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Final Report

Project acronym and title	COMPAS - Ensuring competitiveness on ammonia production through flexible ammonia plants and low-cost electrolysis
Contact information of project leader	Henrik Lund Frandsen DTU Energy Email: hlfr@dtu.dk
Partners	Topsoe, Aarhus University, University of Copenhagen, DTU Energy, DTU Wind
Project period	01.05.2023 – 01.05.2025
Total budget	34.57M DKK

Contents

Executive summary

In order to de-risk the long-term ownership of the first-generation green ammonia production plants, it is essential that they remain competitive during their whole lifetime. One key to this is to ensure that the plants are flexible towards technology advancements, in particular with respect to the electrolysis technology, as the main operating expense is associated with the electricity consumption of the electrolysis in the green ammonia plant. One potential advancement could be an upgrade to the emerging SOEC technology, which will result in an electrical efficiency increase of more than 25 % on the plant level. Besides de-risking on the plant level, the current project also targeted various improvements over the entire value chain - all targeting lower cost and competitiveness.

While the SOEC technology is highly efficient, the current cell technology limits the lifetime of the stacks. WP1 thus focused on improving the cell technology to reach higher current densities (lower CAPEX) and lower degradation (less stack replacements) with MS1: Develop a cell which degrades less than 15 mV/kh at 750ºC and a max of 1.25 A/cm2 over 3000 hours (SoA would result in >300 mV/kh at these conditions). To achieve the very ambitious targets DTU Energy therefore set out on three parallel cell development tracks. One track was terminated half-way into the project as MS1 seemed hard to meet with this track. A second was successful in meeting MS1, and although work is still to be done, this could well result in the next generation of cells. Towards the end of the project the third track also provided very promising results (although the time did not allow for showing the stability over 3000 h). While this track would be easier for Topsoe to implement than the cells in track two, then there are still open questions on how to pre-treat the cells inside the stacks. To further pursue and mature the cell technologies, an EU project was applied for.

Furthermore, WP1 significantly increased the understanding of the degradation of the current cell technology. This was through fundamental studies in collaboration with Imperial College and the University of Copenhagen. The fundamental understanding also helped in providing the right treatment of the cells in the third track towards the promising results observed towards project closure. Here, DTU and the University of Copenhagen have applied for a DFF project on the topic, while also applying for a related topic in CETPartnership project together with Topsoe and other European and US partners. Finally, the mechanical robustness investigations in WP1 resulted in a Mission Green Fuel, pool 3 proposal (MERIT), which was granted.

In WP2, dynamic operation of the SOEC technology was in focus, as the general belief from system integrators is that the SOEC technology is not able to operate dynamically. Therefore, Topsoe ran a series of dynamic operation tests on their test-core (single stack) in Ravnholm and later on their industrial core (12 stacks) in Frederikssund. It was shown that the SOEC system could be at 80 % load within 5 minutes and fully operational within 15 minutes. The end-user in this context would be an ammonia plant with current believed dynamic capability of ~15 minutes. Through the demonstration of the many successful operational cycles on a core, which would 1:1 with those installed at ammonia plants, then MS2: Demonstrate dynamic operation of a SOEC stack-module based on operation strategy defined via input from end-users, was met. The outcome of this is rather crucial as not only is the SOEC technology able to ramp fast enough to full operation, but it is also able to go to zero load without any problems, unlike e.g., the alkaline electrolysis (AEC) technology. The SOEC technology is thus better suited to operate dynamically against fluctuating renewable power sources. Pool 2 of Mission Green Fuel focused on the dynamic operation of PtX equipment, and these results were therefore natural to further into a new project on the topic, which was applied for and granted to DTU, AU and Topsoe.

In parallel to this, AU and DTU Energy worked on understanding the dynamic operation of a combined electrolyser and ammonia plant using detailed models. The two plants influence each other as they exchange feedstock and heat (in the case of SOEC). DTU Energy worked on the part load operation and showed how efficiency remained constant over a wide load span, while low loads, especially compressors showed to be inflexible and have a high power consumption. AU showed a conceptual design for AEC and a Haber Bosch plant (MS3) and based on provided recommendation to redesign of the current ammonia reactors.

These results were integrated into DTU Wind Energy's simulation tool (HyDesign) for hybrid power plants, where the optimal sizing and design of combined wind, solar, and power generation with hydrogen and ammonia were analysed. It was found that pressurized SOEC would result in a lower cost of ammonia compared to alternative technologies (AEC, PEMEC).

Based on the results in WP2, a seminar was given to the industry and organisations with a high interest in dynamically operating green ammonia plants. Ammonia plants in Denmark do, however, not seem to be immediate, and abroad ammonia projects are being pursued for the time being.

Overall scientific results

WP1: SOEC electrolysis cost reduction

The activities in WP1 focused on several key areas:

Cell development: To enhance the competitiveness of solid oxide electrolysis technology, efforts were made to develop the next generation of cells at DTU Energy. This involved two main aspects. First, to follow a processing routine that results in cells with a mechanical support resistant to isothermal degradation. To this end, low-temperature processing with sintering at 1250 °C or below was adopted and further developed. Second, to introduce alternative fuel electrodes to achieve high electrochemical durability at high current densities. Three types of electrodes were investigated:

LSFNT fuel electrode**:** This non-Ni based cell architecture was successfully manufactured, infiltrated, and tested, demonstrating proof of concept for integrating them into the fuel-electrode ceramic-supported cell structure. However, since the performance of the cells did not meet the ambitious targets of WP1, this line was deprioritized mid-project to focus resources on other, more promising lines.

Ni-ScYSZ fuel electrode**:** Efforts were made to tailor the processing method, microstructure, and heat-treatment and reduction of the cells. The developed cells showed excellent performance. **Figure 1** presents the durability results over 3000 h of testing at 750 °C at a current density of 1 A/cm^2 (which corresponds to about 1.25 A/cm^2 at the cell inlet); the cell showed very low degradation, stabilizing down to 3 mV/1000 h during the last 1000 h of the test (after the initial deactivation common in SOECs).

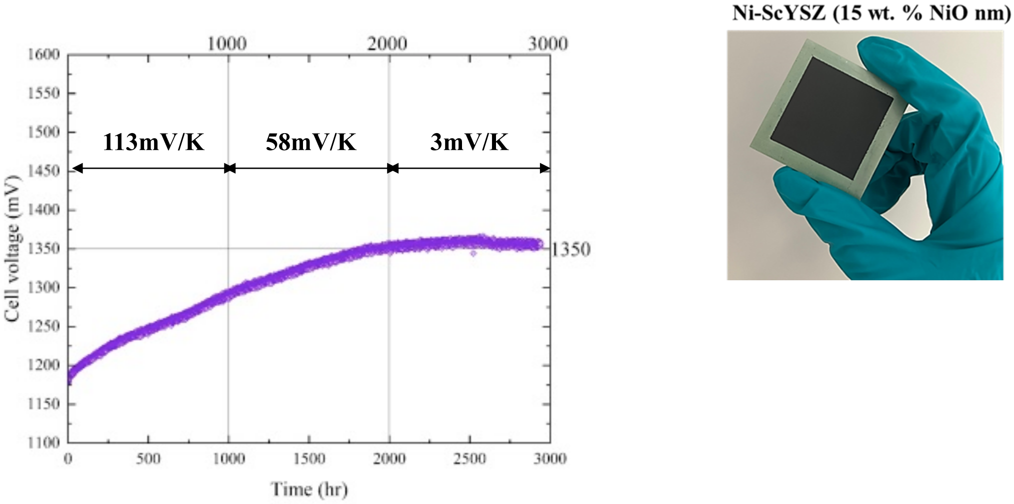

Figure 1. Durability results of COMPAS Ni-ScYSZ fuel electrode cell at 1 A/cm^2 at 750 °C. The manufactured cell is shown on the right.

<u>Ni/GDC fuel electrode:</u> This electrode has shown excellent performance in electrolyte supported architecture but is not common in fuel-electrode ceramic supported cells. The low-temperature processing approach developed in COMPAS facilitated the integration of Ni/GDC in the fuel-electrode supported architecture. Efforts were made to modify the adhesion between layers, microstructure, and heat-treatment and reduction protocols. In addition, chemical interaction (interdiffusion) between materials in the cells and mechanical robustness under current cycling were investigated. **Figure 2** presents the durability results at a current density of 1 A/cm^2 at 750 °C. The cell showed negligible (or even negative) degradation. Despite the high voltage, the cell showed promising results and potential for further improvement. Activities in this line are continuing in a small internal DTU funded follow-up project, and a European project application has also been submitted to maintain development activities.

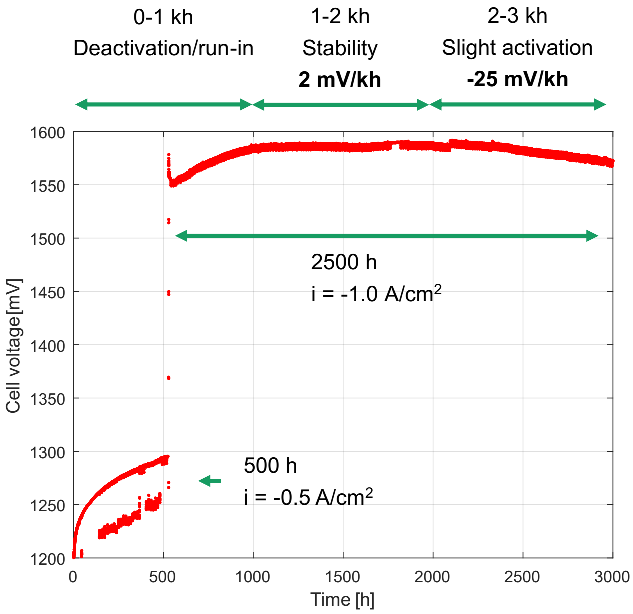

Figure 2. Durability results of COMPAS Ni-GDC fuel electrode cell at 1 A/cm^2 at 750 °C.

Degradation modeling and testing: Activities aimed to gain a deeper understanding of degradation in solid oxide cell fuel electrodes. This was achieved through various approaches and tools, including segmented cell testing, controlled condition studies with clean room prepared model electrodes, operando spectroscopy, high-resolution and sensitivity spectroscopy and microscopy, multi-physics degradation modeling, and DFT studies. These interdisciplinary methods helped analyze and better understand degradation mechanisms. Furthermore, by examining factors such as defect chemistry and co-doping of YSZ, use of pure or alloyed Nickel, and the effect of impurities, design criteria and solution strategies for more durable fuel electrodes for SOEC operation were derived.

Mechanical Investigation: The mechanical behavior of glass sealing, being a crucial component in SOEC stacks, was also investigated in this work package. The studies were primarily experimental, focusing on state-of-the-art Topsoe glass material. Methodologies for effectively assessing the creep properties of the glass ceramic were developed, and the experimental results were modeled to simulate creep deformation of amorphous glass. Furthermore, the effect of crystallization on creep rate, microstructure, and viscoelastic properties was investigated. In addition to the experimental work, various factors such as sealing thickness and thermal gradients were studied computationally to investigate the crack propagation and fracture behavior of sealings in stacks.

The results provided further understanding of the mechanical behavior of glass-ceramic sealants under relevant stack heat treatment and thermal gradient conditions. These studies will continue in a follow-up project (MERIT, MissionGreenFuels Pool 3), where the methodologies and knowledge developed in COMPAS will be instrumental in advancing the research.

Cell development for SOEC cost reduction: Efforts focused on optimizing manufacturing methods to enhance the scalability of state-of-the-art cells. This included both ceramic processing aspects and mechanical robustness. The latter involved characterizing different modes of fracture and understanding the factors with the highest impact on the buildup of mechanical stresses during manufacturing. The results provided guidelines on enhancing mechanical robustness for large-scale manufacturing.

COMPAS also contributed to building testing capacities and software solutions for electrochemical characterization. In addition, improvements beyond the current state-of-the-art cells were considered, aiming to enhance the Ni-8YSZ fuel electrode microstructure to improve cell performance at high current densities and low cell voltages. For example, developments enabled about a 25% increase in current density while maintaining operation at thermoneutral voltage. The cell also demonstrated excellent durability under galvanostatic operation. Detailed microstructural characterization was done using high resolution transmission and scanning electron microscopy techniques coupled with elemental analysis. The interface/attachment of Ni and YSZ phases, and the presence of impurities were investigated. The results were also used for 3D reconstruction of the fuel electrode. Furthermore, modeling activities were conducted to correlate the cell resistance of the R&D cells to the microstructure of their fuel electrode and support.

The developed cells, currently in R&D stage, along with the enhanced know-how, will be implemented in the SOEC cell and stack manufacturing facility in Herning within a few years.

WP2: Electrolysis system operation

WP2 focused on the modelling, experimental validation, and system-level assessment of electrolysis-based hydrogen production integrated with ammonia synthesis. The aim was to evaluate dynamic operation under variable renewable electricity supply and to identify strategies for maintaining stable performance in large-scale green ammonia systems.

Dynamic modelling and simulation of the ammonia production system: The activities in this task focused on the development and validation of a dynamic simulation framework for green ammonia production, combining hydrogen production via alkaline electrolysis with ammonia synthesis and purification.

Hydrogen production modelling: A dynamic model of a 1 MW alkaline electrolyzer system was developed using Aspen Custom Modeler (ACM), including relevant balance of plant (BoP) components. The model was constructed within the Aspen Plus environment to allow future integration with plant-wide process models. Validation was performed using data from the literature, and the results showed good agreement in terms of system response under varying operational conditions. **Figure 3** shows the results of validated model to predict the cold start-up of a 1 MW unit under current control scenario. Subsequently, the dynamic performance of the electrolyzer model was tested using real wind power profiles provided by DTU Wind Energy. The ACM model has been encapsulated as a standalone unit operation block, which can be exported and integrated into other process models. This model package constitutes one of the main outcomes of the task and serves as a flexible simulation tool for further research and process design studies.

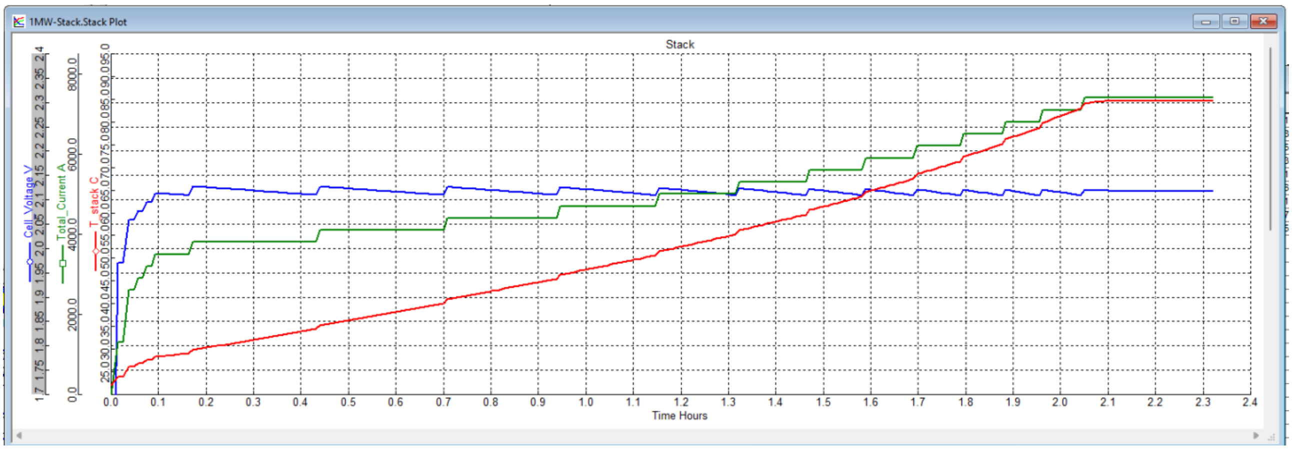

Figure 3. Cold start-up of a 1-MW alkaline electrolyzer unit at current control mode

Ammonia synthesis and purification modelling: A full ammonia factory model was developed based on publicly available data and validated through input and design feedback from the industrial partner, Topsoe. The model includes a reactor based on the S300 design (Topsoe), BoP components, a compression section, and a distillation unit for separating ammonia from unreacted synthesis gas. Initially developed in steady-state mode, the model was later transferred to Aspen Dynamics to enable dynamic operation studies.

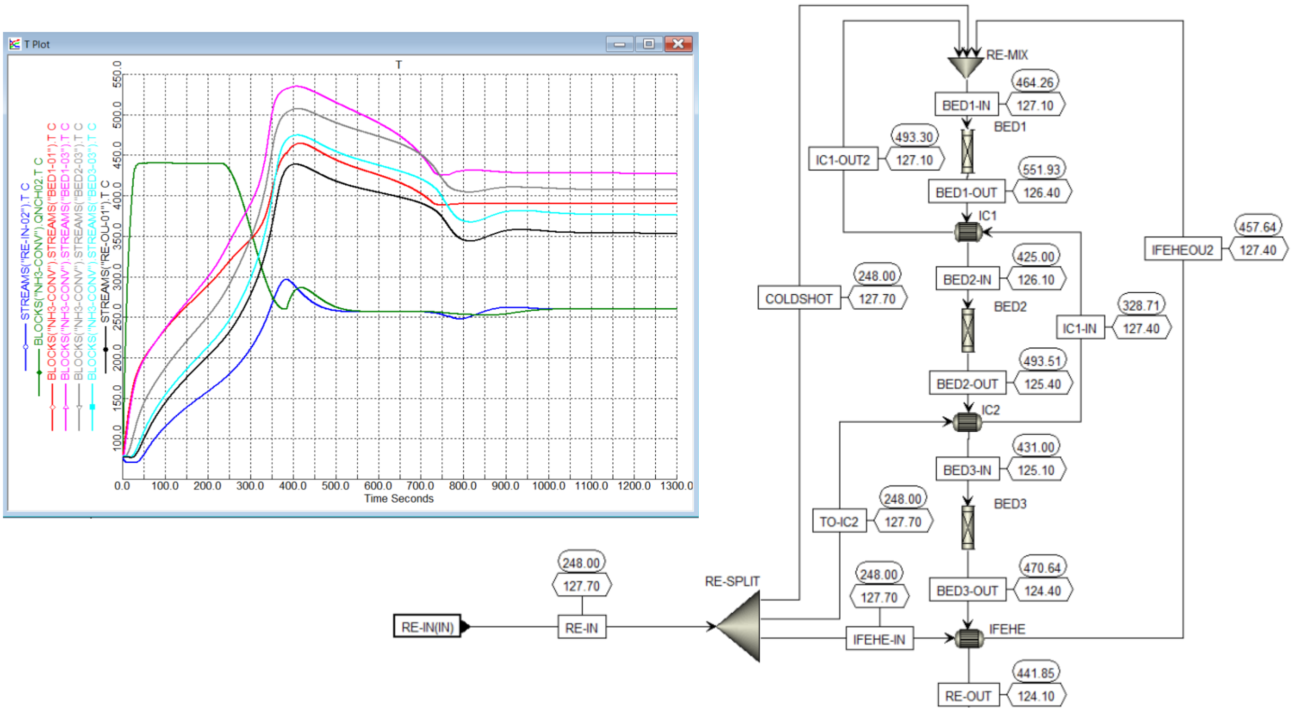

Figure 4. S300 HB reactor design and temperature control response to the disturbance

Advanced control schemes were implemented, including a dedicated compressor control module capable of estimating surge and choke conditions. This module dynamically adjusts compressor performance and kick-back valve operation to maintain loop pressure under challenging conditions, such as a sudden loss of more than 90% of the hydrogen feed. In parallel, the reactor control system was developed to regulate temperature within acceptable limits during dynamic transients. **Figure 4** shows the simulated S300 reactor in the Aspen Plus environment as well as the response of control system to a disturbance in the feed flow and indicates that the system is capable of maintaining the reactor temperature within the safety margins. These efforts enabled detailed evaluation of process operability and control under renewable-driven scenarios.

<u>Integrated AEC + Ammonia system simulation:</u> Following the individual model development, the alkaline electrolyzer and ammonia synthesis flowsheets were integrated to form a complete plant-wide model. The previously developed 1 MW electrolyzer unit model was scaled and replicated to simulate a 550 MW hydrogen production facility. The combined dynamic model enabled the evaluation of overall system behavior under large-scale power fluctuations representative of renewable electricity supply.

Simulation results demonstrated that the ammonia synthesis loop pressure could be successfully maintained even during extreme variations in power input to the electrolyzer—from full-load operation at 550 MW down to 5.5 MW (i.e., 1% load). These findings highlight both the robustness of the implemented control strategies and the technical feasibility of constructing a fully dynamic ammonia factory capable of adapting to highly variable renewable energy inputs.

Dynamic operation of SOEC unit: The demonstration of a Solid Oxide Electrolysis Cell (SOEC) reactor was carried out at Topsoe's test facility in Frederikssund under dynamic operating conditions to evaluate its potential for flexible hydrogen production using variable renewable power sources.

A core module, presented in **Figure 5**, comprising 12 TSP-2 stacks (corresponding to approximately 1,200 cells) was tested at a nominal power of 352 kW, or around 30 kW per stack. During stable operation in potentio-galvanostatic mode, the system demonstrated consistent power consumption over time, producing 115 Nm³ H_2 per hour. Over the steady operation phase, more than 260,000 Nm³ H_2 was produced, equating to roughly 800 MWh of total hydrogen output. This long-duration test confirmed exceptional on-stream performance and thermal stability under industrial conditions. Results highlighted that operating close to the thermoneutral voltage (~1.3 V cell voltage) maximizes system efficiency, while operating under pressurized conditions throughout the experiments demonstrated the potential of the next generation of SOEC reactors.

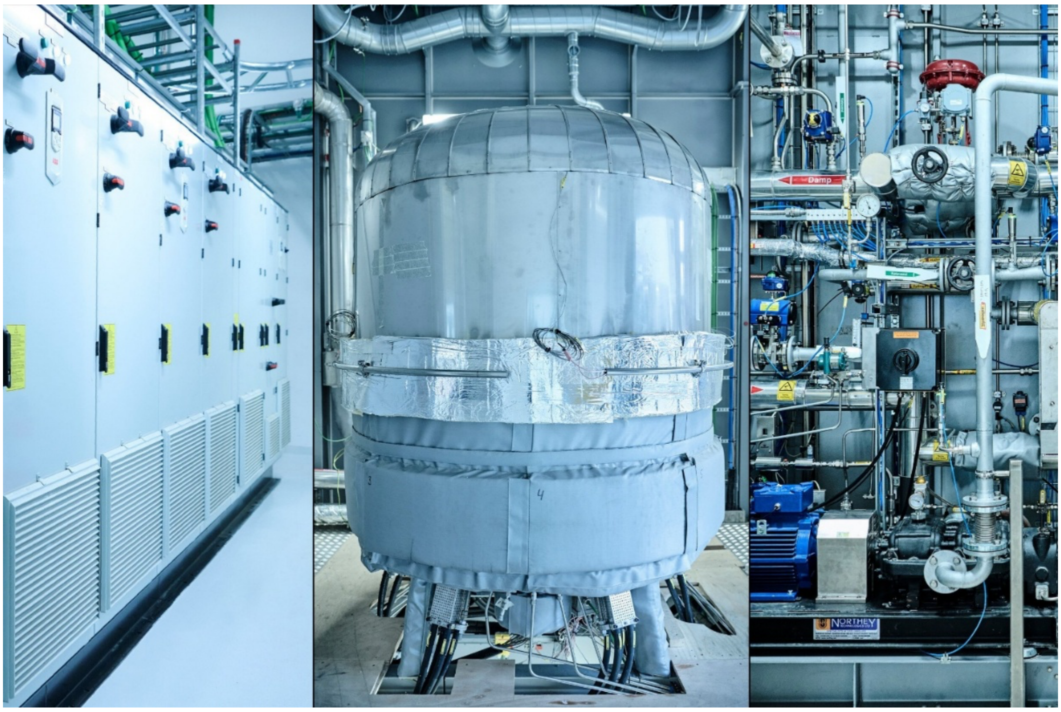

Figure 5. Topsoe SOEC demonstration plant at Frederikssund

Dynamic operation tests were performed to mimic conditions with fluctuating renewable electricity availability and price signals. The system exhibited rapid flexibility, with less than 30 minutes required to ramp hydrogen production from 0% to 100% output and back again. In hot-standby mode, the SOEC core maintained readiness with an electrical consumption of approximately 10 kW, equivalent to about 3% of full-load power consumption (372 kW). Specific tests showed ramp-down from 100% to 0% output in about 6 minutes and ramp-up from 0% to 100% in about 18 minutes.

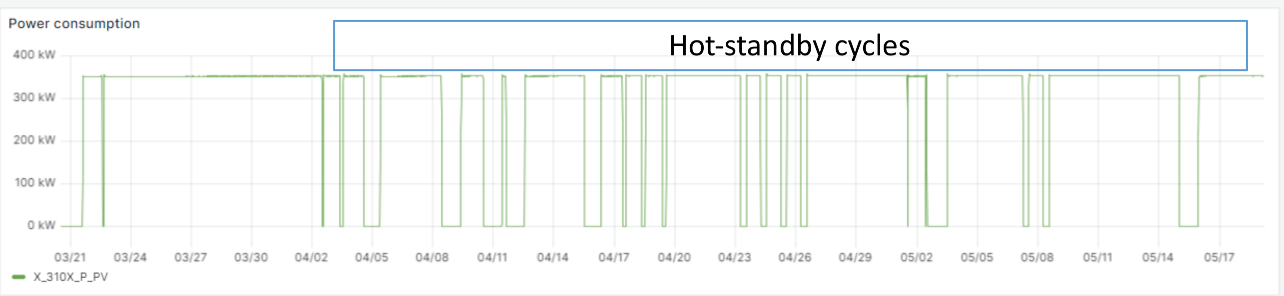

Figure 6. Hot standby cycles demonstrate fast response to power supply and demand

Figure 6 illustrates the power profile of the SOEC core during the hot-standby experimental campaign. These results confirmed that SOEC technology can respond effectively to rapid load changes, with stable thermal and electrochemical behavior across operating modes. This demonstration supports the integration of high-temperature electrolysis into flexible green hydrogen production systems capable of adjusting to variable renewable power supply conditions.

Design and optimisation of a hybrid power plant including hydrogen and ammonia factories: Developing a green ammonia factory also requires understanding how to balance power supply and demand under changing electricity market conditions. In particular, it is important to know how hydrogen production units (electrolysers) and ammonia synthesis can work together within a hybrid power plant and adjust in real time to make the best use of renewable electricity.

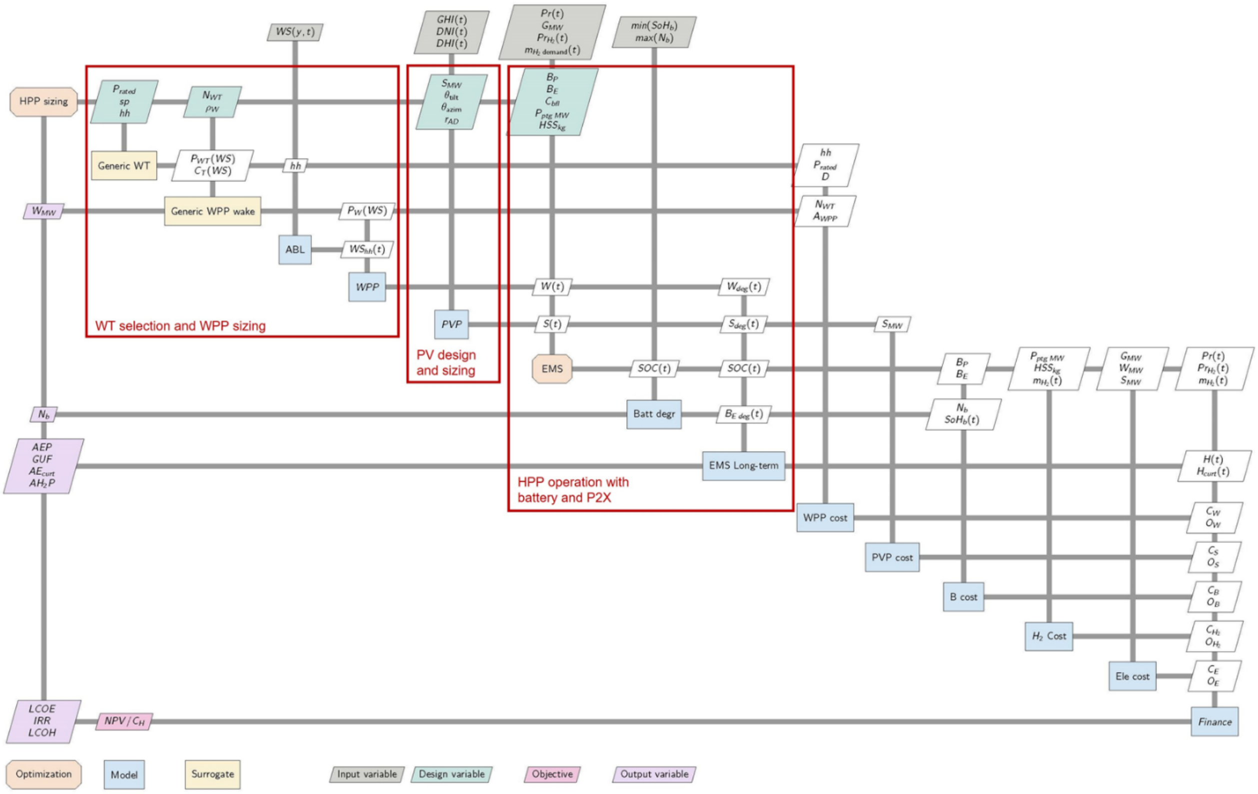

Figure 7. HyDesign Architecture

To address this, tools and methods were developed for the design and operation of a Hybrid Power Plant (HPP) that combines wind and solar generation with hydrogen and ammonia production. The HyDesign software platform was used to optimise the size of each part and test how the plant could perform under different scenarios. **Figure 7** presents the architecture of HyDesign calculation and decision-making framework. The modelling framework includes three electrolyser technologies — Alkaline Electrolysis (AEC), Proton Exchange Membrane (PEM), and Solid Oxide Electrolysis Cells (SOEC) — as well as an integrated Haber-Bosch (HB) model for ammonia production. This allows the full hydrogen-to-ammonia pathway to be analysed and optimised within one system.

A hierarchical control system was also developed to operate the hybrid plant flexibly in real time, adjusting power flows and production levels based on market prices and available renewable energy. The control system works at multiple levels, from high-level market interaction to plant coordination and equipment-level control.

Several case studies tested the approach for different locations, electricity prices, hydrogen prices, and grid usage strategies. Results showed that including hydrogen and ammonia production (P2X) helps make better use of surplus renewable power and can improve economic performance. However, profitability depends on factors such as site location, market conditions, electrolyser size, and technology choice. For example, PEM electrolysers showed better performance than AEC units in some scenarios, despite higher investment costs. Overall, careful sizing, robust control, and integration of the hydrogen and ammonia units are key to maximising the value of renewable energy in green ammonia production.

Contribution to and impact on MissionGreenFuels roadmap

The project has impacted the roadmap primarily in increasing the competitiveness of Danish technology. This has been approached by 1) improving the technical performance of the technology (higher possible current density and lower degradation) and 2) demonstrating the dynamic performance of the technology.

Regarding 1), then the target for the current project was reached, and doubling of the current density / production capacity of the cells seems possible. This would decrease the cost for the cell stacks by approximately a factor of two (only half the stacks needed, as the same stack would be able to produce double the amount of hydrogen).

This would also impact the production capacity, such that the Topsoe plant in Herning would go from being able to yearly produce stacks capable of converting 500 MW of power to hydrogen to the double (1000 MW/year). This would also further the green transition with a significant increment.

Finally, the increase of the cell performance would result in great savings on steel and ceramic materials going into the production of the stacks by a factor of two as well, significantly impacting the sustainability of the solution.

Regarding 2), then this has great impact on the understanding of how this technology can be integrated into the power grid. This is especially important for a country like Denmark, which is on the forefront of integrating renewable power, while ensuring stability of the grid. The project has provided the understanding that the SOEC technology is able to follow loads with a reasonable pace, which was not the case before where all international reports points to that the technology could not be operated dynamically. Perhaps even more important; the load is able to go to zero without additional cost, unlike the AEC technology, which needs costly flushing with nitrogen before startup.

The project partners have had some cross-work project interaction with partners from other projects, such as DynFlex. The partnership meetings have also provided some overall understanding of the parallel activities. The project leader does however think that it is good that there is now a stronger focus on the mission and the partnership.

Key learnings from the execution of the project

The first projects of the partnership were defined very fast over few days, and details for the interaction were not described in detail. This allowed to define some open sub-projects within the frame of the overall project. The PhD students who worked in COMPAS had thus slightly a greater freedom in defining their project, and the results from the students were excellent.

A learning, which has already been implemented, is to set a deadline for the signing of the collaboration agreement. The first projects, amongst these COMPAS, had no deadline and the legal entities amongst the partners were thus not in a rush to finalize the agreements. So, although the technical staff urged and helped as much as possible, then the negotiations carried on for a very long time. At DTU at least, the legal departments are independent of the departments, and the departments are thus unable to influence the process significantly. So, it is good that deadlines for the negotiations are now in place.

Future needs for increased impact

For the use case of the technology, green ammonia, then it is well acknowledged to be a future maritime sustainable fuel. However, only very few demonstration ships are using this, and the market for green ammonia is thus not yet present. CO2 taxation must thus increase significantly before the market is available. Green ammonia will likely never be competitive to “free” fossil fuels.

Gearing of Investment

As described in the executive summary, then several research funding tracks are followed based on the results of the COMPAS project, while Topsoe is further working on the commercialization. This summarizes to:

1. A CET Partnership proposal (ptSOE) – passed phase 1, currently in phase 2 of the evaluation
2. A Mission Green Fuel pool 2.5 proposal (FLEXUM) - granted
3. A Mission Green Fuel pool 3 proposal (MERIT) – granted
4. An EU Clean Hydrogen Europe proposal (ROBHIN) – in evaluation
5. A DFF proposal (SHIELD) – in evaluation

Milestones and deliverables

Milestone/Deliverable	**Achieved/Delivered [y/n]**	**Outcome**
[Milestone 1]	Y	A cell which degrades less than 15 mV/kh at 750ºC and a max of 1.25 A/cm2 over 3000 hours
[Milestone 2]	Y	Demonstration of dynamic operation of a SOEC stack-module based on operation strategy defined via input from end-users
[Milestone 3]	Y	Conceptual design of a flexible ammonia plant, allowing for revamp from alkaline to SOEC based on design from DTU

Communication, dissemination and outreach activities

Scientific articles

1. Beyrami, J., Nakashima, R. N., Nemati, A., & Frandsen, H. L. (2025).
   Lifetime and performance of solid oxide electrolysis stacks and systems under different operation modes and conditions. International Journal of Hydrogen Energy, 102, 980-995. https://doi.org/10.1016/j.ijhydene.2025.01.028
2. Beyrami, J., Nakashima, R. N., Nemati, A., & Lund Frandsen, H. (2024).
   Degradation modeling in solid oxide electrolysis systems: A comparative analysis of operation modes. Energy Conversion and Management: X, 23, Article 100653. https://doi.org/10.1016/j.ecmx.2024.100653
3. Taubmann, J., Frandsen, H. L., & Khajavi, P. (2024).
   Mitigating low-temperature hydrothermal degradation of 2 mol% yttria stabilised zirconia and of 3 mol% yttria stabilised zirconia/nickel oxide by calcium oxide co-doping and two-step sintering. Ceramics International, 50(21), 43108-43121. https://doi.org/10.1016/j.ceramint.2024.08.162
4. Yarahmadi M, Taubmann J, Moragas AL, Frandsen HL, Sudireddy, Khajavi P (2024).
   Development of Ceramic-Supported Solid Oxide Cells with LSFNT-based Fuel Electrode, Proceedings of the Conference: 14th International Conference on Ceramic Materials and Components for Energy and Environmental Systems.
5. Bilalis, V., Sun, X., Frandsen, H. L. & Chen, M. (2024).
   Quantifying Galvanostatic Degradation of Solid Oxide Electrolysis Cells: The onset of accelerated degradation of Ni-yttria stabilized zirconia electrode, Journal of Power Sources. 606, 15 p., 234490.
6. Hutu, A. I., Pervolarakis, E., Remediakis, I. N., Kristoffersen, H. H., & Rossmeisl, J. (2024).
   Scaling Relations on High-Entropy Alloy Catalyst Surfaces. Journal of Physical Chemistry C, 128(25), 10251-10258. https://doi.org/10.1021/acs.jpcc.4c01292
7. Bilalis, V., Li, B., Lopez de Moragas, A., Frandsen, H. L., & Chen, M. (2025).
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8. Schiedeck, M., Nogueira Nakashima, R., & Frandsen, H. L. (2025).
   Heat integration and part-load performance of an SOEC-coupled Haber–Bosch process. International Journal of Hydrogen Energy, 116, 242-256. https://doi.org/10.1016/j.ijhydene.2025.02.335
9. Bilalis, V., Sun, X., Frandsen, H. L., & Chen, M. (2024).
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10. Bilalis, V. (2023).
    Study of Degradation Processes in High Temperature Solid Oxide Electrolysis Cells: Focusing on the Ni/Yttria Stabilized Zirconia Fuel Electrode. PhD thesis, Technical University of Denmark.
11. Taubmann, J., Sun, X., Rizvandi, O. B., & Frandsen, H. L. (2023).
    Advanced insights into gas conversion and diffusion impedance of solid oxide cells by 2D multi-physics modelling. Journal of Power Sources, 588, Article 233739. https://doi.org/10.1016/j.jpowsour.2023.233739
12. Klitkou, M. P., Moragas, A. L., Taubmann, J., Khajavi, P., Pirou, S., Frandsen, H. L., & Hendriksen, P. V. (2023).
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13. Klitkou, M. P. (2024).
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14. Lopez de Moragas, A. (2025).
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15. Taubmann, J. (2025).
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16. Bilalis, V., Li, B., Frandsen, H. L., & Chen, M. (2023).
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17. Kristoffersen, H. H. (2025).
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18. A.-I. Hutu, E. Pervolarakis, I. N. Remediakis, H. H. Kristoffersen, J Rossmeisl (2024).
    Scaling relations on high-entropy alloy catalyst surfaces, J. Phys. Chem. C, 128, 10251-10258
19. T Heiredal-Clausen, D B Drasbæk, P Blennow, J Rass-Hansen, C B Schandel, T Holt Nørby, M Hultqvist, (2024).
    Topsoe Stack Platform for Upscaling and Commercialization of SOEC in Power-to-X, Proceedings of the 16th European SOFC & SOE Forum, EFCF2024, Lucerne, Schwitzerland
20. D B. Drasbæk, C B. Schandel, F Zaravelis, P Blennow, T Heiredal-Clausen, J Rass-Hansen, G Perin, A Hauch, A Mai (2024).
    Advancements in Electrochemical Impedance Spectroscopy for SOEC stack Evaluation and Quality Control at Topsoe, Proceedings of the 16th European SOFC & SOE Forum, EFCF2024, Lucerne, Schwitzerland

21. P Blennow, E Despesse, G Perin, K Thydén, R, Tiruvalam, L F. Lundegaard, S B. Rasmussen, A Hauch (2024)
    Understanding Performance of SOECs by Combination of Advanced Characterization Techniques, Proceedings of the 16th European SOFC & SOE Forum, EFCF2024, Lucerne, Schwitzerland

Manuscripts under preparation

22. Yarahmadi, M., de Moragas, A.L., Taubmann, J., Frandsen, H. L., Sudireddy, B. R., Kiebach, R., Hendriksen, P.V., Khajavi, P., Processing, Characterization, and Testing of Ni-3YSZ Ceramic-Supported Solid Oxide Cells with Integrated LSFNT-Based Electrode, Under-preparation.
23. Taubmann, J., Yarahmadi, M., Frandsen, H. L., Khajavi, P., Development and testing of 10 mol% scandia-1 mol% yttria stabilised zirconia/nickel fuel electrodes for solid oxide electrolysis cells, Under-preparation.
24. Shahriary, P., Frandsen, H. L., Di Stasio, L., Ritucci, I., Khajavi, P., High-temperature creep properties of amorphous glass for SOEC sealing, Under-preparation.

Events/Conferences (include organiser, date, location, number of participants and link if applicable)

1. A cross-MGF partnership workshop on: “Experimental characteristics of electrolysis components, stacks, units and systems”,
    a. 16th of April 2024,
    b. Port House, Fredericia
    c. Organizers: Energy Cluster Denmark, DTI, DTU Energy
    d. Participants: ~20
2. A cross-MGF partnership workshop on: “Modelling of electrolysis components, stacks, units and systems”,
    a. 28th of April 2024,
    b. Port House, Fredericia
    c. Organizers: Energy Cluster Denmark, DTU Energy, DTI
    d. Participants: ~20
3. A seminar on project findings on dynamic operation of green ammonia plants,
    a. 23rd of April 2025,
    b. DTU Kgs Lyngby,
    c. Organizers: DTU Energy
    d. Participants: ~15

Media (include link, or list relevant information about the activity)

Articles reaching out to a broader audience on LinkedIn and in Hydrogen Tech World:

1. https://www.linkedin.com/feed/update/urn:li:activity:7205093718494715905/
2. https://www.linkedin.com/feed/update/urn:li:activity:7107279034643816449/
3. https://hydrogentechworld.com/new-electrolysis-cells-pave-way-for-cheaper-hydrogen

Two articles about COMPAS findings in Ingeniøren:

4. https://ing.dk/artikel/groen-brint-er-dyr-ekstremtemperatur-paa-900-grader-kan-skaere-toppen-af-prisen
5. https://ing.dk/artikel/groen-brint-er-dyr-smart-genbrug-af-industriel-varme-kan-skaere-en-femtedel-af-prisen

Patents (include application no., data and granted (y/n))

None

Educations/Courses (include title of programme/course, and the number of participants)

- An overview to the project and purpose was given in the courses:
    - 47330 Energy storage and conversion
    - 47211 Electrochemical energy storage and Power2X
    - 47213 Introduction to Power-to-X
    - 290192U002 Renewable Energy Technologies
- During the project guest lectures at DTU given by Topsoe have included results from the COMPAS project e.g. course 47305 “Electrochemistry” and the course 47301 “Hydrogen energy and fuel cells”.
- Eight “Power-to-X” presentations for high school students (“High school visit at KU SCIENCE”)

Student engagement

PhDs and master students connected to the project.

1. Matthias Schiedeck, practicum thesis: Heat integration and part-load performance of an SOEC-coupled Haber-Bosch process
2. Niklas Ward Pedersen, bachelor thesis: Effect of processing conditions on the fuel electrode electrolyte interface in fuel electrode supported cells with a Ni-GDC active layer
3. Naidoo, Deshanya, master thesis: Saldanha Bay Green Ammonia Study

Synergies to other projects/initiatives

- Collaboration with Technical University of Münich on a study of high temperature electrolysis and green ammonia plant part load operation (through the student Matthias Schiedeck).
- Topsoe’s continued collaboration with First Ammonia to establish the first large scale SOEC based ammonia plants.