



Electrolyzer technology insight: Elektrolyse- technologien aus der Sicht eines weltweiten Herstellers?



06 September 2022, Christoph Zahn
Sales Manager - Electrolyzers

CUMMINS



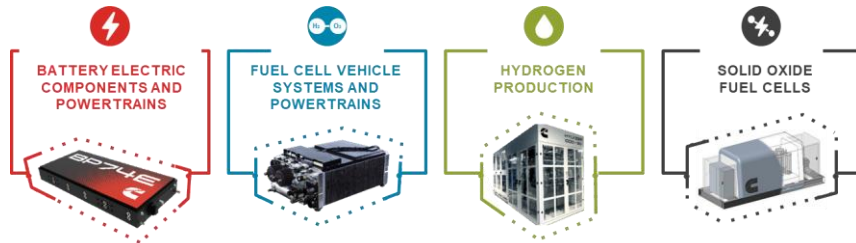
Engines



Power generators

Components

Distribution



New Power

190
Countries



59.9K
Global Employees



1.3M+
Engines built



10.6K
Distributor & dealer locations



\$1.1B
Invested in research & development



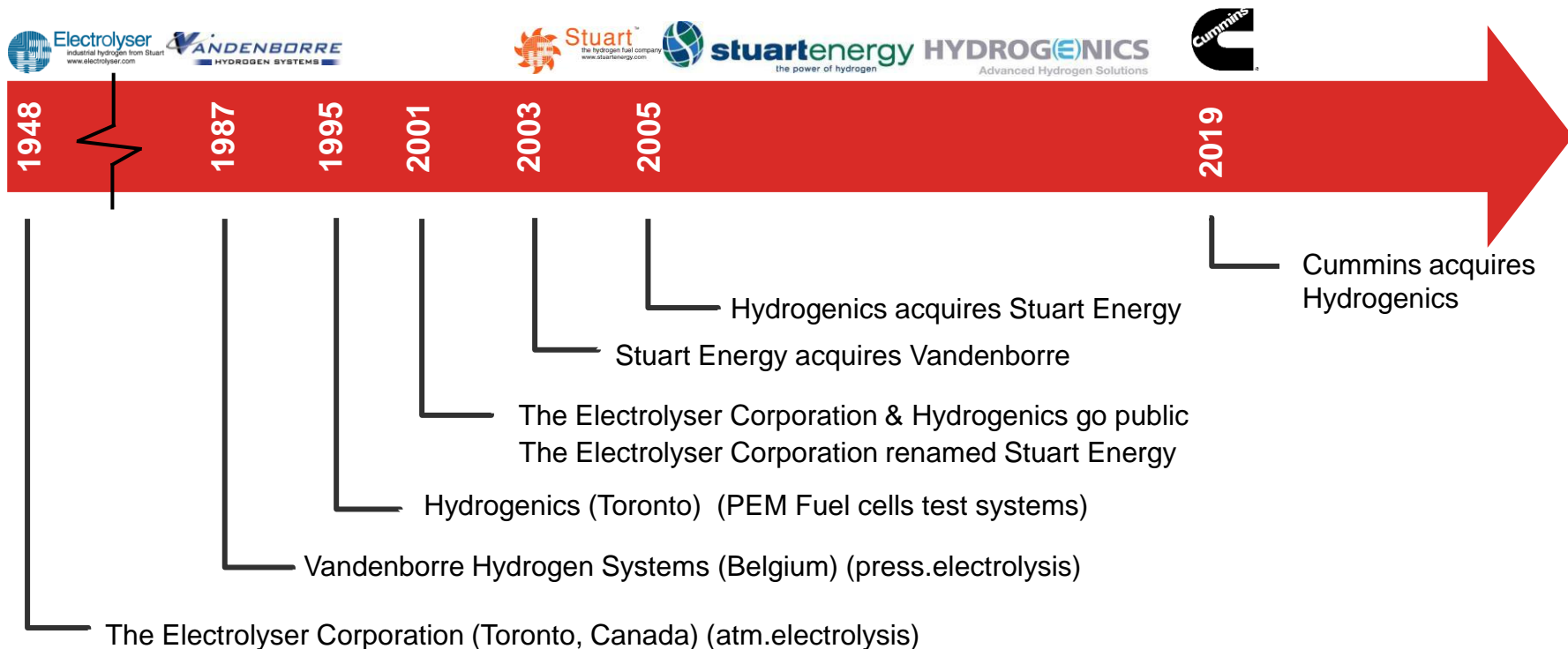
103 YEARS
of industry leadership



*2021 figures

WATER ELECTROLYSIS

HYDROGENICS HISTORY



WATER ELECTROLYSER TECHNOLOGIES AT CUMMINS

1

Alkaline electrolysis

- 30wt% KOH – porous membranes
- Been around for >70 yrs
- Reliable proven technology



Work horse

2

Proton exchange membrane

- 'Polymer electrolyte membrane'
- Compact / high currents
- Wide working range (low-high power)



Race stallion

Commercial

3

Solid oxide electrolysis

- Solid ZrO_2 steam electrolysis
- High temperature – high efficiency
- Less flexible



Cross country horse

R&D

4

Anion exchange membrane

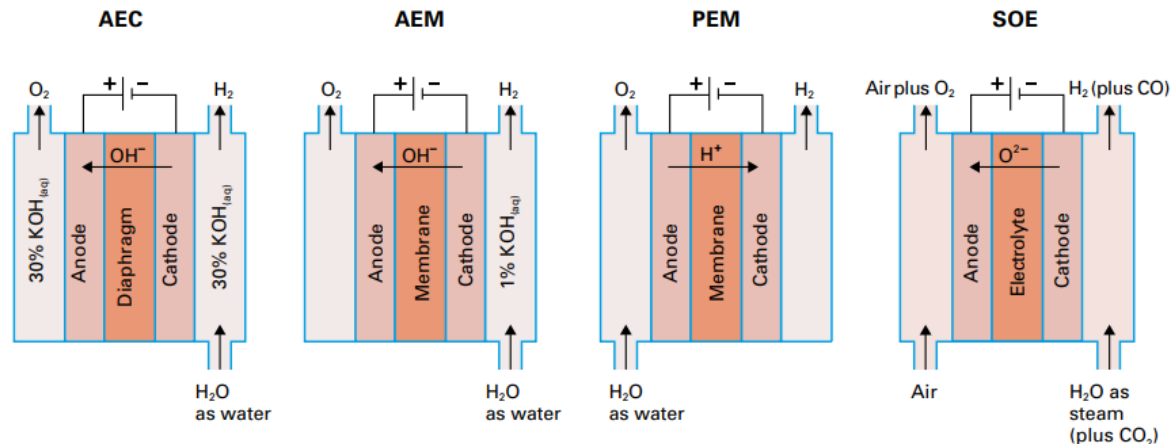
- Alkaline polymer electrolyte
- Little commercialisation



New colt

Notes:

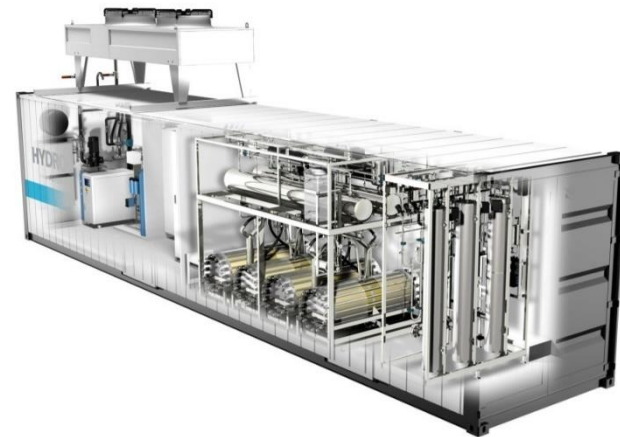
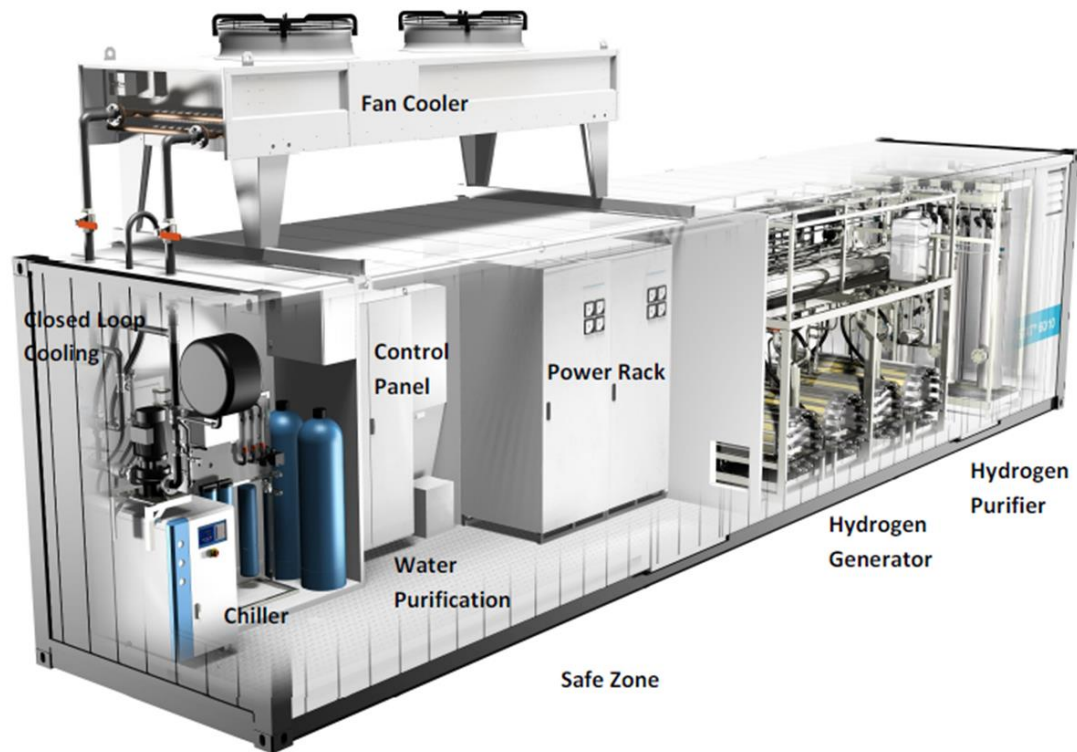
- In the AEC, AEM and PEM, lye or water flow from the electrolyser cell with the oxygen and/or hydrogen gases. These liquids are mixed and recirculated to the electrolyser.
- Air is used to purge the SOE anode to avoid oxygen accumulation which may present a hazard at the high operating temperature.
- Bipolar plates made of stainless steel (titanium for PEM) are used to stack adjacent cells in each electrolyser type.



	Alkaline Electrolysis Cell AEC	Anion Exchange Membrane / Alkaline Electrolyte Membrane AEM	Polymer Electrolyte Membrane/ Proton Exchange Membrane PEM/PEMEC	Solid Oxide Electrolysis Cell SOE/SOEC
Electrode material	– Cathode: Ni, Co or Fe – Anode: Ni	– Cathode: Ni / Ni alloys – Anode: Fe, Ni, Co oxides	– Cathode: Pt/Pd – Anode: IrO ₂ /RuO ₂	– Cathode: Ni – Anode: La/Sr/MnO (LSM) or La/Sr/Co/FeO (LSCF)
Electrolyte	Lye: 25-30% Potassium Hydroxide solution in water	Anion Exchange ionomer (e.g. AS-4)	Fluoropolymer ionomer (eg Nafion, a DuPont brand)	Zirconium Oxide with ~8% Yttrium Oxide
Energy source	100% electrical power	100% electrical power	100% electrical power	~25% heat from steam, ~75% electrical power
Current density	Up to 0.5 A/cm ²	0.2 – 1 A/cm ²	Up to 3 A/cm ²	Up to 0.5 A/cm ²
Hydrogen or syngas product	Hydrogen	Hydrogen	Hydrogen	Hydrogen (or syngas if fed with steam and CO ₂)
Gas outlet pressure	Up to 40 bar	Up to 35 bar H ₂ , 1 bar O ₂	Up to 40 bar	Close to atmospheric
Cell temperature	~80 °C	~60 °C	~60 °C	~750 to 850 °C

1

HYSTAT[®] ALKALINE ELECTROLYSERS : BALANCE OF PLANT



600+ INDUSTRIAL REFERENCES WITH PRESSURIZED ALKALINE ELECTROLYSIS TECHNOLOGY HySTAT®



Saint Gobain, Colombia



Saudi Arabia: Powerplant



Bushan, India



Camao, Brazil



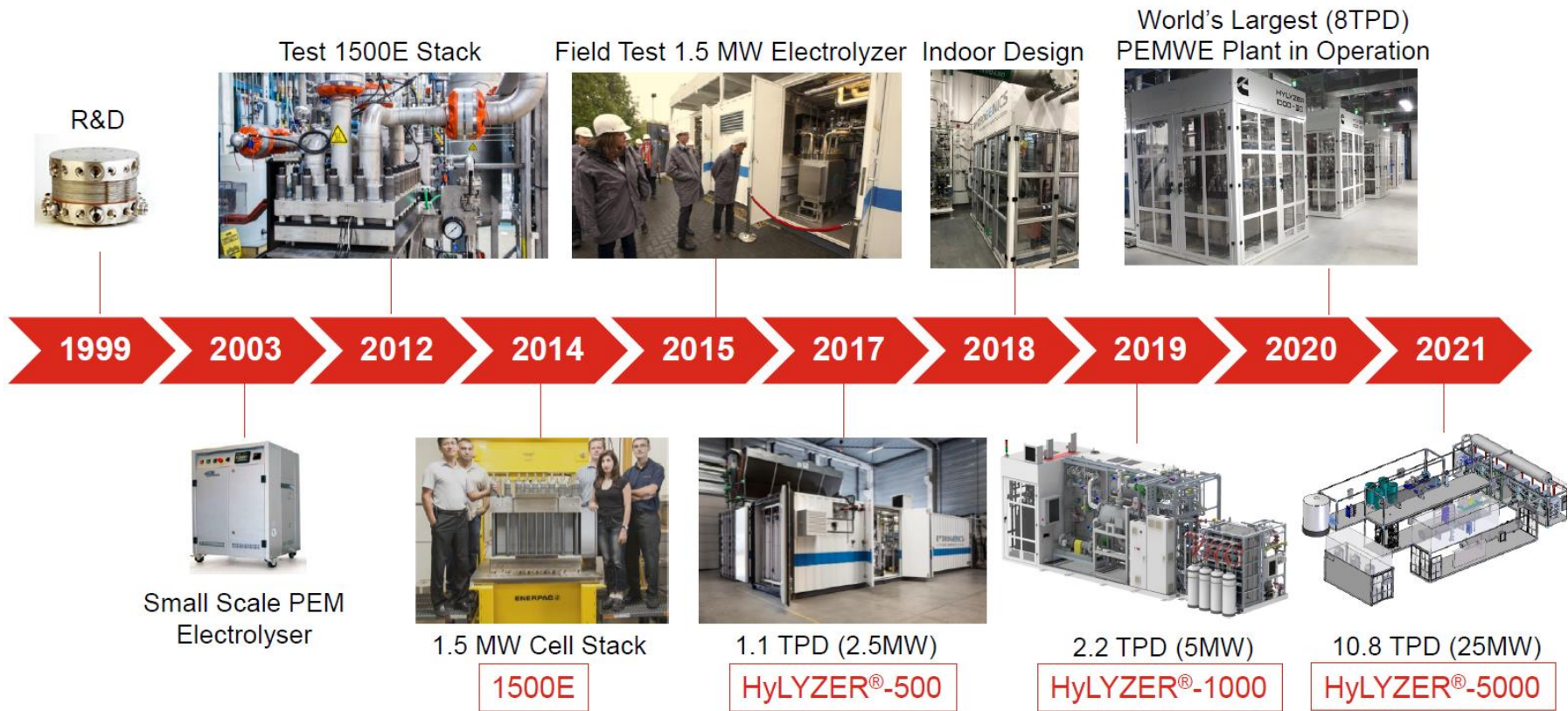
Nyagan, Russia



Kirovgrad, Russia

PEM HyLYZER® WATER ELECTROLYSIS

KEY MILESTONES



SELECTION OF HyLYZER® REFERENCES

Power-to-Gas



Power-to-Power



Power-to-Fuels



Power-to-Mobility

Power-to-Industry

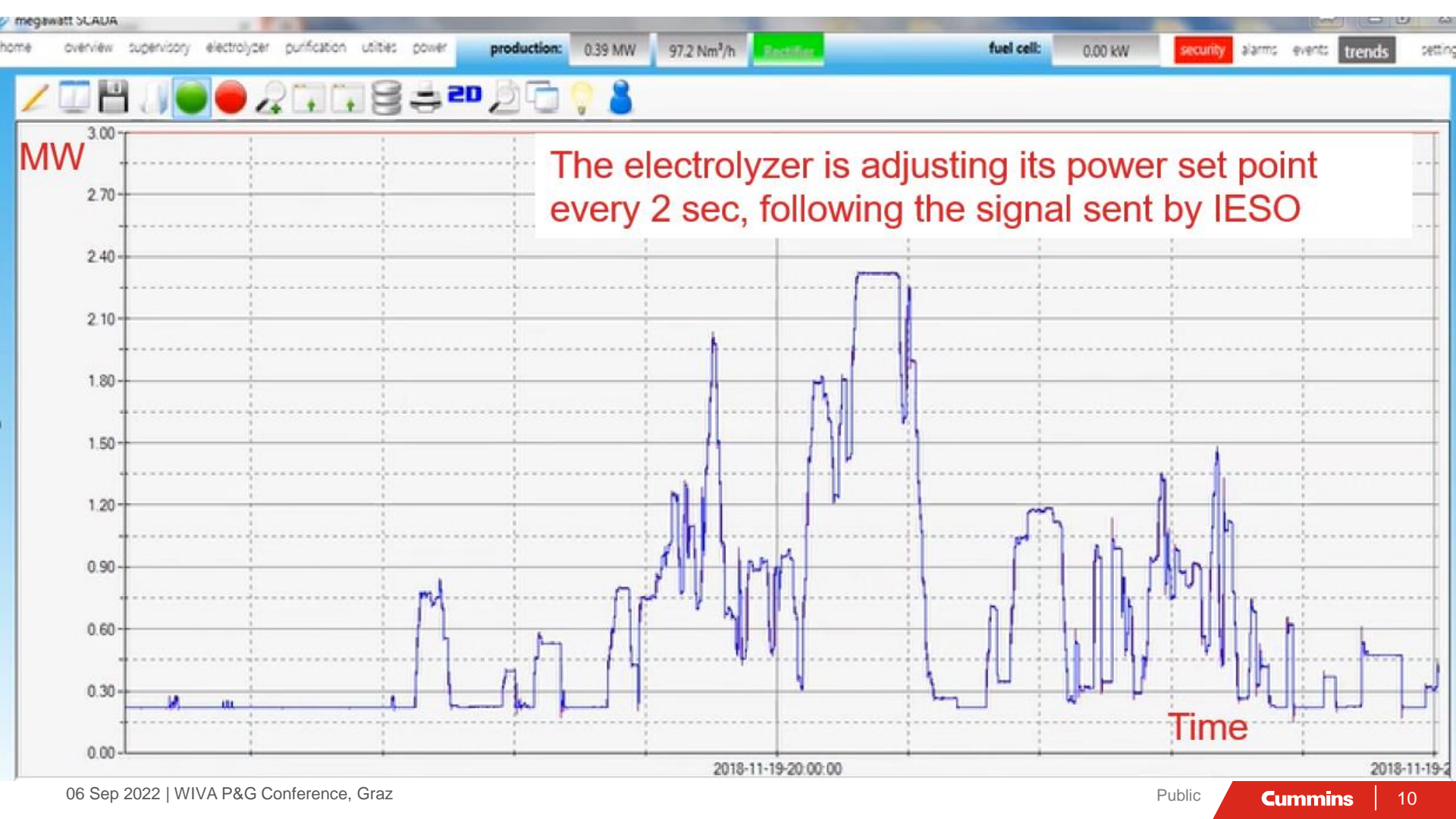


Power-to-Gas



Power-to-Gas





LATEST DEVELOPMENT

2,5 MW PEM CELL STACK

1

MW Scale Electrolyzer Stack

3.0 MW industry benchmark

2

Reduction of Plant Capital Costs

Achieved target system cost

3

Stack Efficiency Improvements

Leading industry performance



4

Fast Response and Dynamic Operation

Key requirement established

5

Very compact

Lowest footprint on the market

6

Reduced Maintenance

Limited and optimized

	1500E cell stack (high)	1500E cell stack (small)
Nominal input power (Max)	2,5 MW (3 MW)	1,25 MW (1,5 MW)
Nominal H2 flow (Max)	500 Nm ³ /h (620 Nm ³ /h)	250 Nm ³ /h (310 Nm ³ /h)
Operating pressure	30 barg	30 barg

WORLD'S LARGEST PEM ELECTROLYZER

20 MW / 4x HyLYZER®-1000

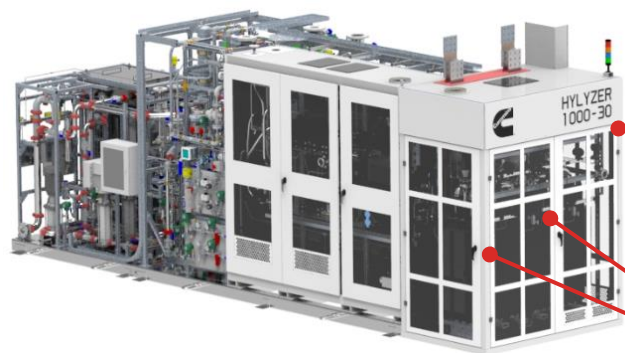


H₂ Plant Scope of Supply

Supplied by Cummins

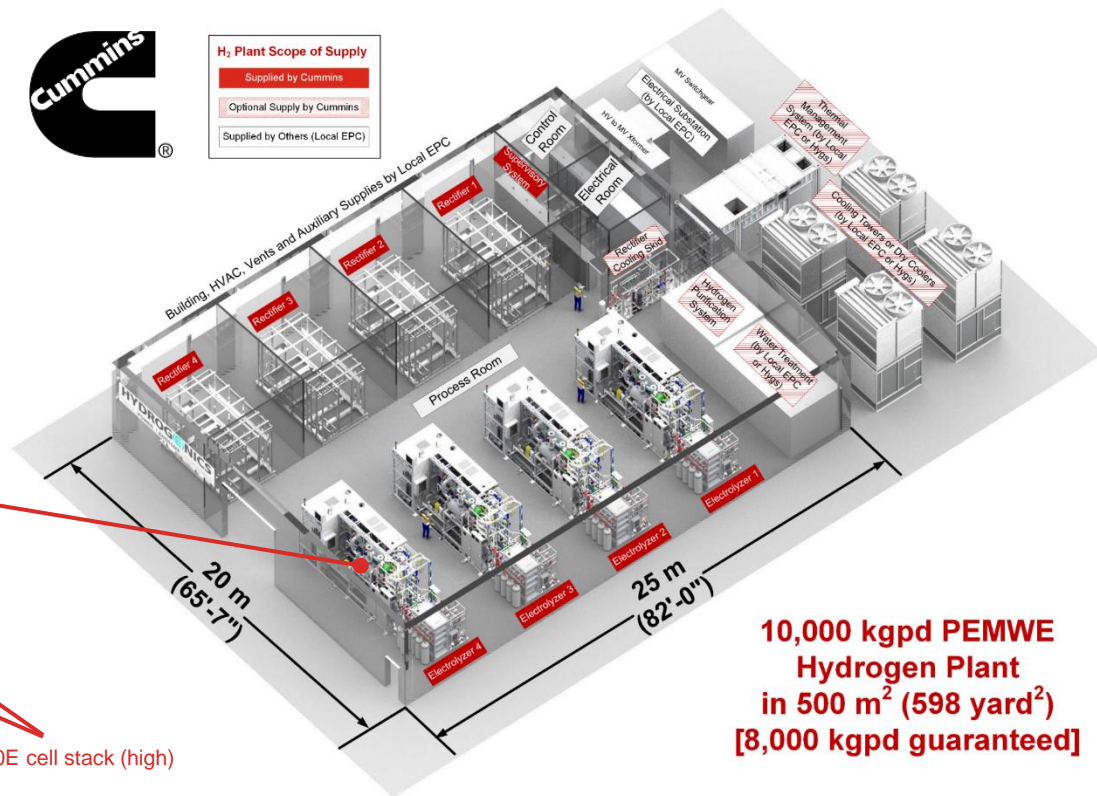
Optional Supply by Cummins

Supplied by Others (Local EPC)



HyLYZER®-1000 – Balance-of-Stack
1000 Nm³/h (~5 MW) in total

2x 1500E cell stack (high)



**10,000 kgpd PEMWE
Hydrogen Plant
in 500 m² (598 yard²)
[8,000 kgpd guaranteed]**

World's Largest PEM Electrolyzer 20 MW

More info & video tour:

<https://www.cummins.com/news/2021/10/04/video-case-study-cummins-hylyzer-pem-electrolyzer-becancour-quebec>

06 Sep 2022 | WIVA P&G Conference, Graz



Air Liquide Becancour, Canada

4x HyLYZER® 1000-30 – indoor – 20 MW – 4.000 Nm³/h

COST REDUCTION LEVIES (CAPEX & OPEX)

FOR PEM ELECTROLYZERS

- **Product standardization** : key technology blocks
- **Innovative product design** : robust & reliable, compact (low footprint), modular (easy to transport), plug&play (reduced installation costs), design to manufacture, design to service, easy to integrate
- **Cell stack upscaling**: more cells, larger active areas, thinner membrane and higher current densities
- **Materials and components**: MEA improvements (efficiency, durability), reduction of iridium and platinum loading
- **Product upscaling** (towards XXL electrolyzer solutions): “bigger is better”
- **Power** transfo/rectifiers optimization (larger rectifiers powering more stacks)
- **Vertical integration and supply chain** optimization
- **Manufacturing upscaling**

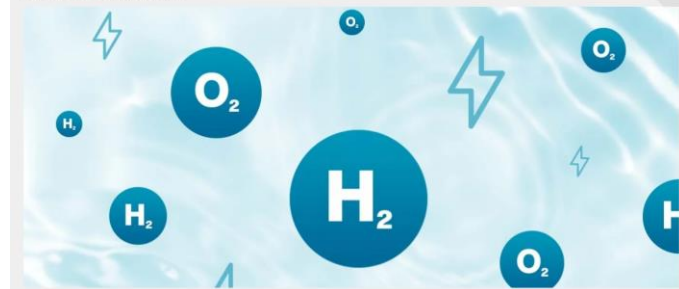
SOLID OXIDE ELECTROLYSIS - SOEC

- High operating temperatures of 800C or greater lead to higher efficiency thanks to thermal energy
- Solid ceramic electrolyte: no precious metals required in system, leading to affordable and readily available materials
- Able to produce hydrogen and other syngas through recycling of CO₂ or renewable energy sources and water
- Ideal for industrial processing applications with excess steam or high-grade heat
- SOEC technology currently in development and producing hydrogen



CUMMINS CONTINUES EFFORTS TO SCALE GREEN HYDROGEN PRODUCTION WITH \$5 MILLION DOE ELECTROLYZER PROJECT

Sep 27, 2021 • Columbus, Indiana



<https://www.cummins.com/news/releases/2021/09/27/cummins-continues-efforts-scale-green-hydrogen-production-5-million-doe>

ANION EXCHANGE MEMBRANE - AEM ELECTROLYSIS

- Project Anione : Anion Exchange Membrane Electrolysis for Renewable Hydrogen Production on a Wide-Scale
- Objectives:
 - develop high-performance, cost-effective and durable anion exchange membrane (AEM) water electrolysis technology
 - combine the advantages of proton exchange membrane and liquid electrolyte alkaline technologies
 - validate a **2 kW** AEM electrolyzer prototype (H₂ flow: ~0.4 Nm³/h)
 - develop innovative reinforced anion exchange membranes in conjunction with non-critical raw material electrocatalysts with high surface areas and membrane-electrode assemblies.
- Duration: Jan 2020 – Dec 2022
- Preliminary results: <https://anione.eu/planned-achieved/>
- This project has received funding from the European Union's Horizon 2020 research and innovation programme (Fuel Cells and Hydrogen 2 Joint Undertaking) under Grant Agreement no. 875613.

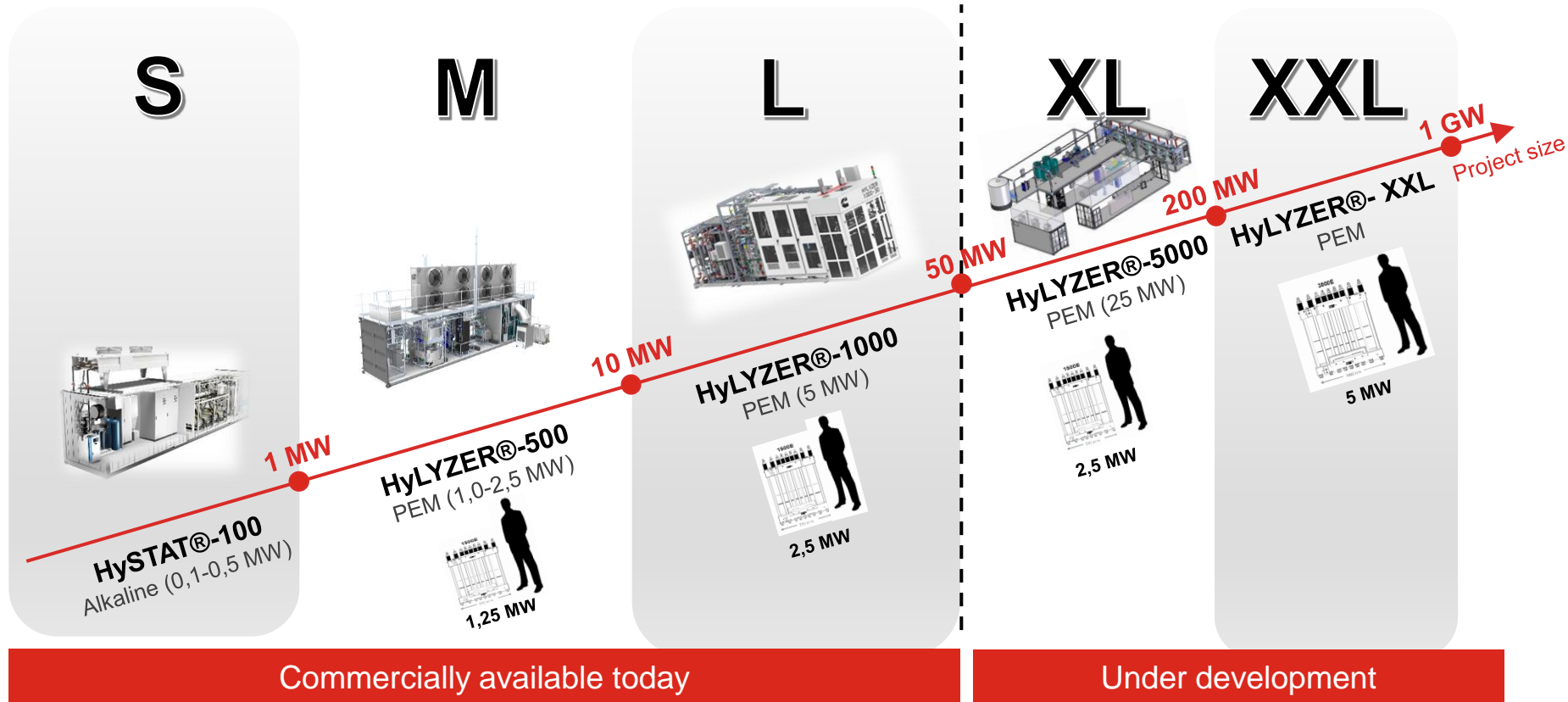
Project



Involved Partners



ELECTROLYZER PRODUCT OFFERING



WE ARE EXPANDING OUR ELECTROLYZER MANUFACTURING CAPACITY ON 3 CONTINENTS



Country	Belgium	Spain	Canada	China	China
City	Oevel	Guadalajara	Mississauga	Shangai	Foshan
Status	Extension	New	Extension	New	New
HySTAT stacks & systems	●				
HyLYZER PEM cell stacks	●		●	●	
HyLYZER PEM systems	●	●	●		● (in JV with Sinopec)

* Based of publicly announced plans by Cummins

GLOBAL ANNUAL CAPACITY: 2+ GIGAWATTS IN 2023

KEY MESSAGES



1. Cummins (through Hydrogenics) has more than 70 years of history, delivering water electrolyzers to the industry
2. Various technologies (will) co-exist with their pro's and con's and with various maturity levels: there is "no one fit's all" solution
3. The industry is scaling up its products and manufacturing capacity rapidly to respond to the increasing demand for electrolyzers (from MW to GW)
4. Cummins is mainly focusing today on PEM technology (HyLYZER®-XXL) for large scale electrolyzer projects and has delivered the World's Largest PEM electrolyzer (20 MW, 12/2020)
5. Cummins is developing also other high potential electrolyzer technologies such as SOEC and AEM.



THANK YOU

Contact: Christoph Zahn – Sales Manager- Electrolyzers
Email: Christoph.zahn@cummins.com