Optimising industrial scale green hydrogen plant LCOH in intermittent mode

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Introduction

As the green hydrogen production follows the low carbon power profile, it could be either continuous (e.g. nuclear, hydroelectric) or intermittent (e.g. wind , solar). In case of fluctuating production, the design shall propose enough flexibility to compensate the intermittency of the power source and cope with offtaker constraint (usually constant or slow reactive).

Levelized Cost of hydrogen

Compared to standard hydrogen production by Steam Reforming, the OPEX, mainly the electricity price, represents a non-negligible part of the cost of the produced hydrogen. To take into account this high OPEX, the design objective is to minimize the Levelized cost of Hydrogen:

$$LCOH = \frac{\sum_i \frac{CAPEX_i}{(1+d)^i} + \sum_i \frac{OPEX_i}{(1+d)^i}}{\sum_i \frac{H_i}{(1+d)^i}}$$

- $CAPEX_i$ is the CAPEX spent on year i of the project
- $OPEX_i$ are the OPEX spent on year i of the project
- H_i is the production of hydrogen on year i of the project
- d is the Discount rate of the project (7% to 14%)

There is three main levers to reduce the LCOH:

- Optimise the efficiency ($OPEX_i$),
- Maximise the production (H_i)
- Minimise the $CAPEX_i$

Maximisation of the production

To maximise the production, the dynamic of the plant is the key driver.

Plant Flexibility:
- Standby mode
- Low turndown
- Hydrogen Storage (Buffering)

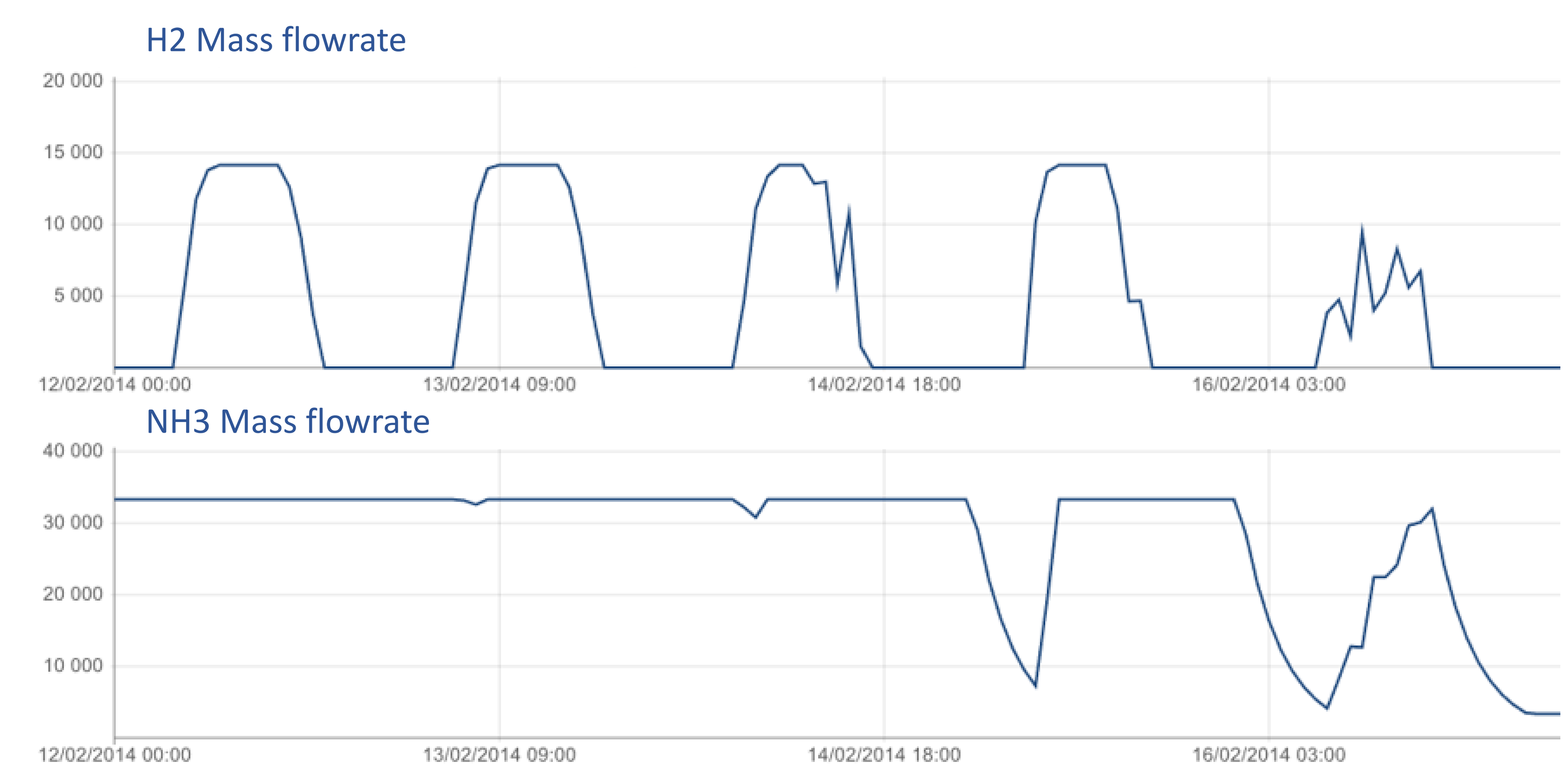
Plant Reactivity:
- Fast response time (>4%/sec)
- Quick restart from Standby

Plant flexibility

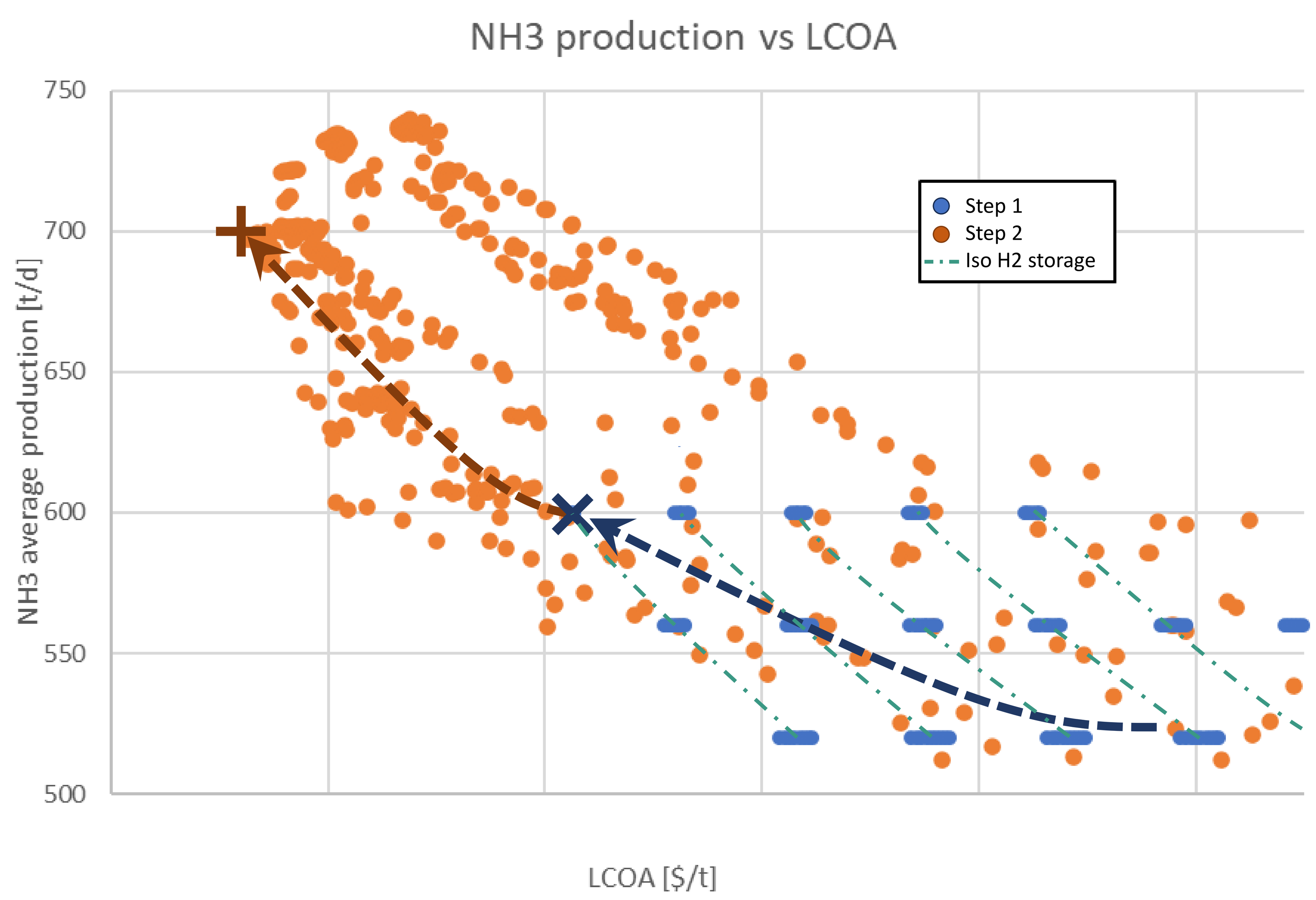
The power intermittency requires:

- A standby mode, to ease and shorten the restart time.
- A low turndown, to minimise the number of electrolyser put in standby.
- A Hydrogen storage with high pressure compression, to compensate hydrogen production shortage and maintain a minimum supply to the offtaker.

A macro dynamic model, built in Odyssey® identifies the configuration reaching the best Levelized Cost of Hydrogen, or any other molecules.



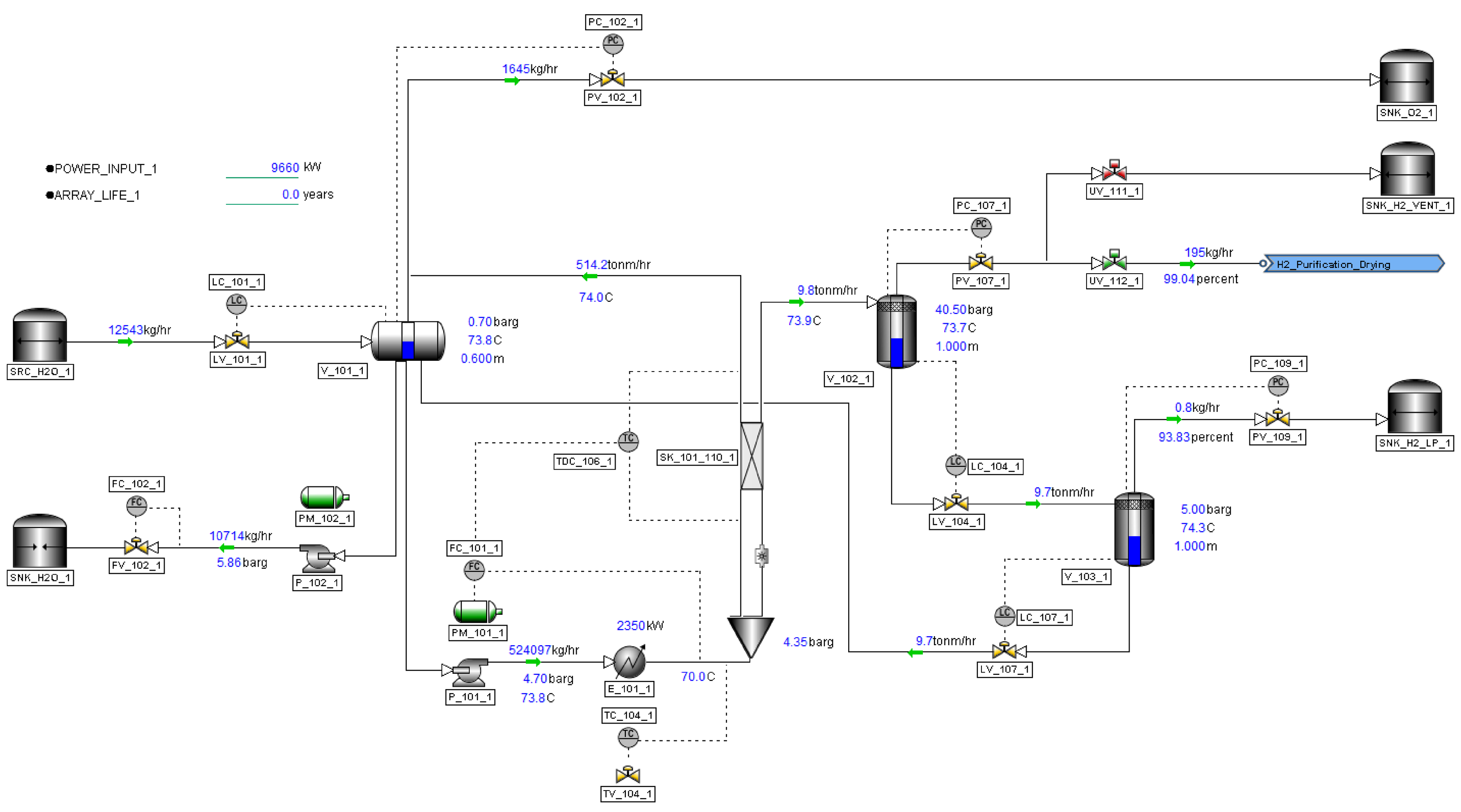
As an example, for a given solar farm capacity, it allows to define the best Ammonia plant capacity considering Hydrogen storage capacity variation (step 1), and ammonia plant production operation (fluctuating or constant) (step 2)

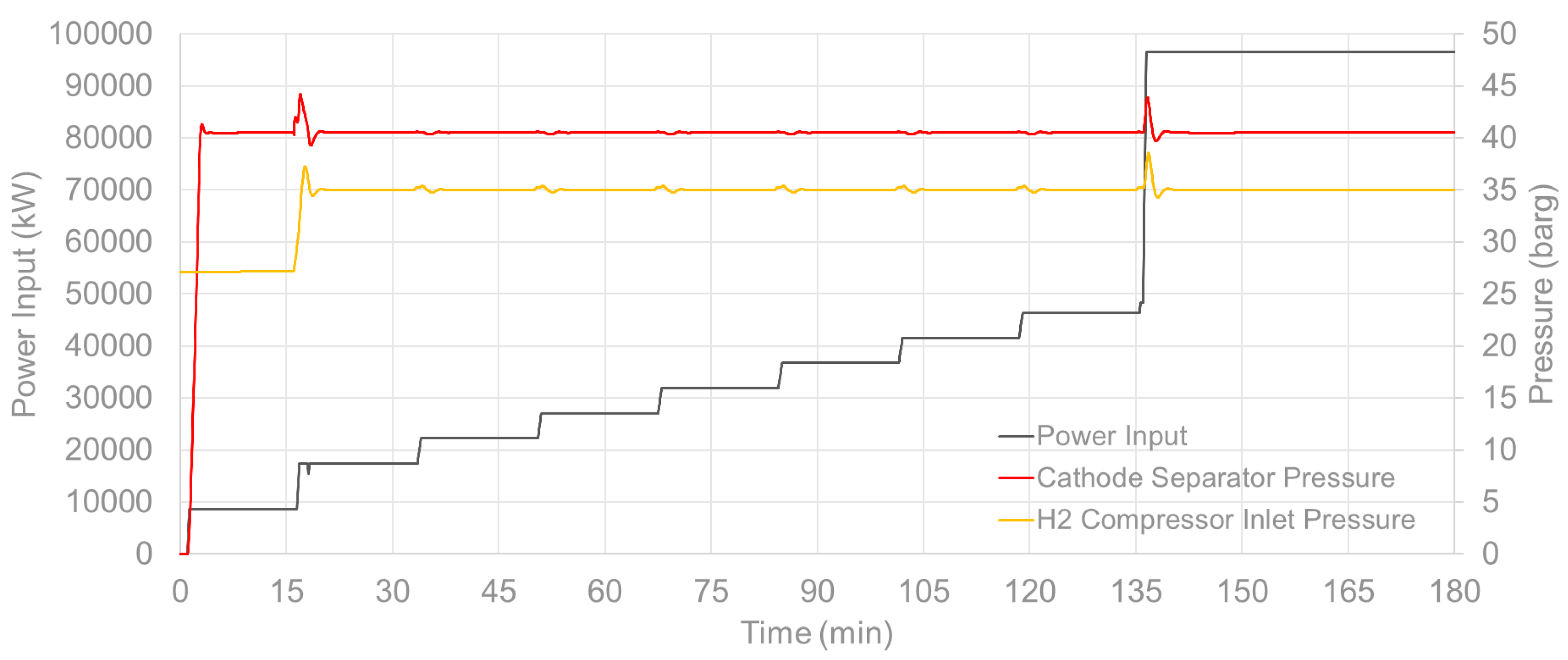


Plant reactivity

The electrolysers have a fast response time, up to 4% per sec. If this reactivity allows to follow the sudden variation of power, especially in case of wind power, the Balance of Plant will respond slowly to any variation.

Dynamic simulation is key to estimate the actual response time of the whole plant and adjust the estimated production.



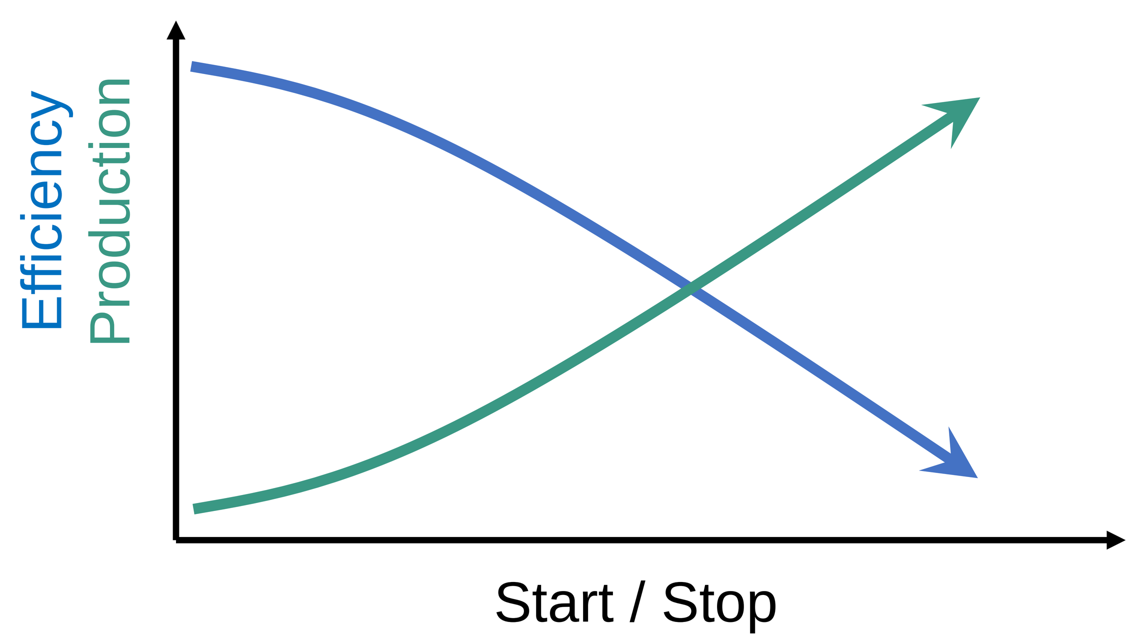


At electrolyser level it also allows to optimise the restart time (typically <10 min. from hot standby), adjust the PID controller and select the best operating set point. It derisks the process safety time of the unit.

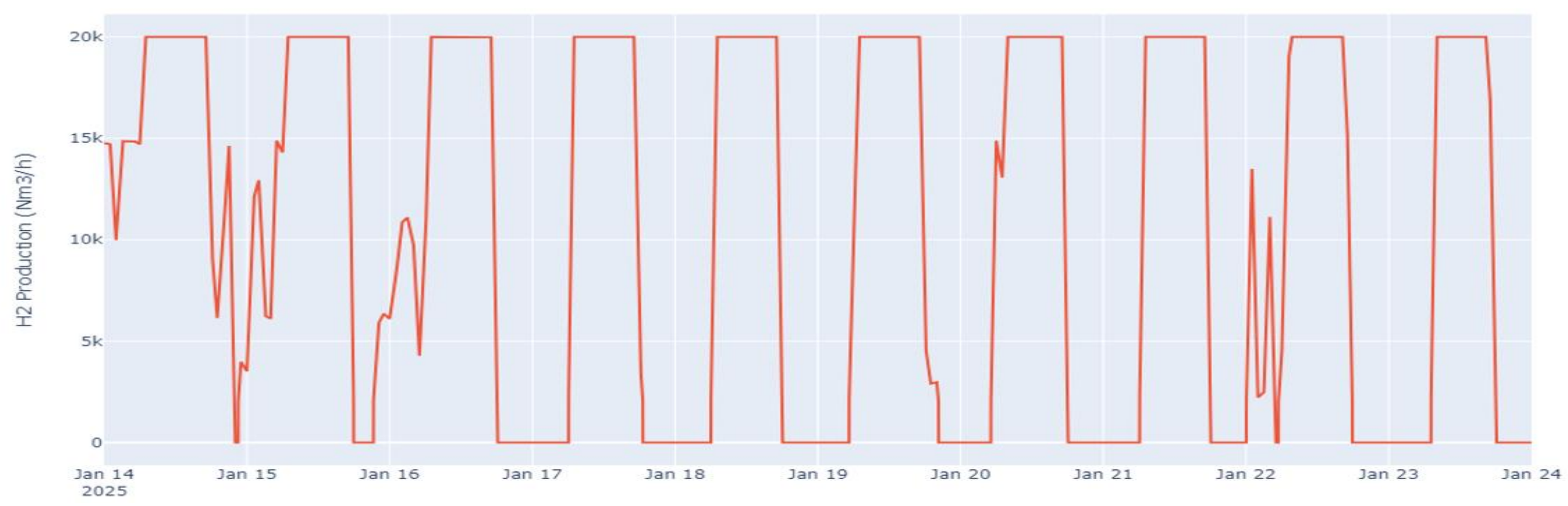
Plant operation recommendation

Once the architecture and the dynamics of the hydrogen production unit are defined, sensitivities are performed to select the best operating model of the plant.

If at first sight, minimisation of the LCOH, it obviously requires to maximise production, and as such restart the electrolyser even at partial load for short duration, but a large number of start and stop degrades the performance of the electrolyser stacks.



Thanks to an inhouse tool, recommendation can be made to reach an optimum, limiting start and stop could improve the LCOH



Short run suppression	0hr	1hr	2hr	3hr	4hr
Production ratio	1.000	0.999	0.987	0.979	0.971
Start/stop per day	1.42	1.39	1.21	1.13	1.07

Key Takeaways

- Optimum Green Hydrogen plant design is not only driven by CAPEX minimisation, but by LCOH reduction.
- Intermittency management is a key driver to optimising the LCOH. Iterative technical economics modelling is needed.
- Dynamics comprehension and optimisation at equipment level is mandatory to troubleshoot the design and propose the best operating model.