



WELCOME to the HySTrAm Newsletter

Over the last project period, HySTrAm’s consortium translated key research results into an operating ammonia demonstrator at ANWIL—by scaling materials, validating performance windows, and (crucially) adapting the engineering design when lab tests revealed an unexpected materials incompatibility.

Rather than repeating event/dissemination content, this newsletter focuses on the R&D and engineering evidence that enabled the ANWIL demonstrator: the catalyst & sorbent scale-up, the March 2025 incompatibility discovery, the resulting “Plan B” two-reactor configuration, the commissioning outcomes at site, and the supporting modelling, dashboarding, and LCA work

Vincenzo Liso, coordinator of the HySTrAm project, stated that “The ANWIL demonstrator shows how HySTrAm turns scientific learning into engineering reality. When combined-bed testing revealed a catalyst–sorbent incompatibility, the consortium reacted fast—separating functions, scaling up materials accordingly, and commissioning a pilot that operated continuously and produced measurable ammonia. These are exactly the lessons needed to mature innovative ammonia-based synthesis and storage pathways.”

Learn more reading our last press release [here](#).



PROJECT CONCLUSIONS

Material development enabling the demonstrator and defining the operation window

HyStrAm's demonstrator was built on two core material pillars: a high-activity ruthenium (Ru) catalyst and a high-capacity ammonia sorbent, both successfully scaled beyond laboratory level during the project.

Johnson Matthey synthesized and evaluated approximately 20 Ru-based catalyst candidates before selecting the formulation that achieved the project targets. The selection was based on activity performance in HYSTRAM's milder operating conditions and scalability easiness. The best material was successfully produced at 3Kg scale for the demonstrator.

In parallel, the $\text{MgCl}_2/\text{Al}_2\text{O}_3$ sorbent was successfully scaled and achieved 0.125 g NH_3 per g sorbent capacity at 38 bar and 300°C and 95% capacity retention over 20 adsorption-desorption cycles.

These results confirmed that both materials, when assessed individually, met the performance targets required for pilot-scale integration.

Although some activity loss due to Cl-poisoning of the catalyst was expected based on literature data, system-level testing revealed a critical interaction effect as combined-bed experiments conducted at TU/e showed no detectable ammonia formation when the catalyst and sorbent were layered together in a single configuration. Post-test characterization confirmed significant chlorine accumulation in the spent catalyst consistent with HCl release from the sorbent and subsequent catalyst poisoning. During the testing, a high pressure drop was also observed due to catalyst dusting which was also a consequence of the Cl-poisoning. This high pressure drop made the reactor inoperable in this configuration.

This incompatibility was experimentally demonstrated, causing the redesign of the demonstrator configuration to ensure material compatibility and safeguard pilot-scale operability.

Moreover, HySTrAm's modelling framework supported both design and operating logic. AAU conducted parametric analyses across 20–50 bar pressure and 250–325°C temperature.

These studies identified ~40 bar and ~300°C as promising operating points balancing conversion potential and system feasibility.

CFD and process simulations supported both the original layered concept and the final separated configuration. Experimental findings — especially the incompatibility result — were directly incorporated into modelling assumptions.

The modelling framework remains validated qualitatively and continues to serve as a predictive decision-support tool for future optimization.



Scale up of the MgCl_2 sorbent:
discharge of the final product and
packaging under inert atmosphere

Scale up of the Ru catalyst:
final product just after the calcination step

Reactor configuration: three weeks of continuous operation at ANWIL

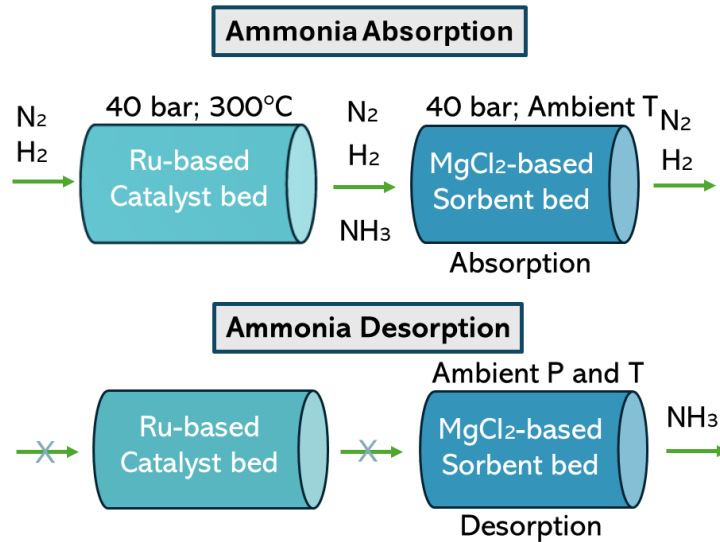
Following the material compatibility findings, the consortium implemented a two-reactor configuration consisting of two reactors in series, the first for ammonia synthesis based on a Ru catalyst, and the second reactor for ammonia sorption/desorption using an MgCl_2 -based sorbent.

As illustrated in the figure, the process is organized in two distinct operational modes—synthesis with in situ ammonia capture (upper scheme) and regeneration/desorption (lower scheme).

In the upper section (ammonia sorption), a feed stream of N_2 and H_2 enters the Ru-based catalyst bed operating at 40 bar and 300°C. Under these thermochemical conditions, ammonia is formed, resulting in an outlet stream composed of N_2 , H_2 , and NH_3 . This stream is directly routed to the downstream MgCl_2 -based sorbent bed, which operates at the same pressure (40 bar) but at ambient temperature.

At these conditions, ammonia is selectively captured by the sorbent, while the unreacted N_2 and H_2 exit the unit as a purified recycle stream.

The lower section of the figure (ammonia desorption) represents the regeneration step. During this phase, the synthesis reactor is isolated (indicated by the crossed lines on the inlet and outlet), and the $MgCl_2$ -based sorbent bed undergoes desorption. By switching to ambient pressure, the previously sorbed ammonia is released as a concentrated NH_3 stream. The figure highlights this step by showing NH_3 exiting the sorbent bed during desorption.



The pilot unit—engineered and PED-certified for operation up to 60 bar and 550°C—was commissioned at ANWIL and operated for approximately three weeks. Throughout the campaign, the synthesis reactor ran continuously, 24/7, under stable operating conditions, demonstrating reliable integration of materials, controls, and reactor engineering in an industrial environment.

The test programme delivered clear and measurable results. Ammonia concentrations between 13–18% mol% NH_3 (\approx vol%) were achieved at the synthesis reactor outlet, with maximum performance observed at 350°C and 40 bar. Multi-day steady operation confirmed mechanical and thermal stability. During the desorption phase, pure (100%) ammonia was released at pressures below 6 bar, validating the functionality of the sorption–desorption cycle.

A commissioning challenge related to axial temperature non-uniformity was successfully resolved by reallocating heating hardware, resulting in uniform temperature distribution along the full reactor length. In later sorption cycles, an immediate NH_3 slip of approximately 4% was observed, indicating incomplete sorbent regeneration and identifying a clear, quantified area for future optimization.

Overall, the ANWIL campaign demonstrated stable industrial-site operation and delivered reproducible, data-backed ammonia production results—marking a significant step forward in translating HySTrAm’s R&D into operational reality.

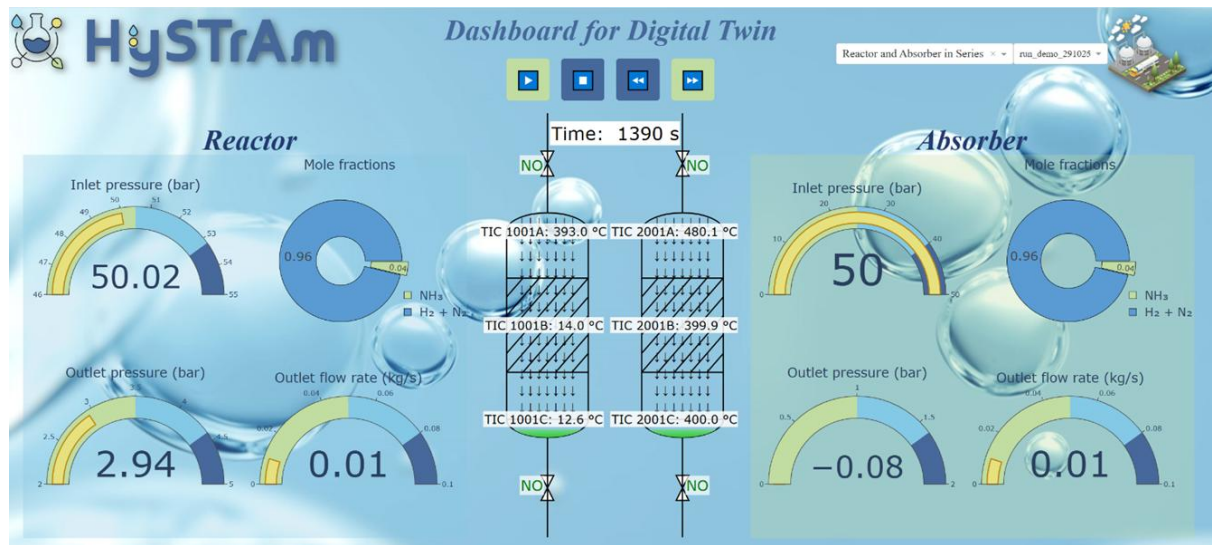
The ANWIL demonstrator was supported by a digital twin dashboard (v0.8), providing real-time visualization of:

- Inlet/outlet pressures
- Axial temperature distribution
- Gas composition (H_2 / N_2 / NH_3)
- Valve states and operational mode
- NH_3 production rate

The system is designed for OPC UA integration with simulation frameworks and plant control systems, and was tested via VPS hosting and REST API communication.

This ensured direct comparison between predicted and measured NH_3 levels, rapid identification of operating deviations, structured recording of pilot data for future scale-up studies

HySTrAm therefore demonstrated not only hardware functionality, but also structured data acquisition for evidence-based iteration.



Life Cycle Assessment: measuring impact alongside performance

Sustainability assessment progressed in parallel with technical validation. Tecnia updated LCI/LCIA for catalyst and sorbent materials and completed a pilot-scale LCA benchmarked against a 300 t/day ammonia plant as state-of-the-art reference.

The assessment concludes:

- HySTrAm shows long-term sustainability potential, particularly in energy efficiency and system flexibility.
- At current maturity, total environmental impacts remain higher than the SoA benchmark, highlighting targeted improvement needs.

The LCA therefore provides quantified direction for next-phase development — especially in sorbent production efficiency, catalyst production optimization, and durability improvements.

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