# *ECONOMIC EVALUATION OF ONSITE GREEN HYDROGEN SUPPLY STRATEGIES FOR THE INDUSTRIAL SECTOR*

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## Overview

EU climate goals define the pathway to decarbonise energy consumption towards 2050, demanding to restructure a historically grown energy system with new requirements and challenges. Whereas several applications can be adapted to the direct use of green electricity, many industrial processes heavily rely on hydrogen as an input, such as oil refining, ammonia and steel production, with a definite growing trend in the upcoming years [1]. Electrolysis enables the transformation of large-scale renewable electricity (wind and solar power) into green hydrogen [2]. The electricity consumption cost makes up a large part in the onsite production of green hydrogen and holds vast optimization potential. The present work, therefore, investigates different operational strategies of onsite green hydrogen production for industrial use. It aims at a comparison of the levelized cost of hydrogen and storage (LCOH&S) through different electrolyser operation strategies. Two case studies with different demand profiles are conducted.

## Methods

Figure 1 describes the $H_2$ generation process. The electrolyser consumes green electricity from the grid to split water ($H_2O$) into $H_2$ and Oxygen ($O_2$). $H_2$ can either directly cover demand or be stored in tanks intermediately.

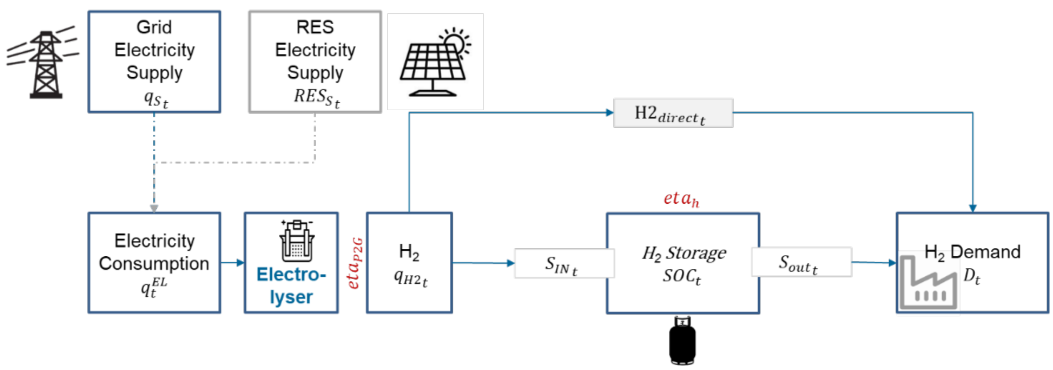


Figure 1 Hydrogen Production process

The hydrogen generation strategies with a grid-connected electrolyser that are considered and compared based on the resulting LCOH&S are 1) electricity price optimisation and hydrogen storage, 2) just in time hydrogen production either exposed to the electricity spot market price or assuming a fixed price agreed in a power purchase agreement.
The operation strategies are compared implementing an alkaline (ALK) or proton exchange membrane (PEM) electrolyser and their respective efficiency for lower loads. The faraday efficiency (see equation 1) describes the share of the actual achieved efficiency ($\eta_a$) based on the theoretical maximum efficiency ($\eta_{th}$) and decreases with a declining load factor [3]. The ALK electrolyser is characterized by higher maturity and lower investment cost but provides limited performance at lower load factors compared to a PEM electrolyser.

$$\eta_f(r_h) = \frac{\eta_a}{\eta_{th}} \quad 1)$$

The dependency of the faraday efficiency on the load factor and electrolyser capacity requires a two-step optimization in order to solve the problem in a MILP: first, the capacity is calculated before the faraday efficiency can be considered accordingly. To evaluate the LCOH&S for the different strategies, not only the electrolyser and storage CAPEX and electricity cost are considered, but also expected additional CAPEX and OPEX based on [4]. The base scenario accounts for electrolyser CAPEX of 2000€/kW and storage cost of 15c/kWh stored hydrogen. In this case study for Spain, the Spanish spot market price of 2019 has been used. The demand that shall be covered represents the Spanish industrial gas demand profile characterized by a weekly pattern.

## Results

In Figure 1, the result from electricity price optimization is compared with the LCOH from JIT production with ALK or PEM electrolyser respectively. At first, the same electrolyser CAPEX is assumed for both technologies before a cost advantage of the more mature ALK electrolyser is considered in the comparison in the end.

If the PEM electrolyser is used in both cases, electricity price optimization leads to savings of 4% compared to JIT production (light grey). If, however, the ALK technology is used for both, the lower efficiency at lower load factors reduces the arbitrage potential for an optimization, which makes it between, 1.3-5% more expensive compared to JIT (dark grey). As shown by the blue bars, implementing a PEM electrolyser for electricity price optimization to achieve better performance in variable operation leads to savings of about 3% compared to an ALK electrolyser for JIT production. The other way round, the lower efficiency performance of the ALK electrolyser in variable operation eliminates the benefit from electricity price optimization and makes JIT production with a PEM electrolyser 4% cheaper (dark blue).

The minimum load factor in JIT production is 0.39 resulting in a minimum faraday efficiency of 92% for the PEM and 81% for the ALK electrolyser. Eventually, the green bars account for a cost advantage of ALK electrolysers. In that case, irrespectively of the chosen strategy, the ALK electrolyser results in the cheaper LCOH&S. While it is obvious that the higher cost of a PEM electrolyser for JIT production may not pay off (dark green), the cost advantage of an ALK electrolyser for JIT clearly offsets the arbitrage potential using a PEM electrolyser and makes the latter 13% more expensive (light green).

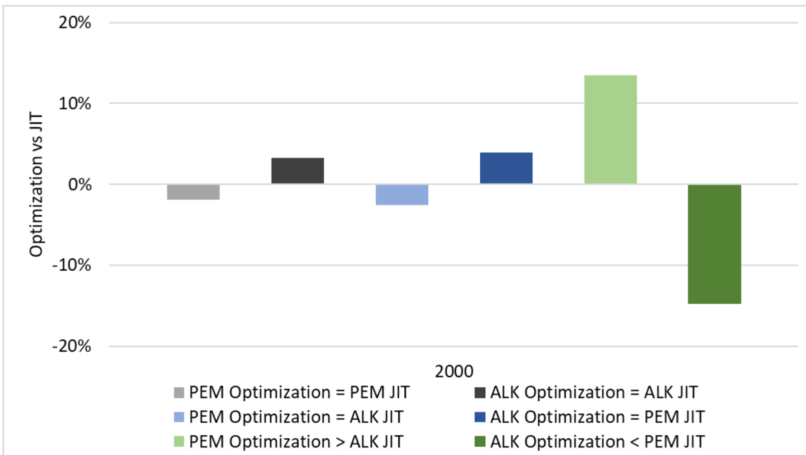


*Figure 2 Relationship between electricity price optimization LCOH&S and JIT (both PEM electrolysers)*

## Conclusions

The arbitrage potential in electricity price optimization can only offset the hydrogen storage cost and effort if the electrolyser investment cost is low enough to install substantial capacities for the exploitation of low electricity prices. If the advantages of an alkaline electrolyser, such as maturity and lower cost are taken into account, plus the eliminated storage effort of just in time production, the effort of electricity price optimization and storage may not pay off in the end.

## References

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