MOBILITY & PRODUCTION

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Industry and related business is currently suffering from a time of irritation, unclear perspectives and hesitation.

These days, we too often hear about workers being laid off, bankruptcies and other signs of an economy in fall. As a consequence of this, industry is presently disinclined to form alliances with and make contributions to universities. The major question now is: should science mimic the same dynamics of anxiety and paralysis as industry? The answer is a definite no! Times of recession are the best phases to make time for further education and for thinking about the future, because one thing is clear: when the order books of industry are full, nobody is willing to hear about future technologies. This means we have an opportunity to prepare our common future now! The future of industry is mainly in innovation and this depends on the input of universities. So we as a university undoubtedly do have the clout to encourage industry, to create feasible concepts and to assist industry in making good ideas for the future viable. We are happy to show an example of this in the current issue of our research magazine, namely how decarbonisation can work even in a highly traditional working environment. So please enjoy the report by Susanne Lux and stay deeply future oriented.

Susanne Lux, Viktor Hacker

Iron and Hydrogen – A Perfect Match

Iron and hydrogen, the first a typical heavy metal, the second a classical non-metal – two elements that could not be more different at first glance; and yet they form a perfect team giving access to a decarbonised future.

Iron – the first – has been the most important raw material since the iron age. The amount of pig iron produced is more than ten times greater than that of all other metals combined. In short, iron and steel are an integral part of our daily lives. However, their production is responsible for a major part of the industrial sector's CO_2 emissions. >

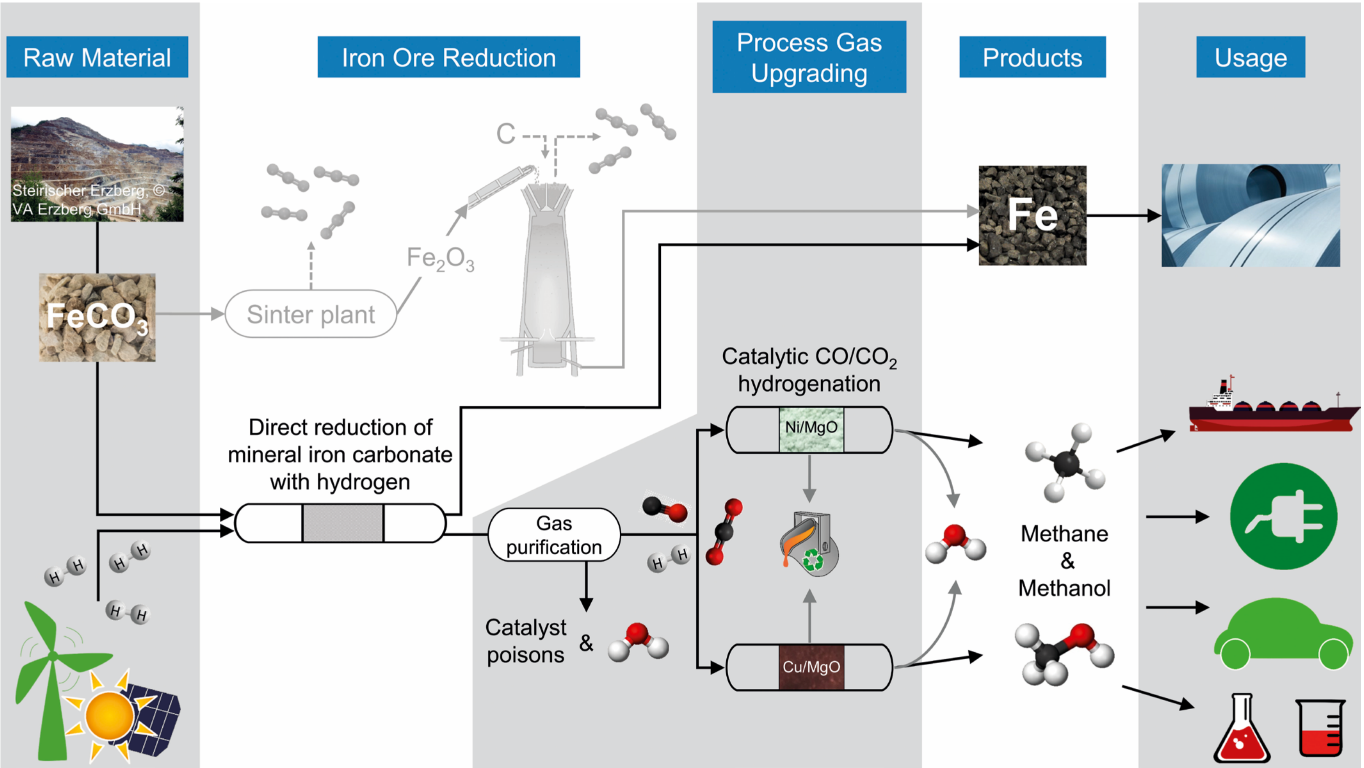

Figure 1: Process scheme of direct reduction of siderite ore with hydrogen combined with catalytic CO_2/CO hydrogenation for carbon neutral iron production.

Austrian mining and iron and steel production look back on a long tradition. Even though the Alps are considered to be "rich in poor deposits", for Austria, the mining and processing of iron ores and the subsequent production of steel have been an important cornerstone of economic and regional development over centuries. There is even a verse dedicated to mining in the Austrian national anthem ("Land der Hämmer, zukunftsreich!"). The most-used iron ores for pig iron production are iron oxides. In regions with large deposits of siderite ore such as Austria, this ore, which contains ferrous carbonate, is also used for pig iron production – although its iron content is lower and processing is more elaborate. Processing of siderite ore contributes to further CO_2 emissions due to the release of CO_2 from the carbonate. Thus, the search for measures to substantially reduce the high level of CO_2 emissions is a high priority task.

Hydrogen – the second – is the most common element in the cosmos. About two thirds of the total mass of the universe consists of hydrogen. In the earth's crust, every sixth atom is a hydrogen atom and, as is generally known, hydrogen can be produced from water. It is ideally suited as a chemical reducing agent and, as a versatile energy carrier, it is seen as playing a key role in the transformation process towards a decarbonised energy economy. However, hydrogen transport and storage are still the subject of debate.

Significant CO_2 emissions in iron production, especially from siderite ore, and complex and cost-intensive transport and storage of the promising energy carrier hydrogen; two pending questions, one of which could contribute to solving the other. Hydrogen may be the key to CO_2 emission-free iron production from siderite ore, where iron in turn shows potential to solve the storage and transport issue of hydrogen.

DIRECT REDUCTION OF SIDERITE ORE WITH HYDROGEN

Direct reduction of mineral metal carbonates with hydrogen, also termed “reductive calcination”, is a novel approach that was developed by the Chemical Reaction Engineering Research Group at the Institute of Chemical Engineering and Environmental Technology. It tackles the problem holistically and opens up a completely new pathway for metal carbonate processing in general and iron production in particular with the potential of becoming a CO_2 breakthrough technology. Direct hydrogen reduction of siderite ore does not need the conventional two-step route of roasting and reduction in the blast furnace, as elemental iron is directly formed from the iron carbonate in one process step; even at relatively moderate temperatures of 700–800°C. This results in a CO_2 emission reduction of more than 60%. Compared to siderite roasting (oxidation to hematite) followed by hematite reduction with hydrogen, 33% less reducing agent hydrogen is required for the direct reduction process. In addition, the process gas is upgraded by the formation of methane and carbon monoxide instead of simply releasing CO_2, thus further reducing overall CO_2 emissions [1].

Figure 2: Siderite ore from the Styrian Erzberg.

IRON AS A HYDROGEN CARRIER

Materials with high storage densities and efficient energy conversions are needed to transport hydrogen. The use of metals such as iron offers interesting prospects, as iron is readily available and can reversibly store and release hydrogen in a chemical cycle. >

Figure 3: Test stand for heterogeneous gas-phase reactions at the Institute of Chemical Engineering and Environmental Technology.

Source: Blendpunkt

In this novel approach, energy is stored by reducing iron oxide to metallic iron. This can even be done directly from natural ores, for instance siderite ore. Reoxidation of the iron-based oxygen carrier material with steam releases the stored chemical energy in the form of pure hydrogen and heat. A chemical looping hydrogen process with iron oxide as the contact mass, the so-called Reformer Steam Iron Cycle (RESC), was developed by the Hydrogen Research Group at the Institute of Chemical Engineering and Environmental Technology. A recent study revealed synergistic effects of mixed ionic electronic oxygen carriers in ceramic-structured environments with highest hydrogen storage capacity that effectively avoids sintering [2].

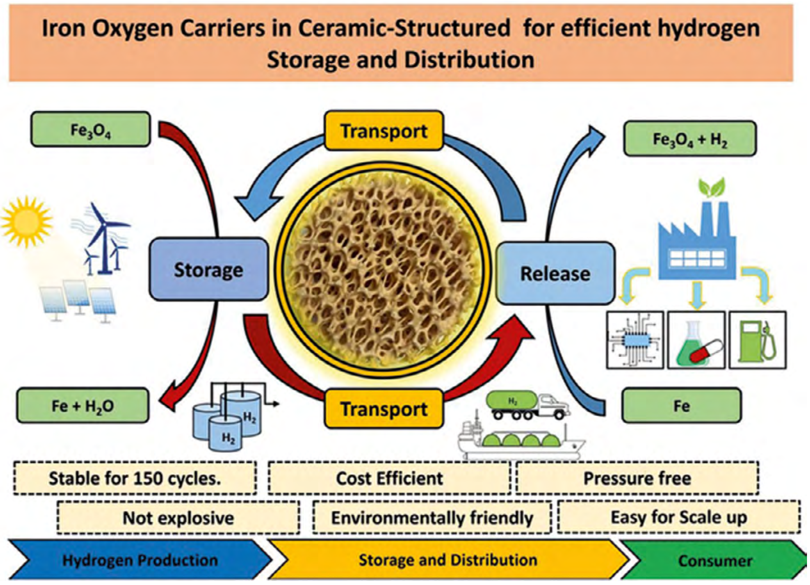

Figure 4: Iron oxide carriers in ceramic-structured environment for hydrogen storage and transportation.

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[2] Blaschke, F.; Hasso, R.; Hacker, V. Unlocking synergistic effects of mixed ionic electronic oxygen carriers in ceramic-structured environments for efficient green hydrogen storage. International Journal of Hydrogen Energy 2024, doi:10.1016/j.ijhydene.2024.08.508.

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Source: Lunghammer – TU Graz

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