TECHNO-ECONOMIC ASSESSMENT OF WASTE HEAT RECOVERY FOR GREEN HYDROGEN PRODUCTION: A SIMULATION STUDY

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Hydrogen, functioning as a green energy carrier, has emerged as a promising solution in the transition process to renewables. During times of abundant electricity generation, it can store excess energy for a diverse range of sectors like mobility, industry, electricity production and heating. Nevertheless, producing green hydrogen by electrolysis comes with a substantial energy loss in the form of heat. Alkaline Electrolysis (AEL), a mature and low-temperature technology, has an efficiency of 60 – 80 % regarding the higher heating value of hydrogen [4], which means that at least a fifth of the input electricity is lost. With a growing demand for electrolysers, it becomes paramount to investigate paths to re-purpose this thermal energy and increase the overall efficiency [1, 2, 5]. District Heating Networks are an example of potential heat sinks for the generated waste heat as the supply temperatures for innovative heating networks are below 100 °C [3].

Objective

The aim of this work is to conduct a techno-economic assessment on the utilization of electrolyser waste heat in a district heating network using a python-based simulation framework. The examined alkaline electrolyser system is in the low MW-scale and powered by surplus renewable electricity generated by wind and solar energy (see Figure 1 for system boundaries). Hereby, solar and electrolyser capacity are varied to study the effect these parameters have on the hydrogen and heat output, while storage components for hydrogen or heat are not regarded. Subsequent to a system simulation, a technical and economical evaluation is executed focusing on the effects of re-using generated heat on system efficiency (η) and Levelized Cost of Hydrogen (LCOH). Additionally, the process of selling heat is checked for viability.

Methodology

A detailed alkaline electrolyser model has been added to an existing python-based simulation framework for renewable power plants and is validated against literature. Hereby, a tool capable of conducting a satisfactory analysis for a renewably powered AEL, especially in terms of heat generation, was created, while also preserving simplicity and code performance. Consequently, the electrolyser model not only consists of a thermodynamic and electrochemical part, but also includes a thermal model, which entails a simple cooling mechanism.

During the simulation process, the extracted and useable excess heat from the electrolyser is compared to a thermal load profile of a district heating network [6] to estimate the supplied energy. To conclude the techno-economic analysis, a range of Key Performance Indicators (KPIs) are determined, among them the Levelized Cost of Hydrogen (LCOH) (with and without considering heat revenues) as well as the improved efficiency regarding supplied heat (η_{DH}). Finally, the Levelized Cost of Heat (LCOHeat) is calculated to verify the economic feasibility of selling heat, considering the additional expenditure for the heat exchanger. For this, an optimistic and pessimistic heat price is assumed, at 25 and 40 €/MWh respectively.

Results and Conclusion

Existing experimental data aligns reasonably with the polarisation curve of the integrated electrolyser model, affirming the model's accuracy. Further validation, involving a comparison of hydrogen production rates and a justification of efficiency curves, supports the MW-scale of electrolyser operation.

Generally, a peak in heat generation within the electrolyser is observed at the beginning of an operational period due to initial temperature levels. This is used to heat up the electrolyser and once the

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desired temperature is reached, the cooling mechanism is activated. However, issues with an oscillating cooling system during non-consistent and partial load operation have to be addressed.

The largest (3 stack) electrolyser system is most affected by this effect, as it shows large periods where the electrolyser cannot operate at its nominal power. This affects all KPIs related to the heat output. A bigger electrolyser system leads to a slightly reduced η_{DH} and increased LCOH, while a higher PV capacity causes a lower LCOH and better fulfillment of the district heating demand profile. For one of the systems showing good KPIs - 5 MW PV and smallest electrolyser - the efficiency is enhanced by 10.5 % with heat provision, while the LCOH is 1.6 €/kg in an optimistic heat sale scenario.

The effect of selling heat results in just marginally improved LCOH values; for the optimal single stack system, only around 11.4 % improvement can be achieved and this change in price varies greatly with stack number and renewable capacity. The analysis further indicates a good economic basis for heat sales with one or two electrolyser stacks, whereas the viability diminishes for larger electrolyser configurations. Results are listed in Table 1.

These results indicate that an electrolyser powered by surplus renewable energy has future potential in heat and hydrogen generation under the right conditions. Simultaneously, the analysis motivates a closer examination of the cooling mechanism. To additionally improve the synergy with district heating, the consideration of some form of heat storage could pay off due to high heat demand during winters.

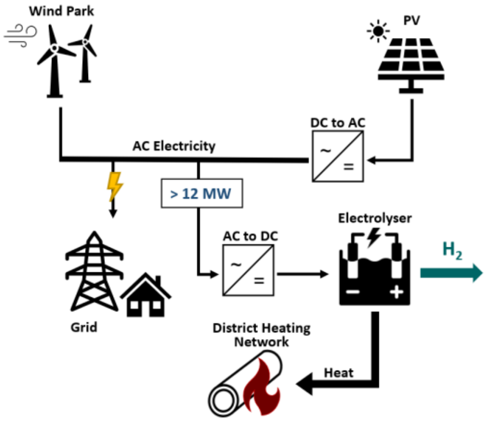

Figure 1: System Boundaries and Visualisation

Electrolyser [MW] KPI	2.13	4.26	6.39
η [%]	77.7	77.8	78.1
η_{DH} [%]	88.2	84.7	82.3
LCOH [€/kg]	1.9	2.0	2.4
$LCOH_{optimistic}$ [€/kg]	1.6	1.9	2.3
LCOHeat [€/MWh]	8.8	15.6	31.4

Table 1: KPI Results for 5 MW PV and 16.8 MW Wind Capacity

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