



Efficient PEM electrolyzers

Eddy van Oort

23 June 2022



Magnus Thomassen

Co-founder and CPO
Extensive background from SINTEF

Fredrik Mowill

Co-founder and CEO
Former CEO at OPRA Turbines

Alejandro Barnett

Co-founder and CTO
Extensive background from SINTEF

Hystar founded based on 15 years of R&D

- Founded in September 2020 as a spin-off from SINTEF
- Based on 15 years of research on PEM electrolyzers
- Raised MNOK 120 since 2020
- Key investors:
 - AP Ventures, SINTEF, Firda
- Three co-founders:
 - Fredrik Mowill
 - Magnus Thomassen
 - Alejandro Barnett



AP Ventures
ADVANCE & PIONEER



FIRDA

Highly qualified core team established

We are a diverse team with different backgrounds, but a shared love of technology, a commitment to green energy, and a whole lot of ambition!

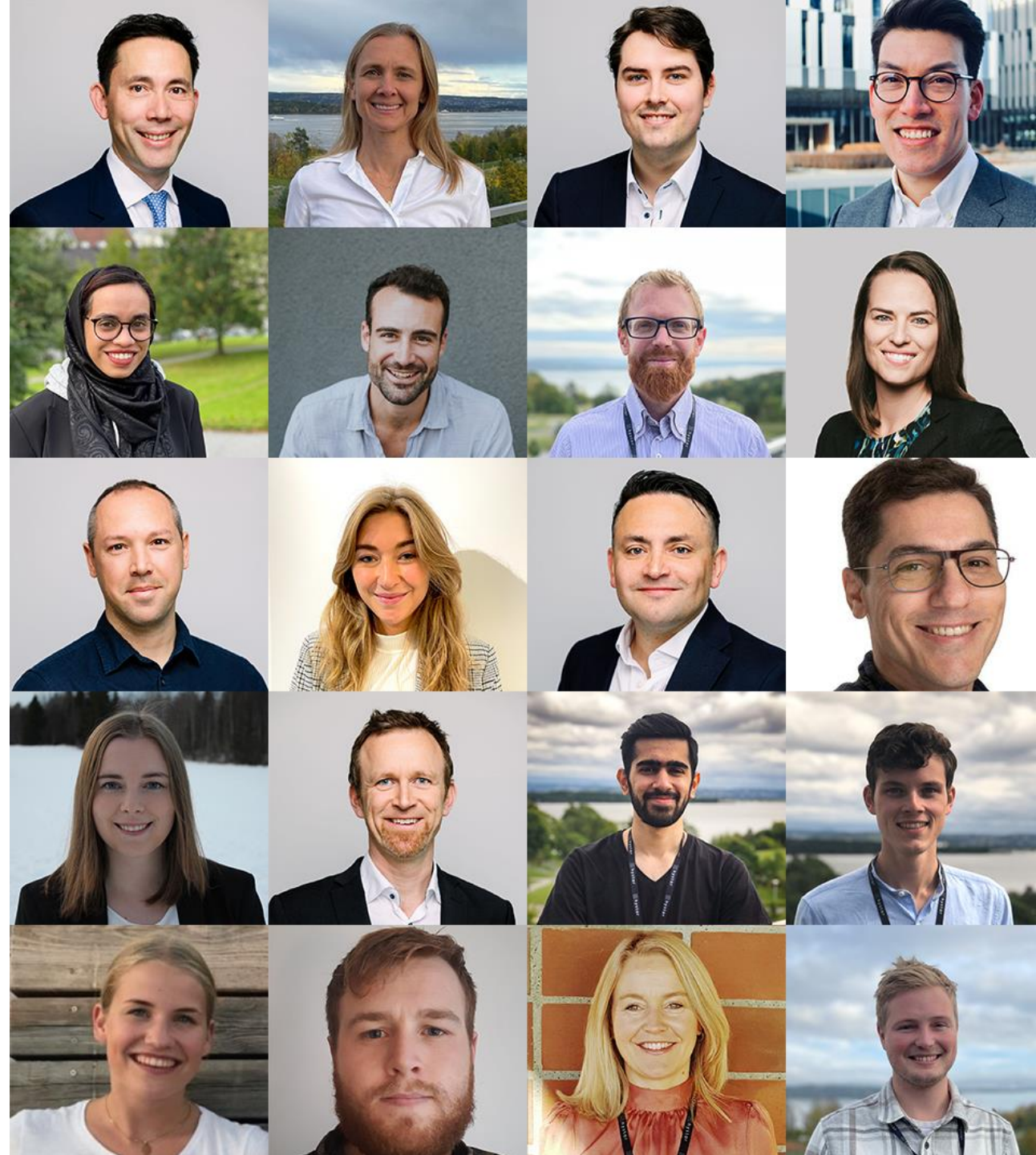
25 employees, representing 17 nationalities

80%

80% engineers (MSc)

35%

35% women



Hystar facilities include HQ, R&D and production

We are headquartered in Høvik, by the beautiful Oslo fjord.

1. HQ and offices
2. R&D/test/pre-production
3. GW-scale automated production facility



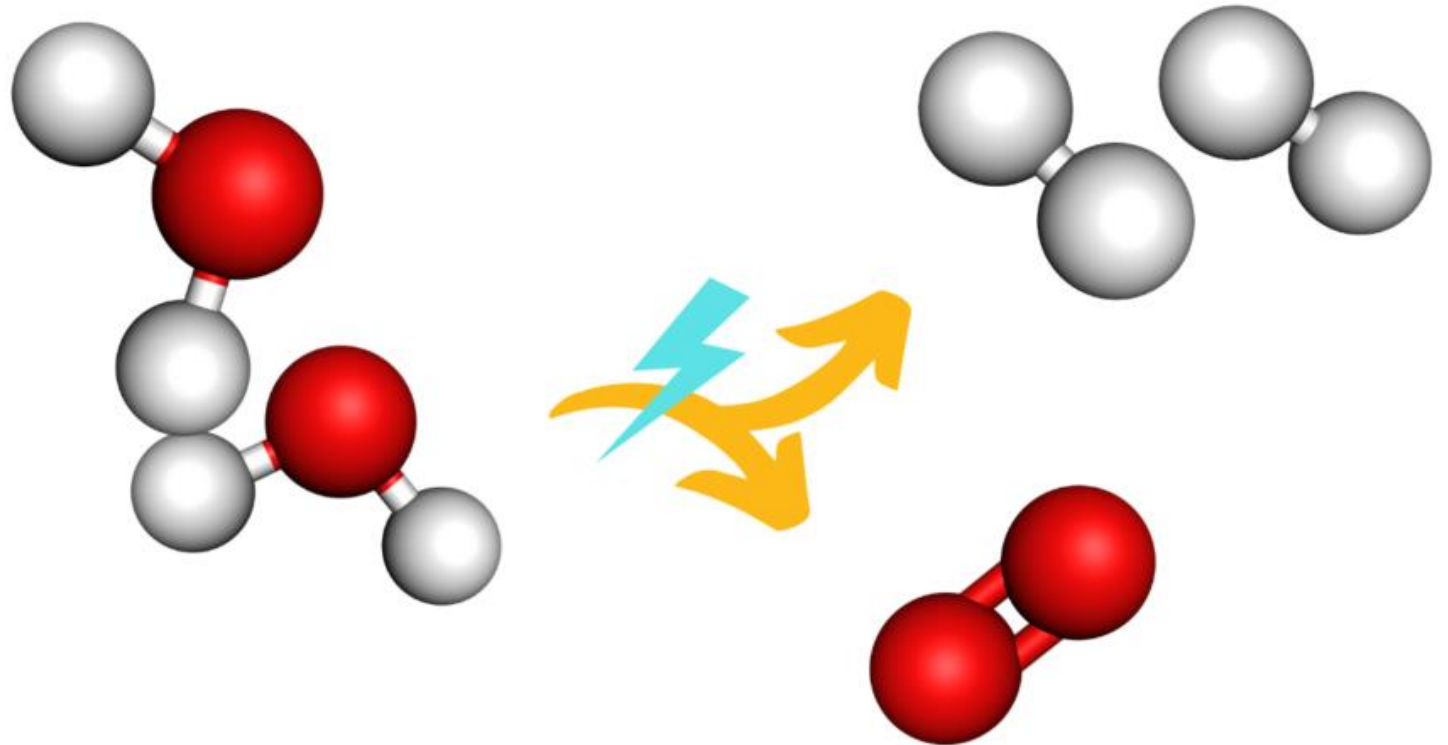
Water Electrolysis

- Splitting of water using electrical energy

- Overall reaction
 $2 \text{H}_2\text{O} \rightarrow 2 \text{H}_2 + \text{O}_2$

Water is split into hydrogen (H_2) and oxygen (O_2)

- 1 kilogram of water is converted into
 - 1.24 Nm³ hydrogen
 - 0.62 Nm³ oxygen

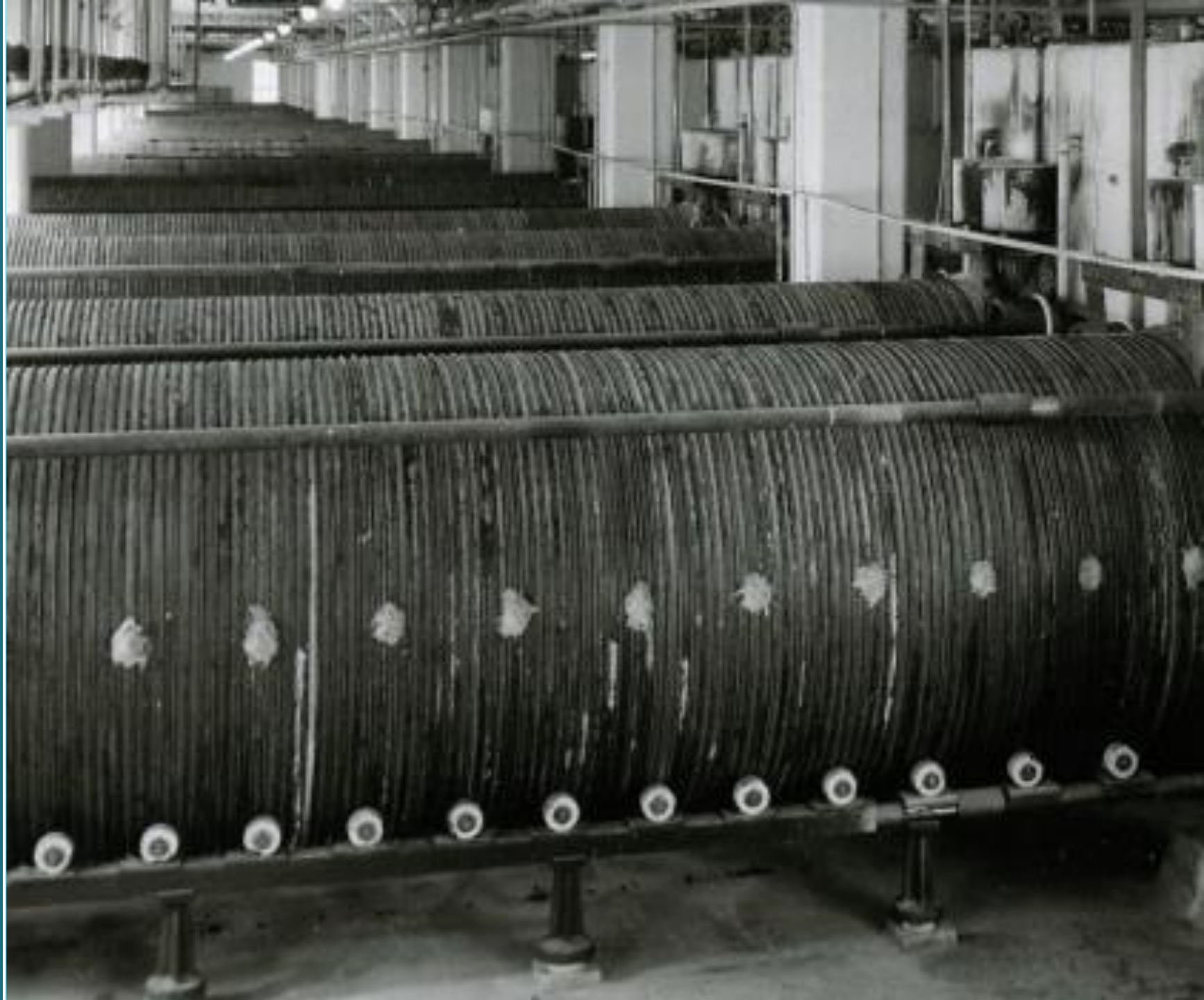


Brief history of water electrolysis

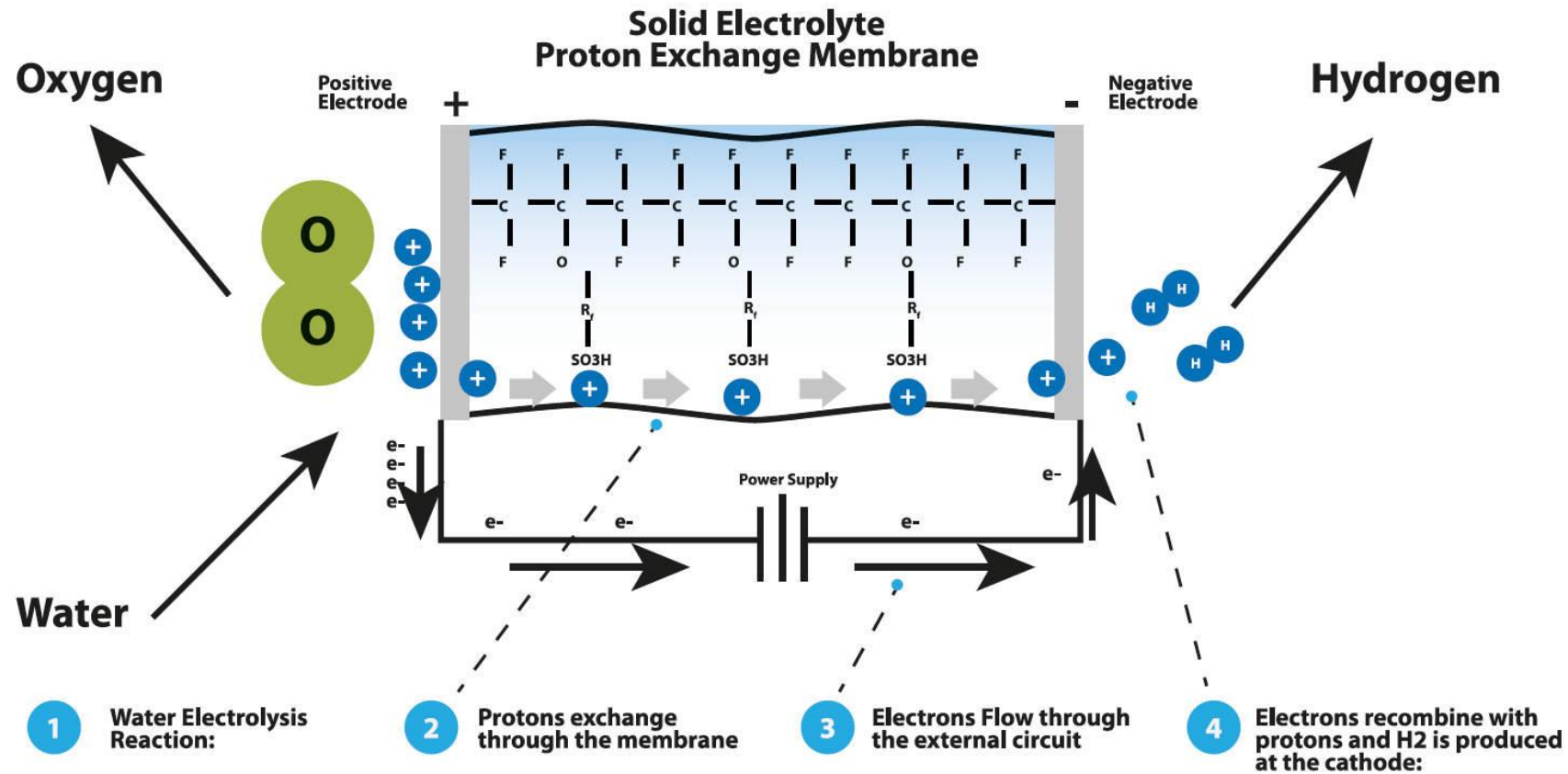
- 1789 – First electrolysis of water (Deiman & Troostwijk)
- 1888 – Industrialization of electrolysis (Lachinov)
- 1910 – Haber-Bosch (Ammonia Synthesis)
- 1929 – Rjukan (167 MW)
- 1938 – 240 km of H₂ pipeline in the Ruhr, Germany
- 1953 – Glomfjord (135 MW)

Current large scale PEM electrolysis projects

- 2020 – Refhyne, Germany (10 MW)
- 2022 – Porsgrunn, Norway (24 MW)
- 2022 – Antwerp, Belgium (100 MW)

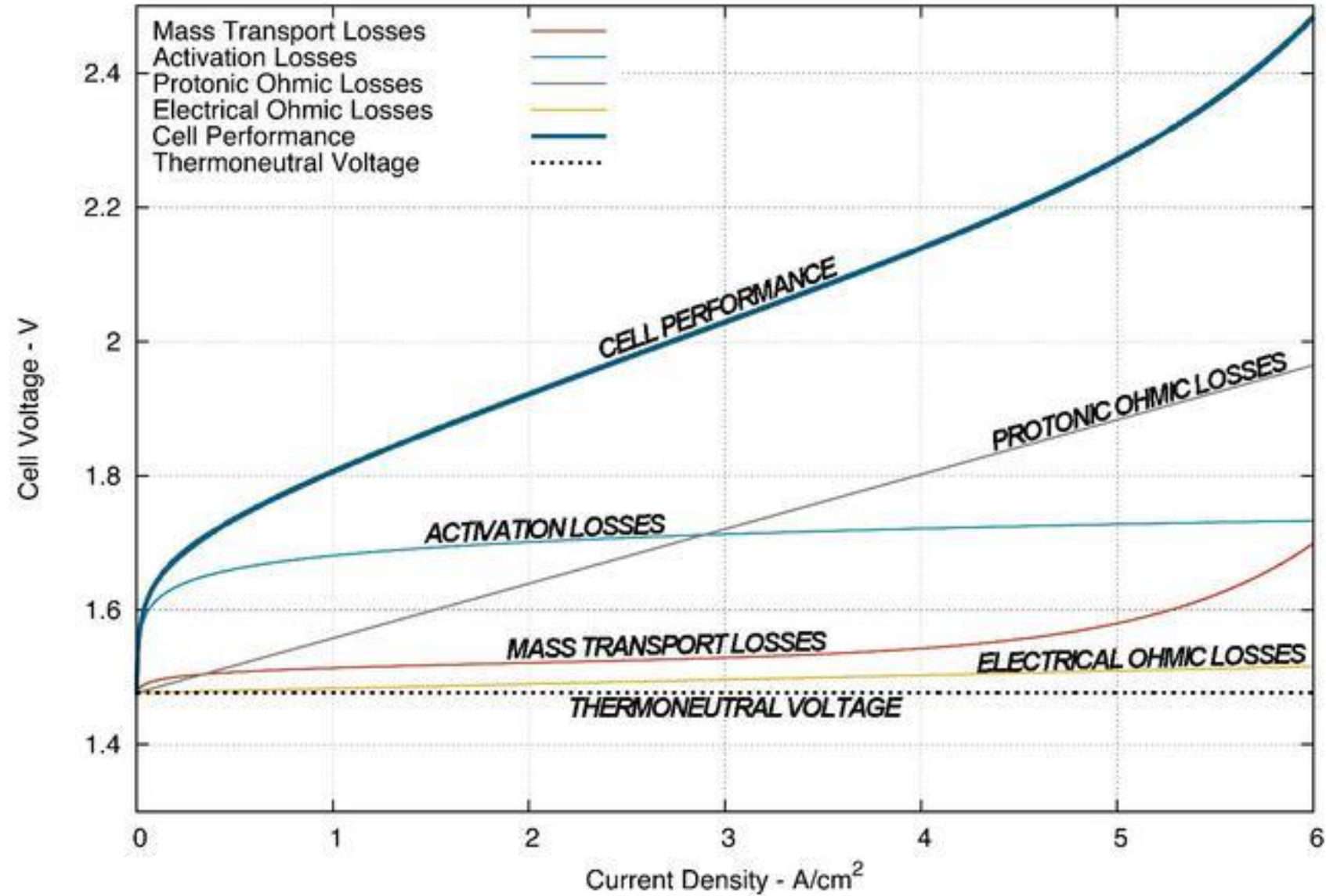


Proton Exchange Membrane Water Electrolysis



Efficiency

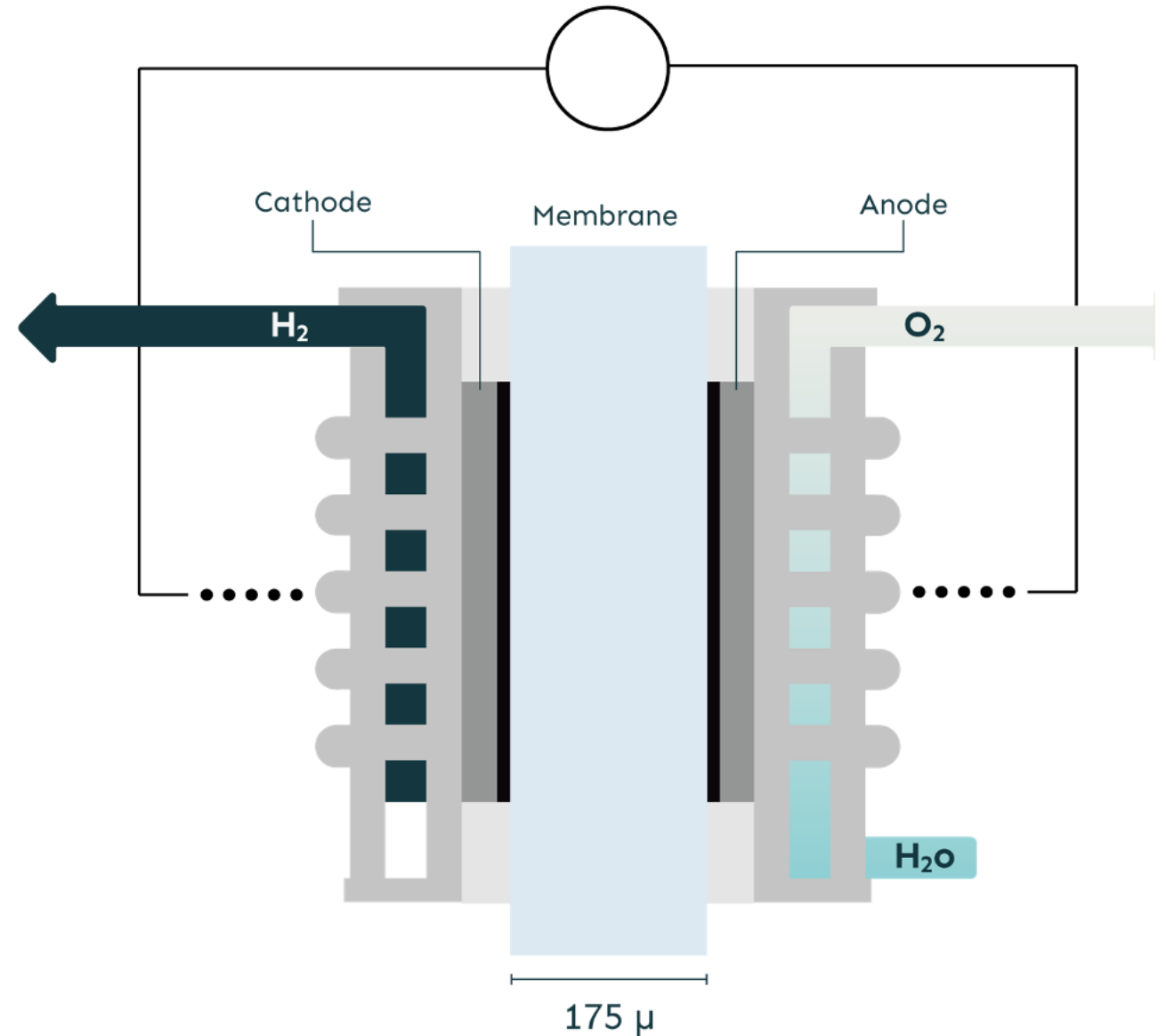
- Efficiency of hydrogen production is defined through reaction voltage.
- Efficiency typically improved by
 - Lower current density
 - Lower operating pressure
 - Higher operating temperature
 - Thinner membrane
 - More active catalyst / lower activation losses
 - Efficient gas bubble removal
- Typical voltage per cell: 1.5- 2.2 V
- Reaction occurs at 1.23V at room temperature



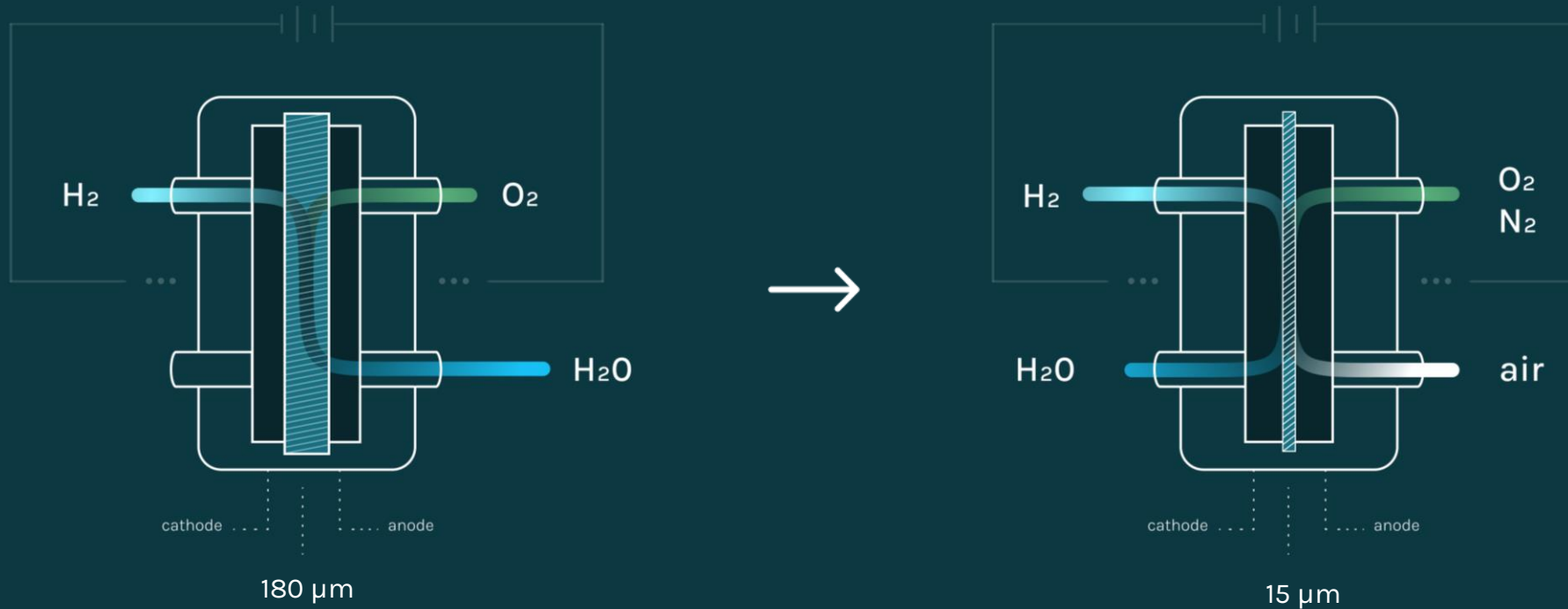
Current PEM technology

- At high current densities, thick membranes may account for up to 35 % of the total losses at stack level (protonic ohmic losses)
- Decreased membrane thickness results in increased H_2 crossover (explosion risk) at differential and elevated cathode pressures
- Recombination catalysts and reinforcement of membrane

State of the art



Hystar's patented solution enables increased efficiency



Conventional PEM electrolyser

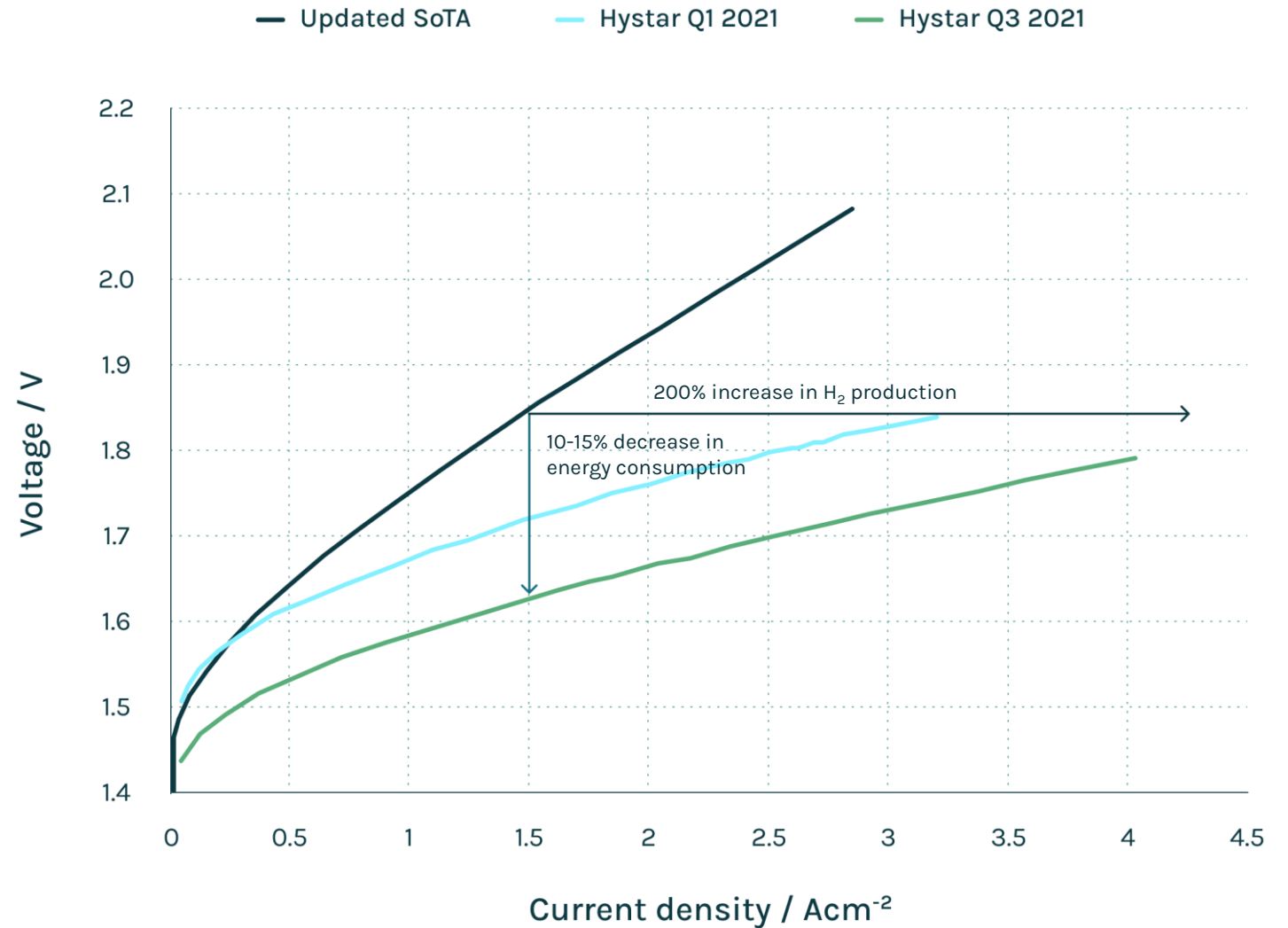
- ✓ Water (H₂O) is split into O₂ and H₂ by adding electricity
- ✓ Thick membranes account for majority of stack losses
- ✓ Thinner membranes will increase explosion risk

Hystar PEM electrolyser

- ✓ Thin membranes provide game-changing efficiency
- ✓ Air circulation on anode side improves safety
- ✓ Water feed on cathode side for optimized flow distribution

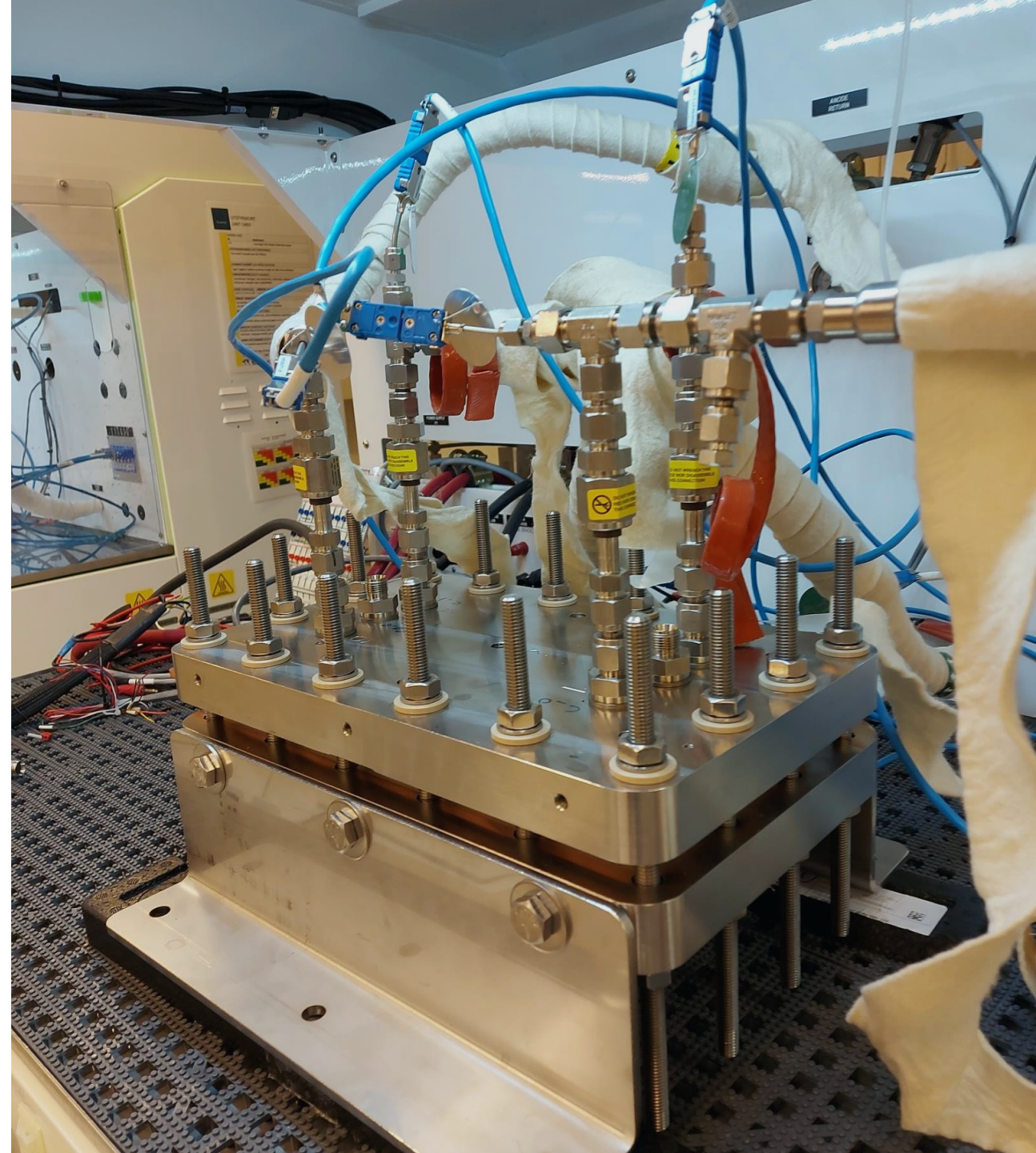
2022 | Latest tests show further improvement vs state of the art technology

- Improved efficiency enabling high Acm^{-2} operation
- Lower OPEX and/or lower CAPEX electrolyzers
- Continuous improvement through component testing



Q1 2022 | Test of new stack design verifies superior performance

- ✓ Class leading efficiency
- ✓ Key components qualified
- ✓ Production version in final design stage



Product comparison

Vega

- Class leading efficiency with >10% decrease in energy consumption

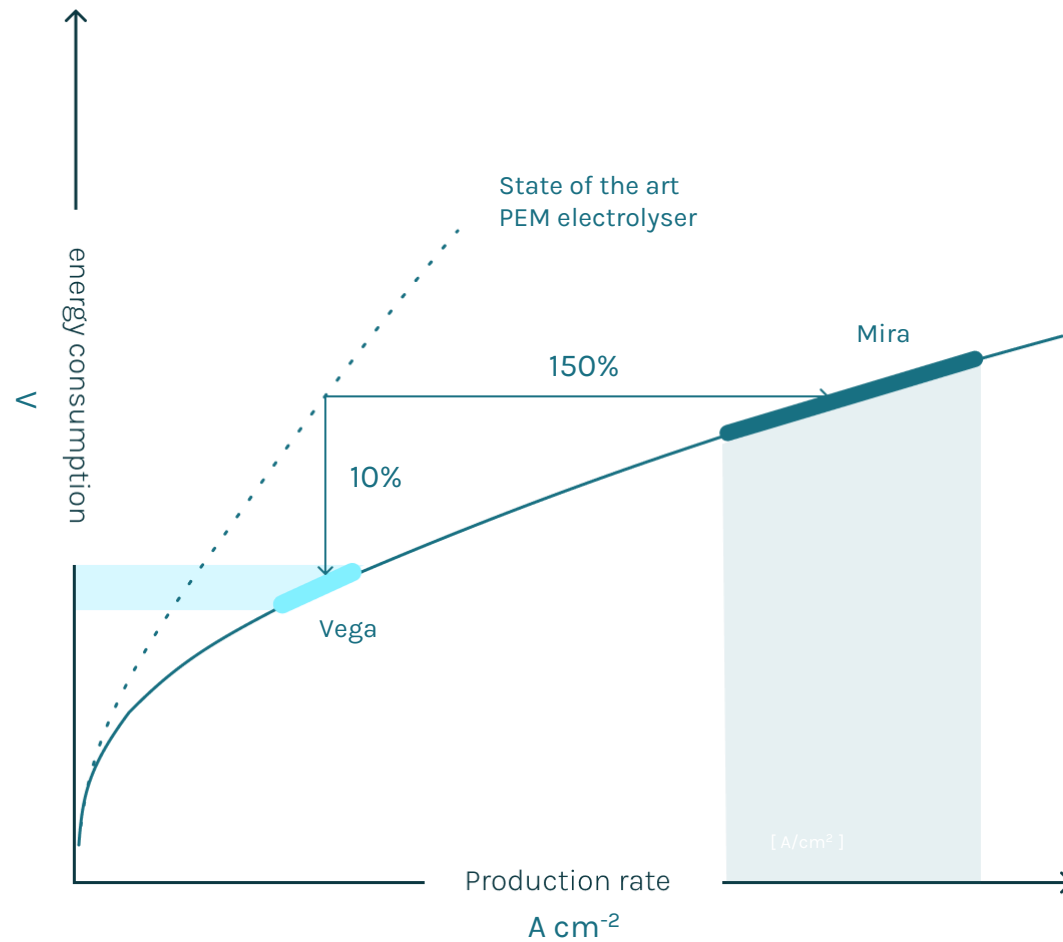
Mira

- High output - >150% increase in production rates

Orion

- Orion can use both Vega and Mira modules to optimise performance

Polarization curves



Product comparison

Vega

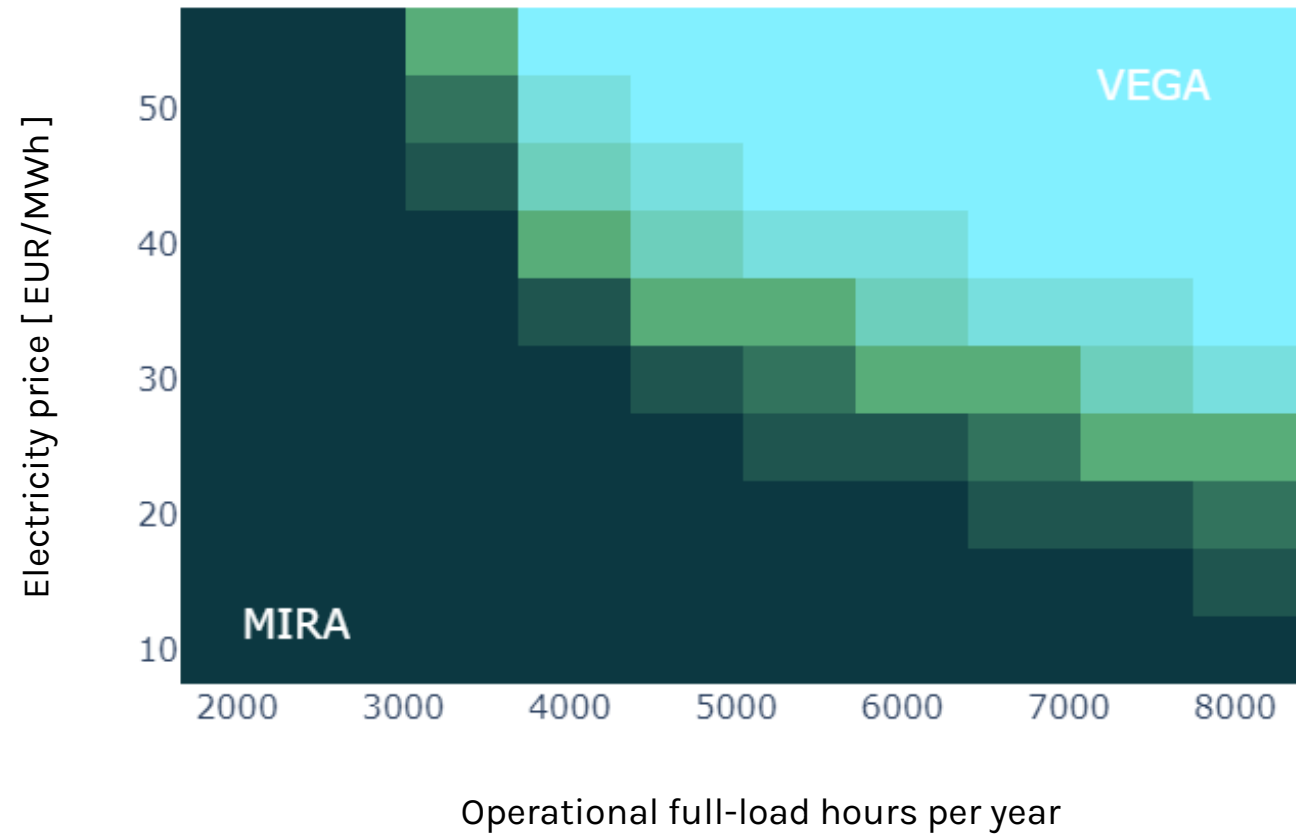
- Class leading efficiency with >10% decrease in energy consumption

Mira

- High output - >150% increase in production rates

Orion

- Orion can use both Vega and Mira modules to optimise performance



Executive summary

- Patented solution provides superior efficiency
- Available, high volume manufacturing processes
- Full-scale stack production capacity in 2025
- Multi-GW electrolyser equipment market
- Contract awarded for 1 MW pilot project in 2023



What we do

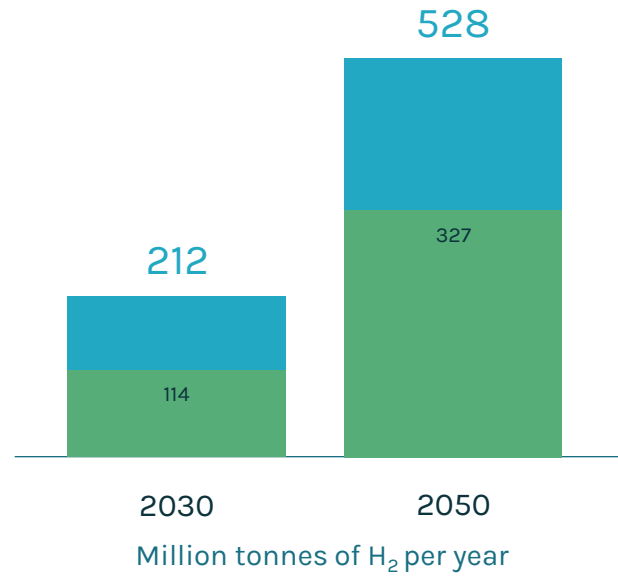
Hystar specialises in ultra-efficient PEM electrolyzers for production of green hydrogen from water electrolysis.



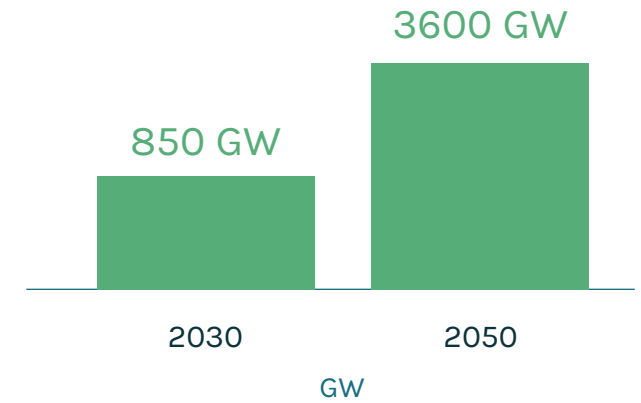
Expected rapid growth in demand for green H₂

- 3600 GW electrolyser capacity required in 2050 (IEA, Net Zero by 2050)

Global demand for H₂

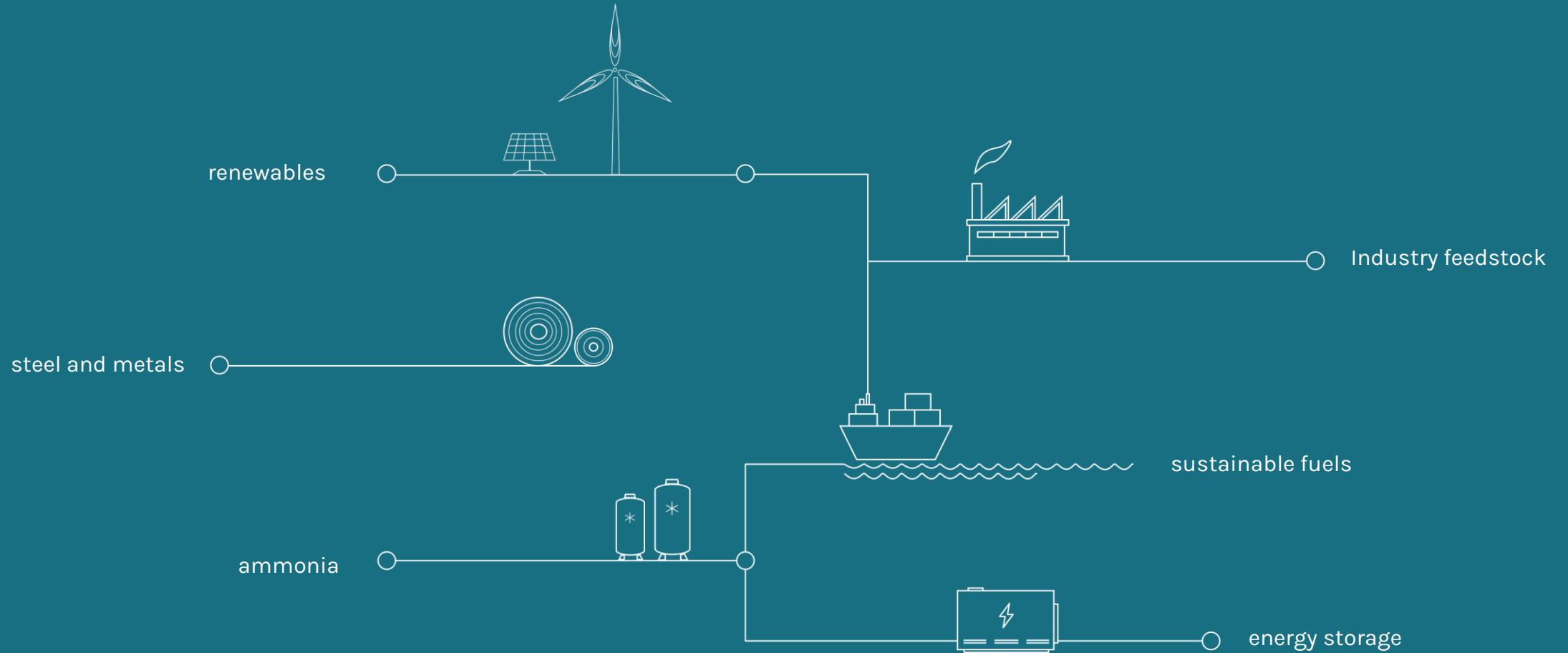


Required electrolyser capacity

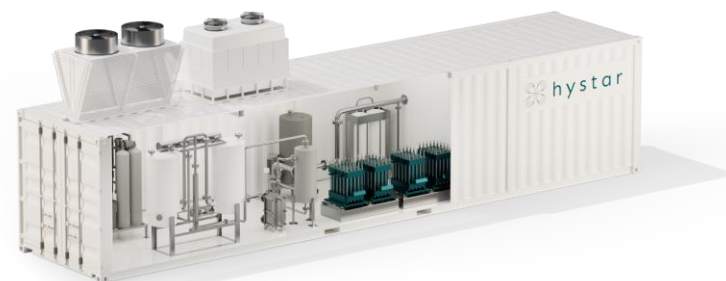
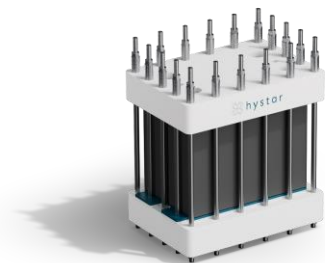


● Green hydrogen ● All hydrogen

Hystar will target large-scale applications



Initial products will be container based with large scale systems available from 2025



2021

Full scale stack development

2022

Full scale stack build

2023

1 MW electrolyser field demo

2024

5MW Small scale installations


2025


Large scale projects
100+ MW

Contract awarded for pilot project in 2022

- Funding from Enova
- 2 industrial customer partners
- Commissioning in 2023
- 1 MW installation at Kårstø Gas Processing Plant



 hystar

equinor 

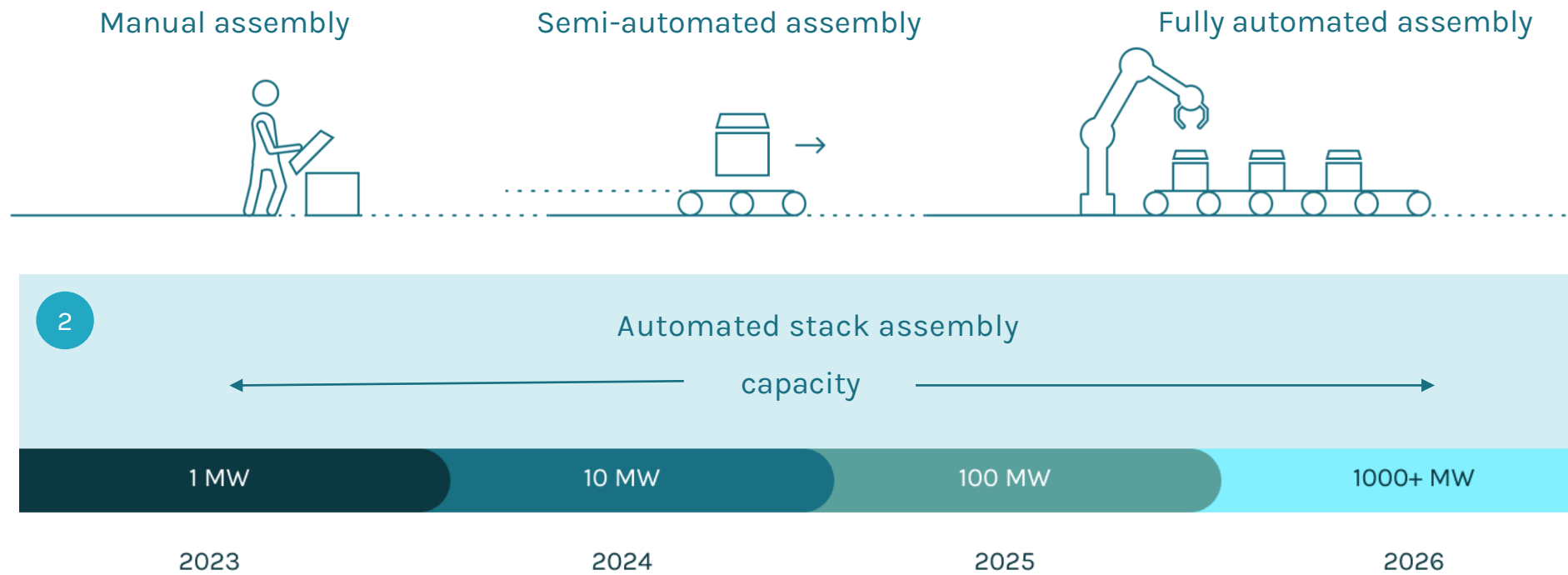
 GASSCO

Orion - large scale solutions 100 MW+ installations

- Modules are clustered together to share BoP components
- Several clusters form a bigger plant



Stack assembly capacity will ramp up to 1000 MW in 2026



In summary...

- Patented solution provides superior efficiency
- Available, high volume manufacturing processes
- Full-scale stack production capacity in 2025
- Multi-GW electrolyser equipment market
- Contract awarded for 1 MW pilot project in 2023



technology for a greener future