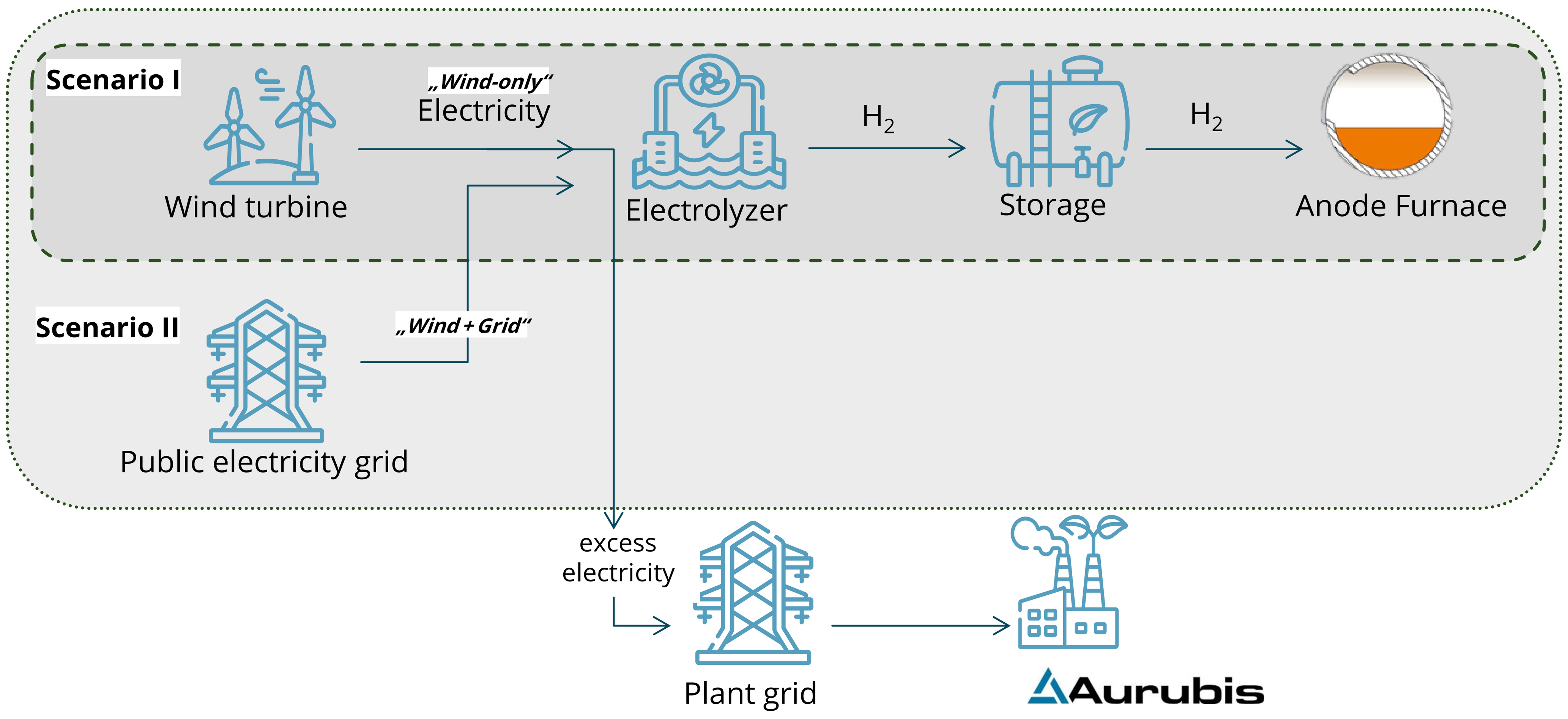
Assessing Wind Hydrogen Production and Resulting GHG Emissions for Aurubis in Hamburg

Introduction

This case study deals with a real-world challenge in the Hamburg harbor area at the Aurubis site. The investigation aims to determine the feasibility of producing on-site green hydrogen for reducing a daily batch of copper-oxide. The target is to substitute natural gas as a reducing agent in the fire refining process of the anode furnace. This avoids the process-related greenhouse gas (GHG) emissions. A technical-economic analysis assesses the feasibility of utilizing an on-site electrolyzer with a wind turbine for the year 2023.



Project Team

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Objective

Evaluation of cost and greenhouse gas emissions of a possible on-site electrolyzer with a 7 MW wind turbine at Aurubis site for producing hydrogen for one batch of copper produced per day.

Methodology

- **Wind energy evaluation:** Calculated hourly wind energy generation at the Aurubis site using site-specific data.
- **Hydrogen production & storage:** Modeled hourly production and daily storage for 2023 based on wind availability.

Scenario	Case	Electrolyzer Capacity	Operating strategy for daily hydrogen demand
Wind-only	1.a	1.25 MW	Electrolyzer sized to produce hydrogen only when wind energy is available. Hydrogen demand is not met on every day, but on an annual average.
	1.b	1.50 MW	
Wind + Grid	2	0.92 MW	Electrolyzer sized for continuous operation at full capacity for exactly one batch a day, preferring wind power and, if necessary, additional grid power.

- **Levelized cost of hydrogen (LCOH) analysis:** Assessed the levelized cost of hydrogen (LCOH) for both scenarios.
- **Scope 2 GHG emissions:** Evaluated time-resolved GHG emissions based on hourly grid emission factors.

Batch-wise hydrogen production

- The electrolyzer produces the needed quantity of hydrogen, using wind energy on an average annual basis. In case 1.a the hydrogen production exceeds the quantity required on 224 days. In case 1.b this is 246 days. However, on 141 days in case 1.a, the availability of hydrogen is limited due to fluctuations in wind energy. For case 1.b this is 119 days.

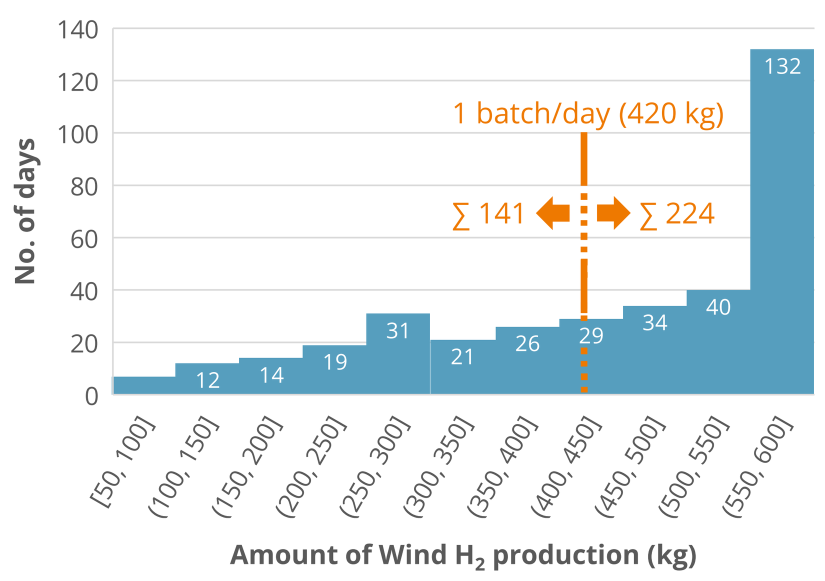

Figure 1: Frequency distribution of H_2 production volumes in case 1.a in 2023

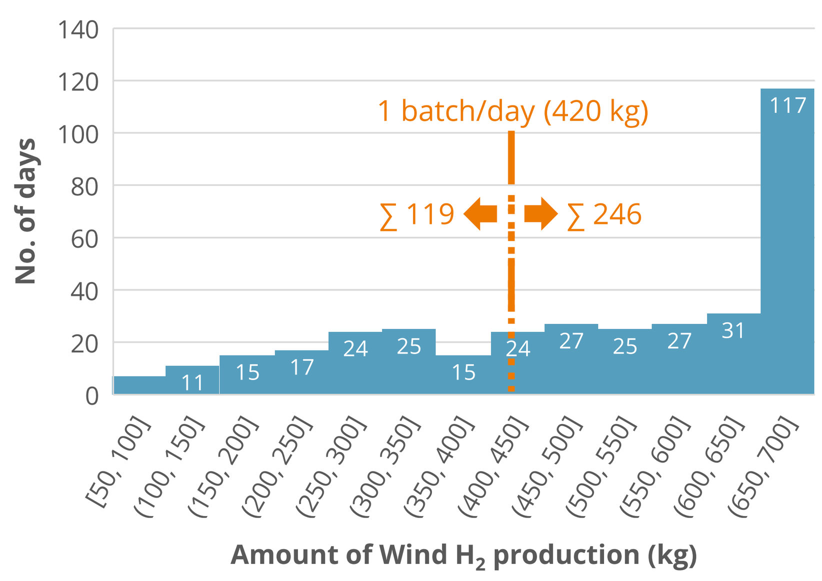

Figure 2: Frequency distribution of H_2 production volumes in case 1.b in 2023

Scenario	Case	Production days with ≥ 420 kg H_2	Production days with < 420 kg H_2	Average daily H_2 production (kg)
Wind only	1.a	224	141	435
	1.b	246	119	492
Wind + Grid	2	365	0	420

Further improvement through flexibility:

- **Process perspective:** The immediate consumption of hydrogen upon the accumulation of 420 kg H_2 for a batch, as opposed to a fixed daily schedule, allows for the processing of a greater number of batches (up to 13% more per year) within the same time frame (see Figure 3).
- **Production side:** Optimization of the storage strategy, adapting hydrogen production to fluctuating renewable energy based on GHG emissions of the electricity mix, increased electrolyzer size.

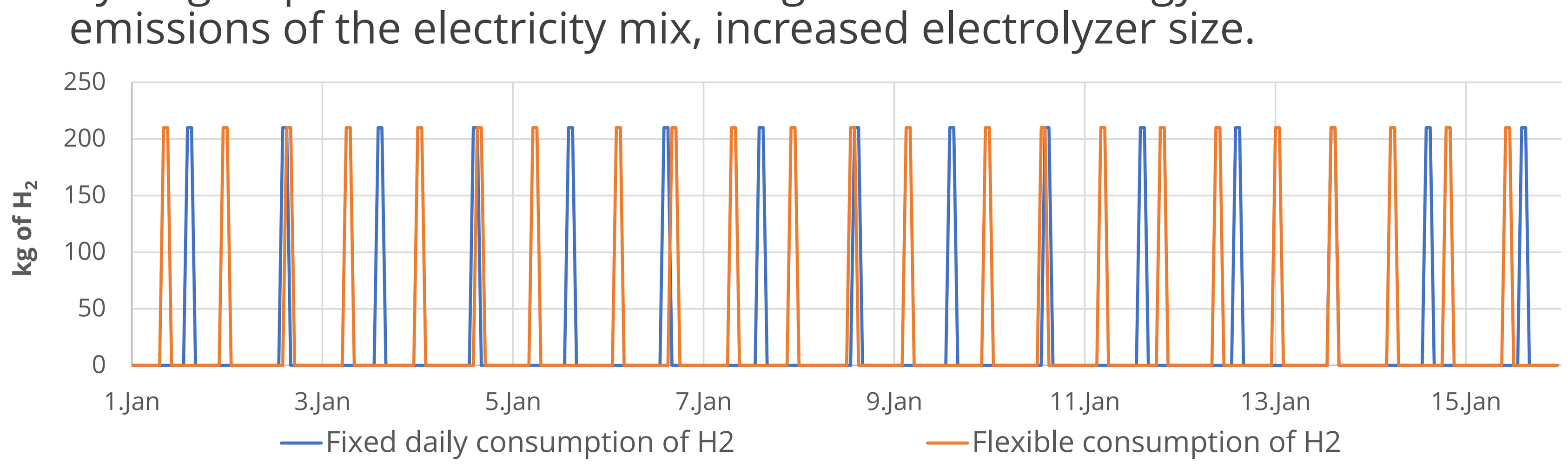

Figure 3: Increased wind H_2 production rate through demand shifting in times of high wind availability.

Levelized cost of hydrogen$_{2023}$ (LCOH)

Scenario	Case	Power grid	LCOH (ct/kWh)	(€/kg)
Wind-only	1.a	Feed-in excess electricity	19.3	6.4
	1.b	Feed-in excess electricity	19.6	6.5
Wind + Grid	2	Power purchase (20%)	17.4	5.8

- The electricity generated from wind is assumed to be € 0.08/kWh.
- The electricity purchased from the grid is assumed to be € 0.06/kWh.

GHG emissions$_{2023}$ (Scope 2)

Scenario	Case	Grid electricity usage (MWh)	Total emissions (kg CO_2-eq.)	Specific emissions (kg CO_2 eq./kg H_2)	RED III threshold
Wind only	1.a 1.b	0	0	0	✓
Wind + Grid	2	1,481	545,000	3.5	✗

- Wind-only: The produced hydrogen is CO_2-free, as only wind energy is used.
- Wind + Grid: The threshold value for hydrogen of 3.41 kg CO_2-eq./kg (according to RED III) is exceeded for 2023. Maximum emissions: 528,500 kg CO_2 eq./year.

Conclusion

In case 1, the daily production of sufficient hydrogen for a batch of copper is not feasible due to fluctuations in wind energy. This presents operational challenges for Aurubis. In line with RED III, there are no GHG emissions. The levelized costs are higher, but savings from the energy feed-in are not included. In case 2, constant production is realized, but the GHG threshold for hydrogen according to RED III is exceeded due to the additional grid supply. Flexible production based on the CO_2 emissions of the electricity mix, optimization of plant sizes and operating mode can have a positive impact.

References

- Series of articles concerning hydrogen; Life cycle assessment of hydrogen; Ffe.de – GHG Regulations
- co2-monitor methodenbericht; Ffe.de & TenneT; co2-monitor.org – CO_2 emission factors
- Renewables.ninja – Time-resolved, site- and wind turbine-specific data set
- Hydrogen carbon footprint in the context of clean hydrogen standards; Ffe.de