

# INSIGHTS FROM THE ENERGY TRANSITION FOREFRONT

Two World Firsts, Commercial Scale SOEC & Renewable Dynamic Distributed Ammonia Plants

TOPSOE

Bo Hartvigsen (Topsoe)



# TOPSOE AT A GLANCE: OVER 80 YEARS OF INNOVATION AND LEADERSHIP

We are a leading global provider of technology and solutions for the energy transition. We combat climate change by helping our customers and partners achieve their decarbonization and emission reduction goals.

Based on decades of scientific research and innovation, we offer world-leading solutions for transforming renewable resources into fuels and chemicals for a sustainable world, and for efficient and low carbon fuel production and clean air.

We were founded in 1940 and are headquartered in Denmark.

## #1 NH<sub>3</sub>

Topsoe is the worlds leading provider of ammonia technology and catalysts.

## +2,800

employees

## 1.4B

(USD)  
in revenue



## 9%

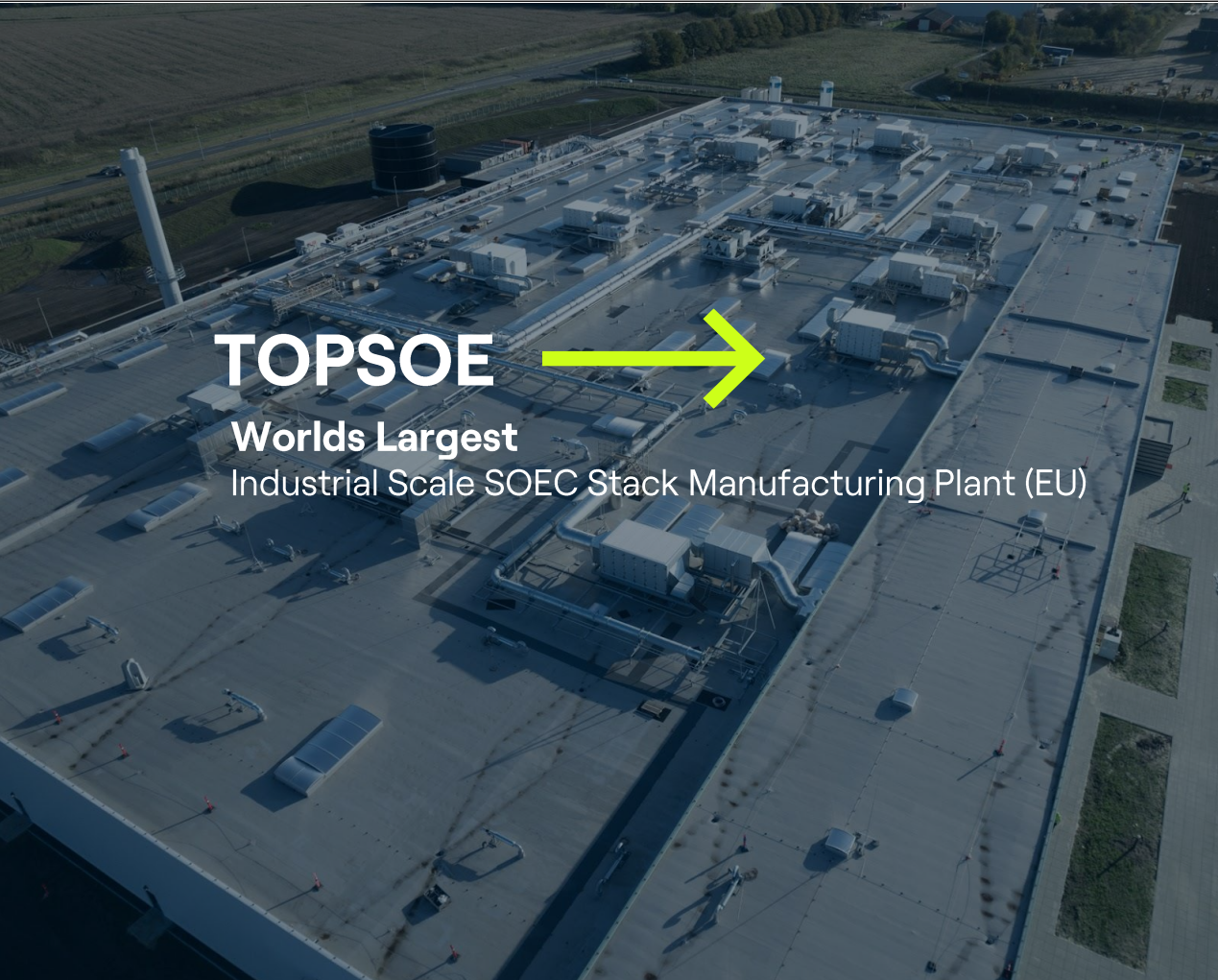
(102m USD)  
invested in R&D in 2023

## +600

patent families

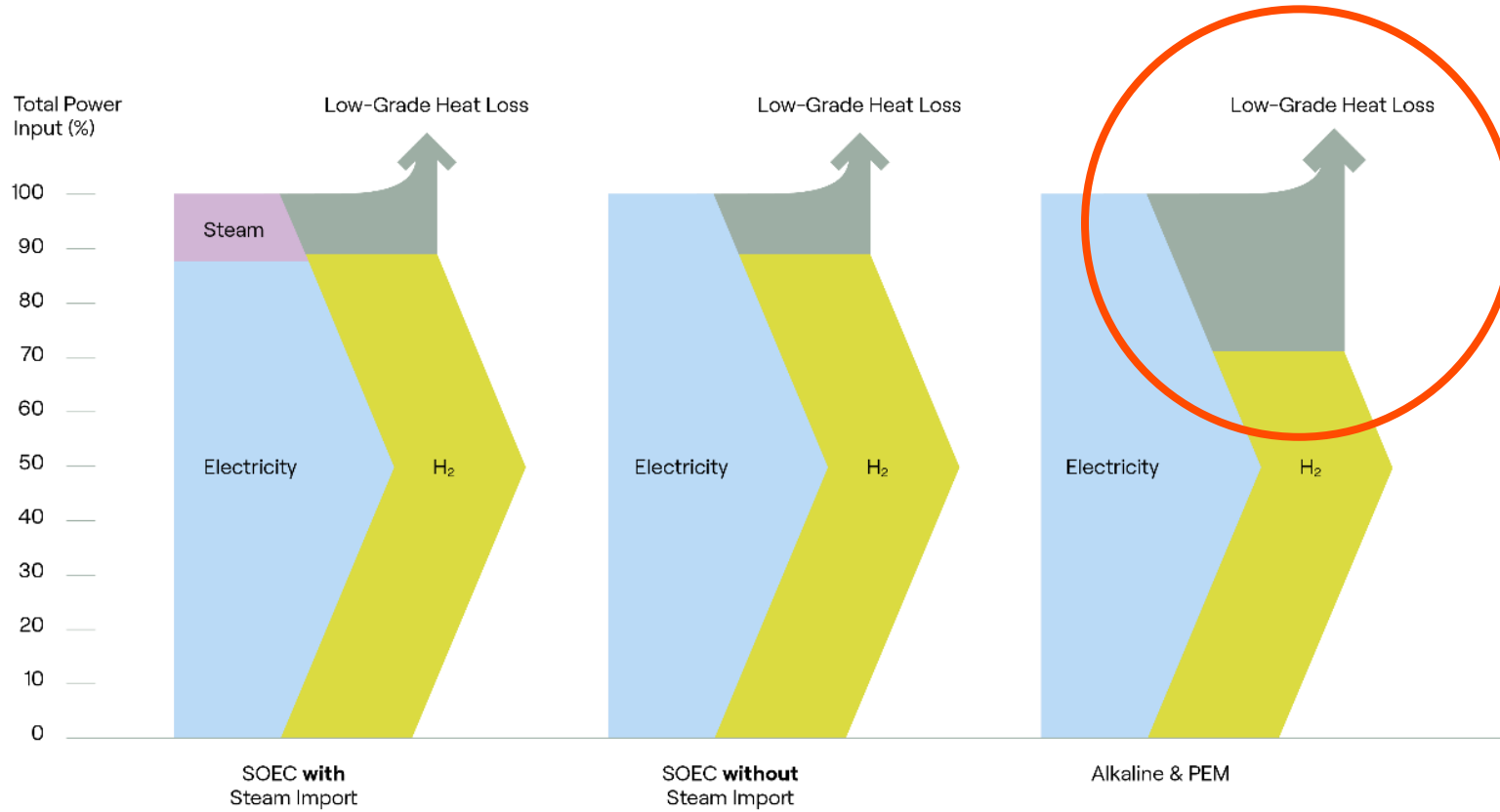
# WHY AM I HERE TODAY?

PROVIDE PROGRESS UPDATES ON TWO WORLD FIRSTS



# WHY SOEC

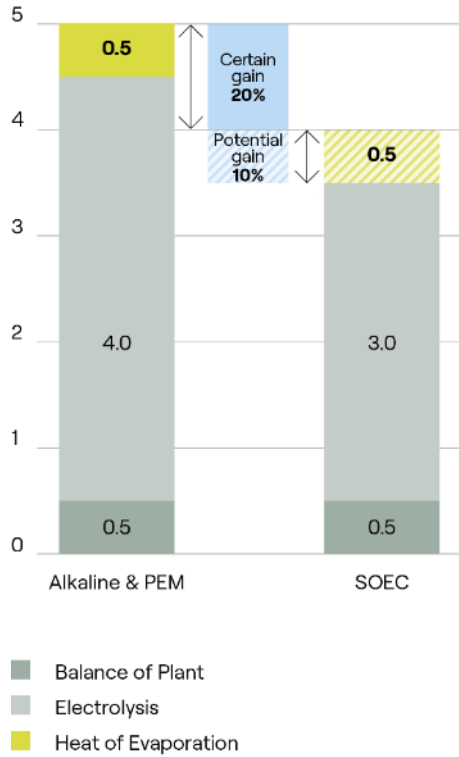
## ENERGY FLOWS AND EFFICIENCIES OF ELECTROLYSIS TECHNOLOGIES



# THE CHEMISTRY BEHIND OUR SOEC ELECTROLYSIS PROCESS

## SOEC'S ADVANTAGE OVER ALKALINE AND PEM TECHNOLOGIES

Efficiency in kWh/Nm<sup>3</sup> of Product Hydrogen

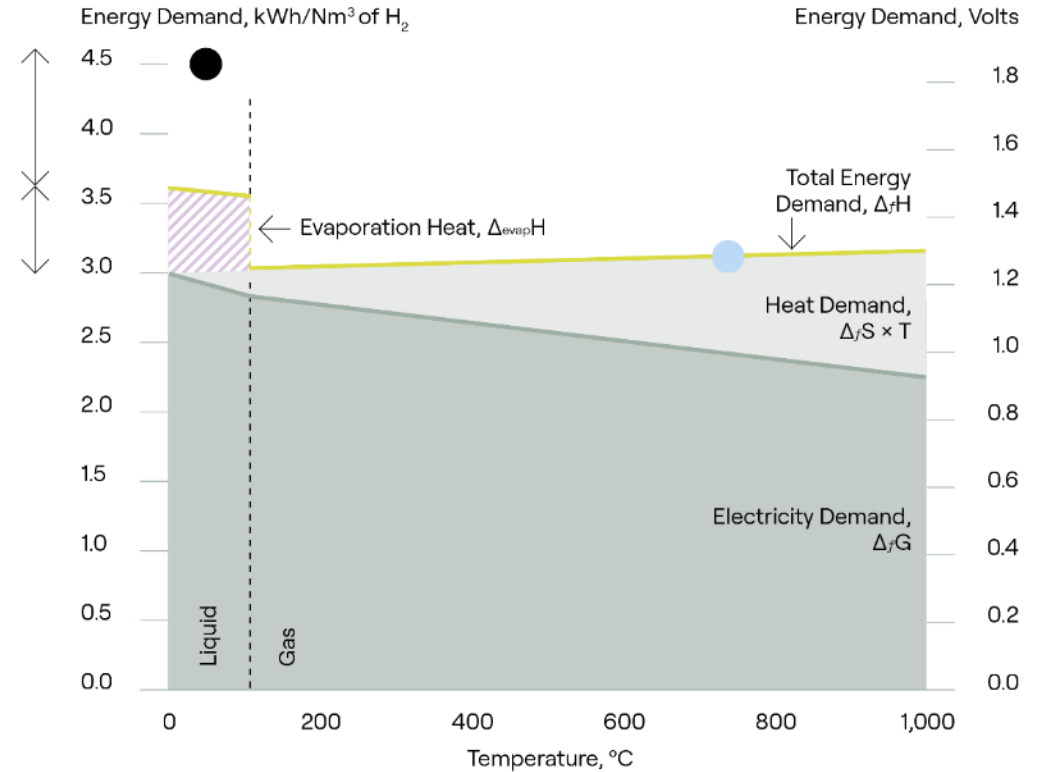


## ENERGY DEMAND FOR WATER ELECTROLYSIS

Certain gain from SOEC compared to alkaline and PEM operation at better kinetics and conductivity

Potential gain if steam is imported

- Total Energy Demand,  $\Delta_f H$
- Alkaline & PEM
- SOEC
- Evaporation Heat,  $\Delta_{\text{evap}} H$
- Heat Demand,  $\Delta_f S \times T$
- Electricity Demand,  $\Delta_f G$



# FROM CONCEPT TO NEXT GENERATION

## HOW WE GOT HERE AND WHAT COMES NEXT



### Section Section

Each section contains two transformers, eight SOEC cores and a common piping module

### SOEC Core(s)

Eight SOEC cores on one SOEC section

### Pipe rack module

Serving two or more SOEC sections

### Common Cabinet

PSU cabinet (rectifiers) and Electrical cabinet containing core LV panel

### Piping module

Common piping module connecting all 8 SOEC cores

### Transformer

One transformer serves 4 SOEC cores

→ 1989

### Solid Oxide Fuel Cell (SOFC) developed

SOFC cell and stack can also be used as SOEC

Electrolysis of both water and CO<sub>2</sub>

→ 2014

### Focus Shifts to SOEC

Demonstration and industrial SOEC units since 2015

Continuous optimization & innovation

Market leading efficiencies

→ 2024

### EU's biggest SOEC manufacturing facility

Initial 500 MW annual production capacity

Expansion to 1,2GW Annually by 2031

Potential extension to 5 GW capacity

# SOEC CORE DEMO – FREDERIKSSUND

## 12 TSP-2 STACKS

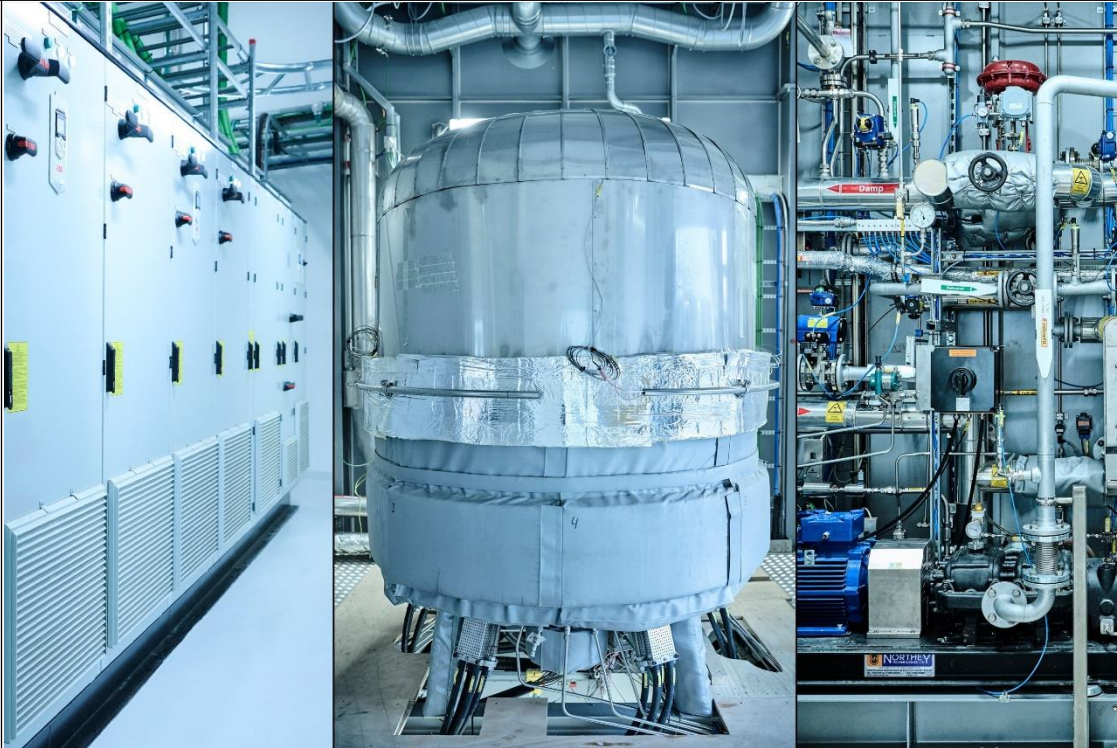
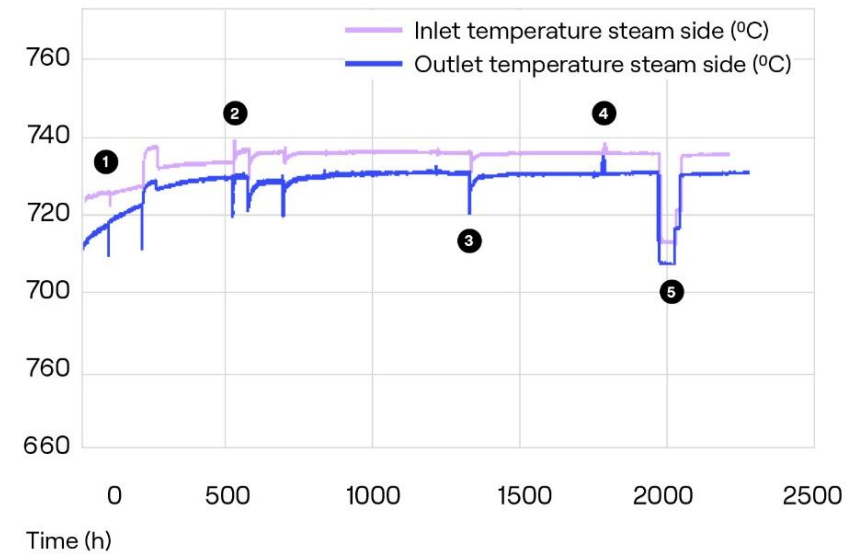


Image above: Topsoe SOEC Demo Core

Successful demonstration of complete hydrogen plant, Frederikssund, Denmark 2023.

## TEMPERATURE

Temperature (°C)



# TOPSOE SOEC STACK MANUFACTURING FACILITY

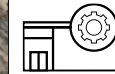
## HALDOR TOPSOE'S VEJ 2, 7400 HERNING, DENMARK



Topsoe awarded EUR 94 million for the construction of electrolyzer manufacturing facility in Herning, Denmark.



Initial capacity: 500 MW/year, expanding to 5GW



Production plant size 23,000 m<sup>2</sup>



Total land area 72,000 m<sup>2</sup>



150 employees, on-site, when production begins in 2024.



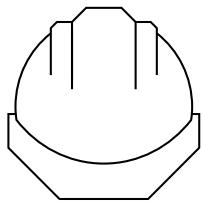
**UPDATE NOVEMBER 2024**  
Green cell production begins.

### About the Innovation Fund

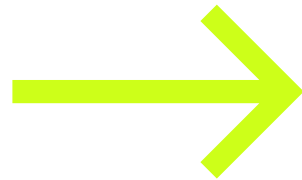
The Innovation Fund is the EU fund for climate policy, with a focus on energy and industry. It aims to bring to the market solutions to decarbonize European industry and support its transition to climate neutrality while fostering its competitiveness. The Innovation Fund is financed through the EU Emissions Trading System (EU ETC).



# WORK IN HERNING BEGAN IN NOVEMBER 2022



**200**  
workers on-site

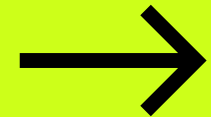


# CONSTRUCTION OF MAIN BUILDING COMPLETED



**December  
2023**

Exterior construction completed and installation begins.



# WORK MOVES INSIDE

## INTERNAL CONSTRUCTION WORK AND INSTALLATION BEGINS



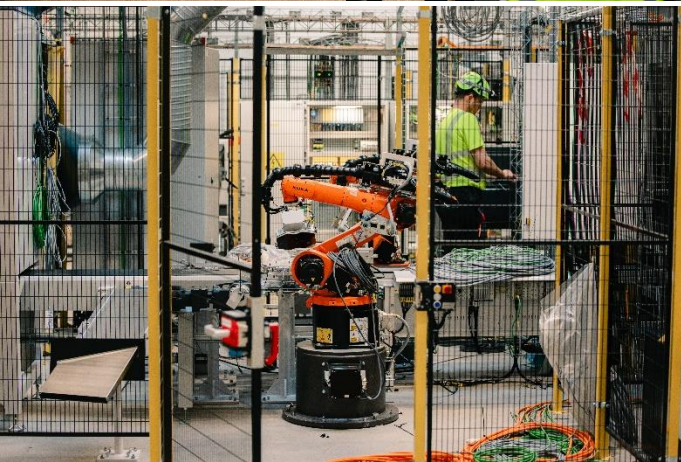
# INSTALLATION ONGOING IN ALL ROOMS

## COMMISSIONING WITH PRODUCT TOOK PLACE IN SEPTEMBER 2024



# FIRST AMMONIA, WORLEY, UNIPER, MAINES GROUP & EIFO VISIT HERNING FACTORY

## PROGRESS UPDATE, START OF GREEN CELL PRODUCTION, SUPPLY & SERVICE AGREEMENT SIGNING



# MODULAR DESIGN



**Location:** Port Victoria, Texas

**Technology:** Complete Topsoe SOEC based electrolyzer Plant, Topsoe Dynamic Ammonia loop.

**Production Capacity:** Phase 1:  
100 MW SOEC and 300 MTPD NH<sub>3</sub>

**Operation begins:** 2026/2027

**Impact:** Elimination of 13m tons CO<sub>2</sub>

# WORLDS FIRST RENEWABLE DYNAMIC DISTRIBUTED AMMONIA PLANT



TOPSOE

*Vestas*

nel

EUDP

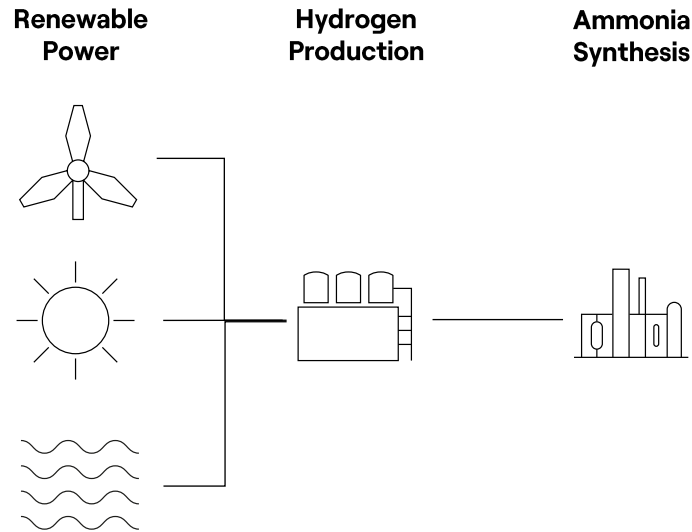


# TRADITIONAL GREEN AMMONIA PRODUCTION FACES A NUMBER OF CHALLENGES GIVEN THE CHALLENGES POSED BY WIND AND SOLAR

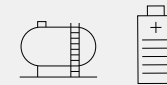
As a fuel alone, green ammonia will play a leading role in the decarbonization of the maritime industry.



## Traditional Green Ammonia Production



Battery or hydrogen storage used as buffer against energy supply fluctuations.



When the energy source is wind or solar, supply will often fluctuate.

This impacts hydrogen production

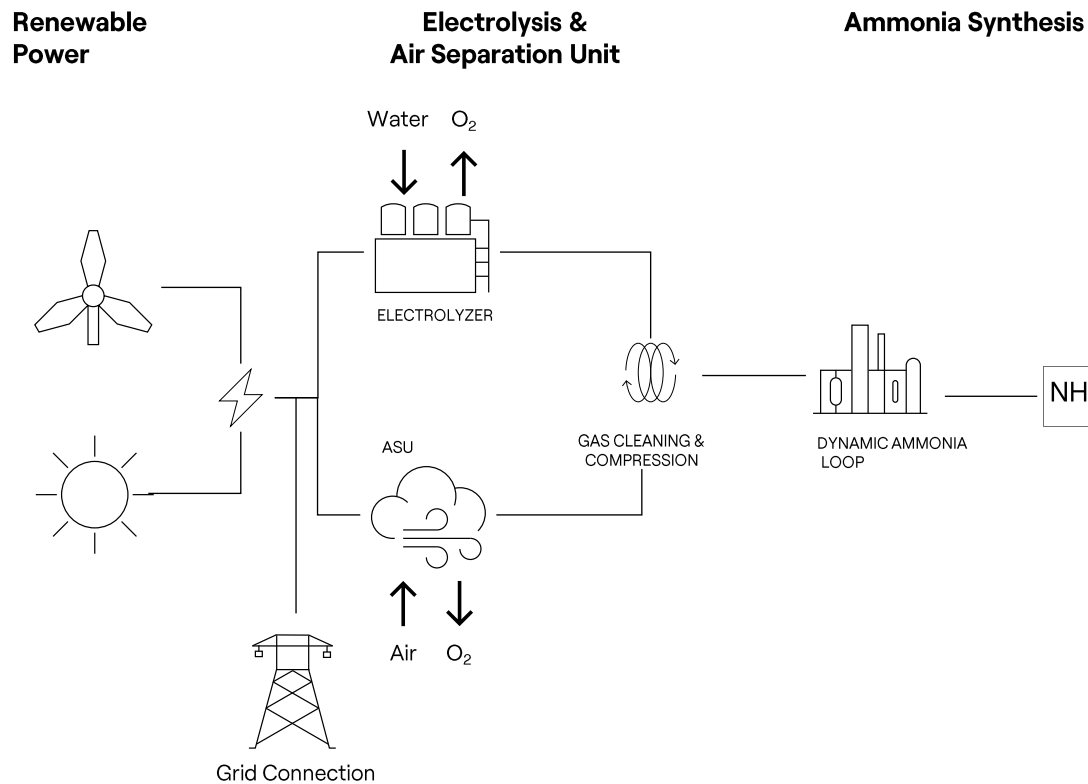
And driving up the cost of the ammonia produced!



# THIS NEW PLANT DESIGN IS A STEP FORWARD

## ADDRESSING THE MAJOR CHALLENGES POSED BY WIND AND SOLAR

### Renewable Dynamic Distributed Ammonia Plant

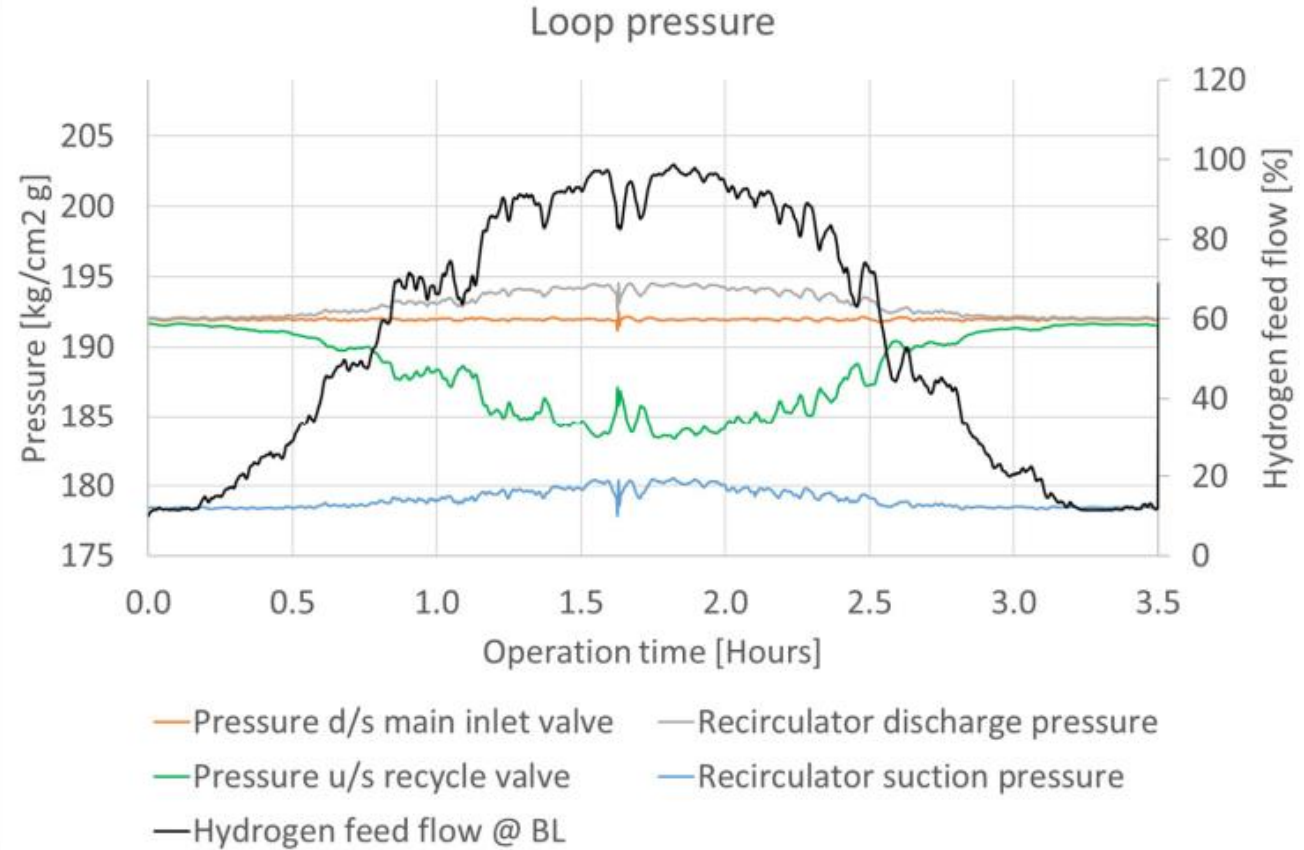
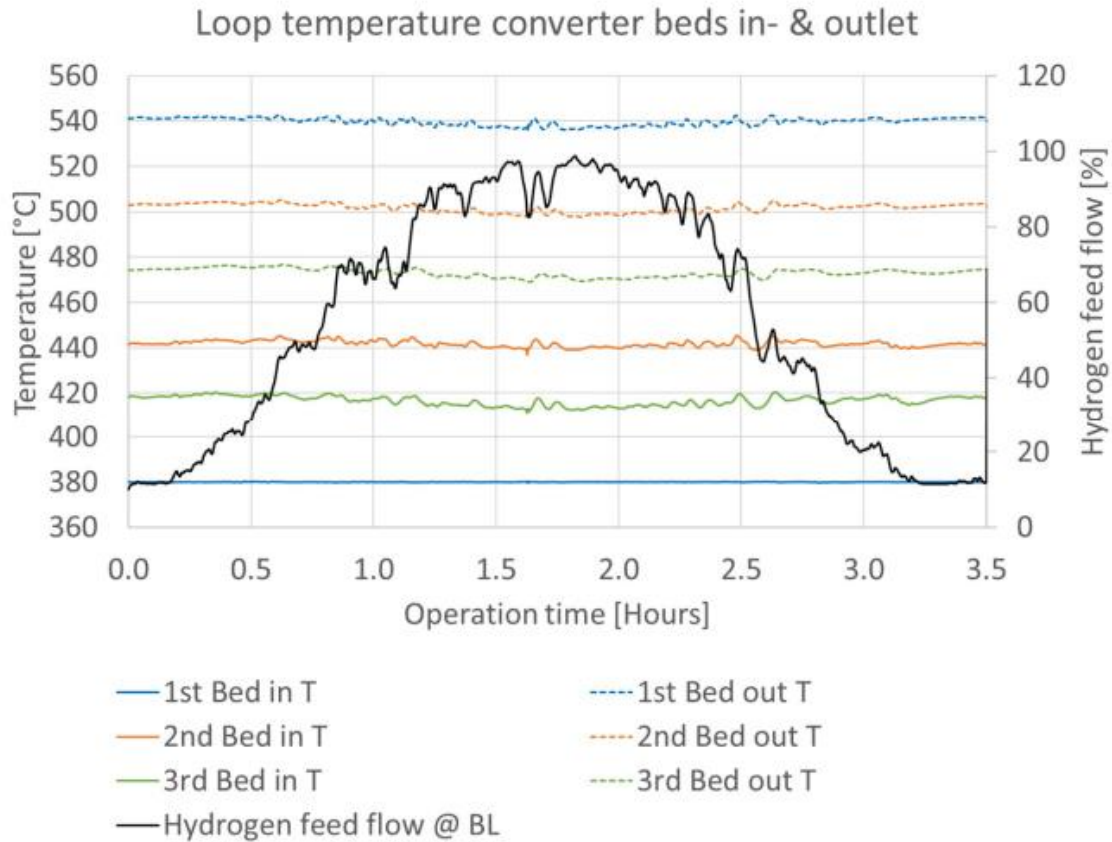


### Key Benefits

- Fully flexible operation 10-100% plant load
- Fast ramping 3 % per minute
- No hydrogen storage
- Store energy as NH<sub>3</sub>/MeOH
- Optional Grid balancing
- Lowers cost of green ammonia production
- Easier to integrate with energy systems

# SOME KEY CHALLENGES IN POWER TO X PROJECTS

## DYNAMIC OPERATION BY TOPSOE



# A WORLD'S FIRST: POWER-TO-AMMONIA

## RENEWABLE DYNAMIC DISTRIBUTED AMMONIA PLANT



### Objective

Demonstrate how renewable energy can effectively power ammonia production, whilst managing the natural fluctuations in renewable power supply to ensure production is costs competitive.

### Project Summary

- The plant is a demonstration project, which have received funding from the Danish Energy Technology Development and Demonstration Program (EUDP)
- Location: Ramme near Lemvig, Northwest Jutland, Denmark
- Output: 5,000 tons of green ammonia annually from renewable power. This production will prevent 8,200 tons of CO<sub>2</sub> from being emitted into the atmosphere every year.
- Power supplied from renewable sources: 50 MW new solar panels and 12 MW existing V80-2.0 MW Vestas wind turbines.
- Skovgaard Energy, Vestas, Topsoe, Nel

# SKOVGAARD REDDAP STATUS

## 24 MTPD GREEN AMMONIA PLANT



### Milestones

Inauguration Aug 2024.

Start-up Q1 2025

Commissioning Q1 2025

Performance data Q2 2025



**“ Not the world  
biggest plant, but  
the worlds biggest  
idea!**

DANSK INDUSTRI

The eFuels market offers enormous potential but demands a partner you can trust.

Topsoe is proven with decades of innovation based on a deep respect for science, rigorous development, and a long history of introducing new technology to market.

**We are the Proven and Prepared Partner for PtX.**

# Let's talk



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