biogas from anaerobic digestion plants. Specifically in Germany with the availability of a natural gas grid, one can use this infrastructure to use the biomethane which was fed-in by decentralized anaerobic digestion facilities in large centralized steam methane reforming facilities to produce green hydrogen already today at lowest risk and cost.