Evaluating chemical energy storage with metals in the context of the Austrian electricity system

(3) Sektorkopplung und Flexibilität

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Motivation and central research questions

In the course of the Renewables-Expansion-Act (EAG) [1], Austria aims to generate additional 27 TWh from renewable energy sources to achieve a fully renewable electricity system by 2030 (net basis). For this transition, finding capable long-term storage solutions to balance seasonal fluctuations is one of the most crucial factors. Low storage costs are particularly important for seasonal storage options, as the energy can only be sold a few times or even just once a year. Furthermore, the storage material used should be safe and environmentally sound in order to store energy in large quantities and enable decentralized operation to avoid transportation efforts and costs. A novel possibility to meet these criteria is the use of metals as energy storage material. Within the research project MILES (Medium- and long-term storage technologies on the way to 100% renewable energy in Austria) [2] various storage systems are evaluated and classified with respect to the criteria described above.

The main research questions addressed in this project are:

- Which metals are suitable for large-scale energy storage in terms of local abundance, costs, reactivity, and recyclability?
- What process options exist for energy storage with metals and metal oxides?
- What is the overall demand and what are the challenges concerning charging and discharging (duration as well as charging cycles per year) imposed on the technology from the electricity system?
- What is the most promising system concept and material for future R&D activities?

Methodology

Metal oxides offer a potential solution for storing excess renewable energy to compensate fluctuations in the future energy system. The possible applications of metal oxide range from thermal energy storage (TES) such as latent (LES), sensible, (SES) and thermochemical energy storage to chemical looping-based storage methods [3]. An innovative concept therefore is the Reformer Steam Iron Cycle (RESC), a thermo-chemical process for the production of high-purity hydrogen and the mid- and long-term storage of chemically bonded energy [4]. An oxygen carrier, mostly a metal oxide, is reduced to a metal or to an oxide with lower oxidation state by reductive gases comprising either pure hydrogen sourced from water electrolysis using renewable power or by a syngas mixture from the gasification of biomass. In times of limited availability of primary energy, the metal can be oxidized again with steam for hydrogen production or with air to release energy for heating purposes without any harmful emissions (cf. Figure 1) [5]. Our previous study proved a European natural iron ore could significantly reduce the specific investment cost for energy storage to 7.5 - 15 $ per MWh, which is several orders of magnitude less than conventional (thermochemical) storage systems with synthetic materials [5]. Experimental results demonstrate reasonable cycle stability and a good volumetric storage capacity of 1.7 and 1.8 MWh m^{-3} for hydrogen and heat, respectively. The applicability of this system will be further investigated in a laboratory system on a kW scale with the identified criteria from the holistic evaluation within the project.

The applicability of suitable metal oxides strongly depends on the energy storage density, cycling stability, availability and costs, as well as the environmental sustainability. Due to its favored thermodynamic properties, iron is mostly used as the basic material for oxygen carriers. Furthermore, it is easy to handle and the abundance ensures considerably lower prices. The specific doping of iron oxides with various alternative oxides improves the long-term stability and other properties depending on the application of either hydrogen production or energy storage.

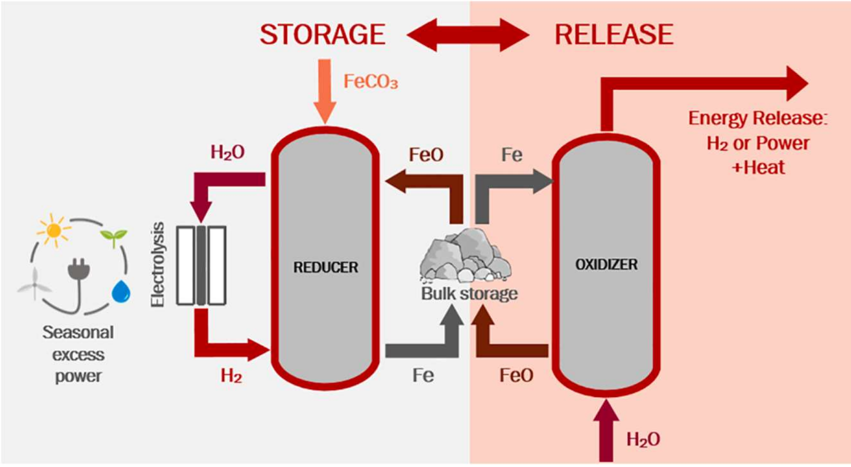

Figure 1: Possible energy storage concept with iron as the energy carrier [5]

Expected results and conclusions

The following results from the research project, which has been running since October 2022, will be discussed in the presentation:

- The selection of suitable metals that meet the criteria regarding occurrence, stability, environmental impact and costs in the context of energy storage.
- Discussion of metal-based storage systems in the context of the Austrian power system.
- Available experimental data for an exemplary storage system.
- Establishing a reference for the development of novel storage processes.

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Literature

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