



MW-scale PEM electrolysis

Lessons learnt from HyBalance and
way forward

HyBalance

Denis THOMAS, Cummins – Hydrogenics
denis.thomas@cummins.com

24 September 2020, online webinar

WHO IS CUMMINS?



Engines



Power generators



Electrification



Hydrogen & Fuel Cells

190
Countries



61.6K
Global Employees



1.4M+
Engines built in 2019



8K
Distributor & dealer locations



\$1B
Invested in research & development in 2018



100 YEARS
of industry leadership



*2019 figures

CUMMINS IN EUROPE

11



Manufacturing Sites

18



Distribution Sites

300



Dealers

7,000



Employees

€70m



R&D in Europe on average per year

€3.63bn



Goods produced each year



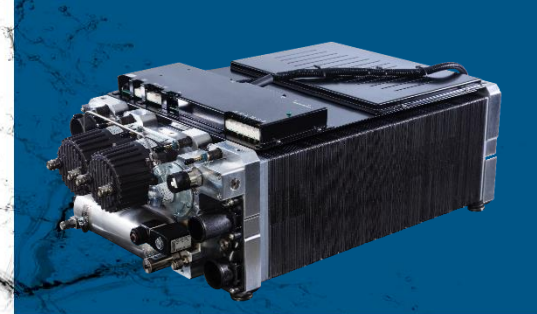
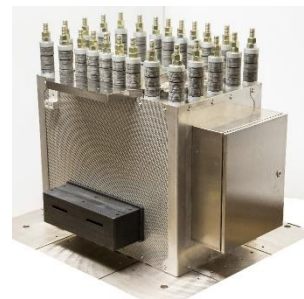
HYDROGEN ACTIVITIES

■ Key technologies

- Alkaline Electrolysis
- PEM Electrolysis
- Solid Oxide Fuel Cells
- PEM Fuel Cells
- Hydrogen storage tanks

■ FCH manufacturing sites in EU

- Belgium: alkaline and PEM electrolysis
- Germany: PEM Fuel Cells integration & H2 storage tanks



■ Recent acquisitions and partnerships

- General Electric (US)
- **Hydrogenics*** (Belgium, Germany, Canada)
- MOU with Hyundai
- **Loop Energy** (Canada)
- JV with **NPROXX** (Germany)

**Air Liquide is still owning 19% of Hydrogenics*



PEM WATER ELECTROLYSIS- KEY MILESTONES



Test Large Stack



Field Test 1.5 MW Electrolyzer



Indoor Design



HyLYZER®-1000 Architecture (5MW)



1999

2003

2012

2014

2015

2017

2018

2019

2020



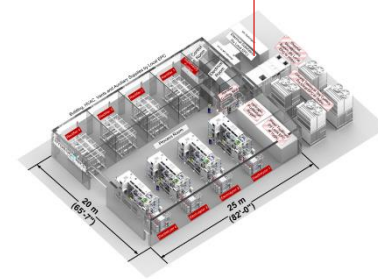
Small Scale PEM Electrolyser



1.5 MW Cell Stack



Dual Cell Stack Design



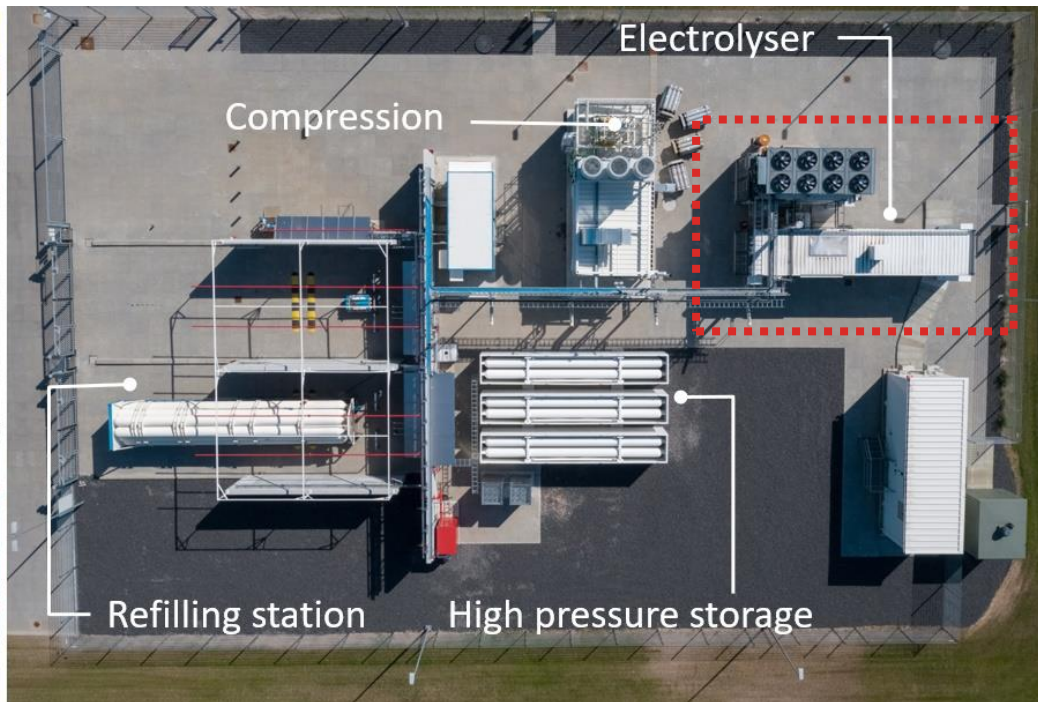
First 20 MW online



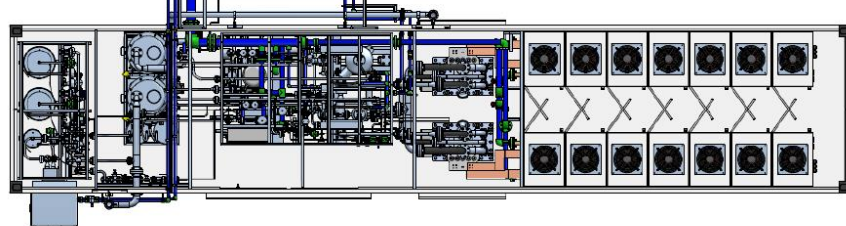
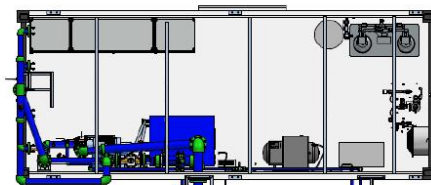
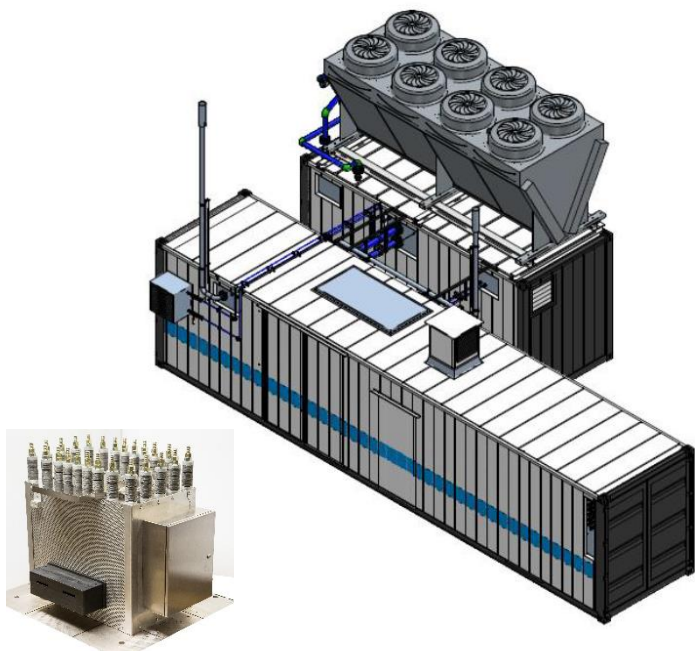
HyLYZER PEM Cell Stack - 1500E

250 Nm³/h - ~1,25 MW (max: ~1,5 MW)

HyBALANCE PROJECT: TOP VIEW



PEM ELECTROLYZER DESIGN



- 40 ft container: power racks (rectifiers), dual cell stack + Balance-of-Plant
- 20 ft container: R/O system, control panel, rooftop cooling, compressed air



Air Liquide, HyBalance, Hobro, Denmark
HyLYZER® 230-30 – dual stack



HYDROGENICS
SHIFT POWER | ENERGIZE YOUR WORLD

Air Liquide, HyBalance, Hobro, Denmark
HyLYZER® 230-30 – dual stack



HyBalance

Air Liquide, HyBalance, Hobro, Denmark
HyLYZER® 230-30 – dual stack

LESSONS LEARNT FROM HYBALANCE (1)

- 'First of its kind' unit with 2 MW-class PEM cell stacks running in parallel on the same Balance-of-Stack
- A large amount of hardware and software improvements due to pilot design
- High dynamic response capability validated during the testing phase
- Mainly lessons learnt on the dual stack operation and maintenance
- Considering pilot nature of electrolyzer very reliable operation
- Balance-of-Stack assembly in clean room
- Development of in-house testing protocols



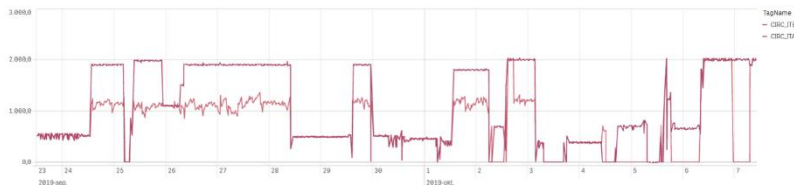
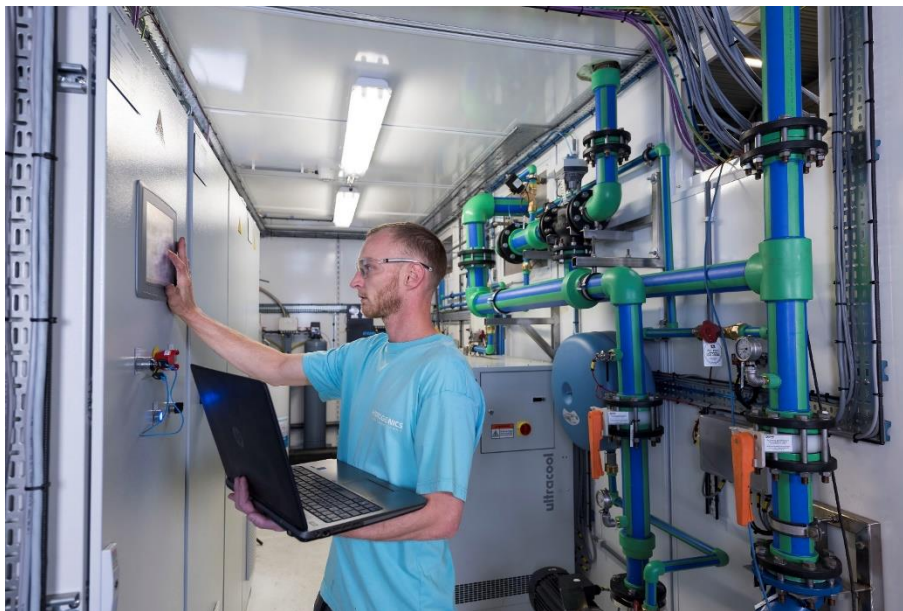
LESSONS LEARNT FROM HYBALANCE (2)

- Onsite installation : 1-day lift works ([video](#))
- Controlling and maintaining water quality is crucial to prevent stack contamination (filters, reverse-osmosis maintenance, water polishing system)
- Development of stack swap procedures
- Development of annual testing procedures
- Operating experience to further develop and improve the HyLYZER®-500 platform

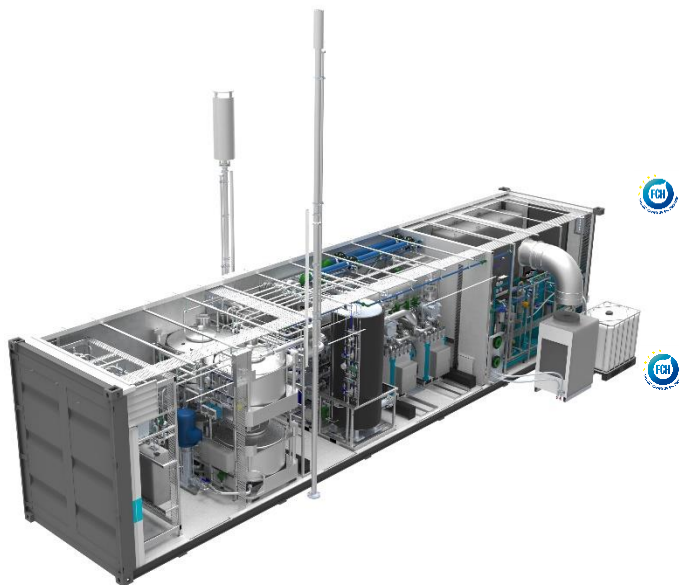


LESSONS LEARNT FROM HYBALANCE (3)

- **>120 tons** of hydrogen produced and delivered to end-user
- **>13,937 hours** of operation
- Overall system efficiency (incl. all utilities): **56,5 kWh/kg** (target: 57,5 kWh/kg)
- Cell stacks can be operated asymmetrical
- Fast reaction time for grid balancing services (FCR): **<10 sec** (in real operation), but the system can react in **<2 sec** (in hot conditions)



LEVERAGING THE HyBALANCE EXPERIENCE: DEVELOPMENT OF THE **HyLYZER-500 PLATFORM**



HyLYZER®-500 - Process container

Country	Project	Size	Year	Platform	Power	Gas	Industry	Mobility	Fuel
Denmark	HyBalance	1.2 MW	2017	HyLYZER®-500			•	•	
Canada	Embridge P2G	2.5 MW	2017	HyLYZER®-500		•			
Thailand	EGAT	1 MW + 300 kW FC	2017	HyLYZER®-500	•				
Germany	WindGas Brunsbuttel	2.4 MW	2017	HyLYZER®-500		•			
Germany	MefCO2	1 MW	2018	HyLYZER®-500					•
Norway	Haeolus	2 MW + 100 kW FC	2018	HyLYZER®-500	•		•		
Belgium	HRS CMB	1 MW	2019	HyLYZER®-500					•
Germany	HRS Wuppertal	1 MW	2019	HyLYZER®-500					•
Australia	Jemena	0,5 MW	2019	HyLYZER®-500		•			
New Zealand	Halcyon Power	1.5 MW	2019	HyLYZER®-500					•
Canada	AL Becancour	20 MW	2019	HyLYZER®-1000			•		
Poland	Zepak	5 MW	2020	HyLYZER®-1000					•
USA	Douglas County	5 MW	2020	HyLYZER®-1000					•

CURRENT 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

SCALABLE PRODUCT PLATFORM

8,000 KG/DAY / 20MW / 4x **HYLYZER®-1000**

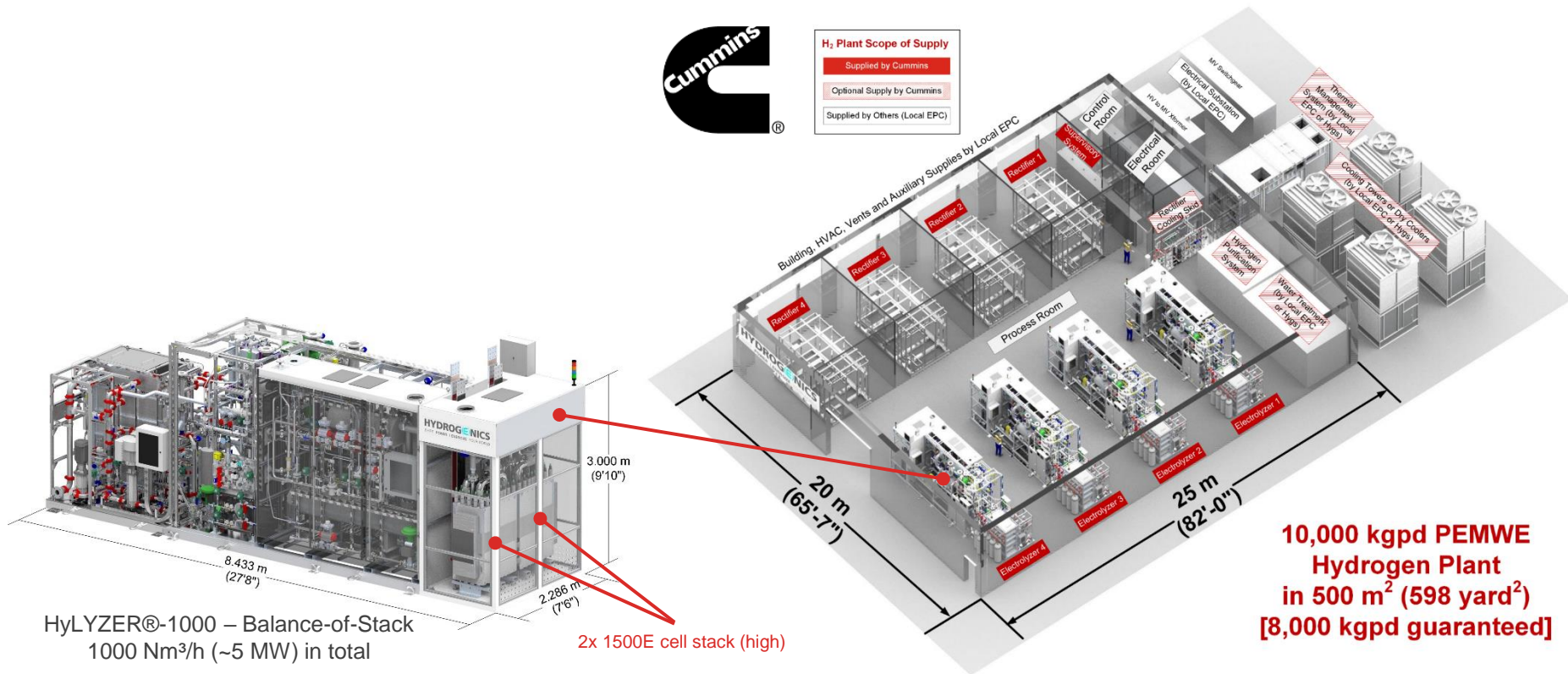


H₂ Plant Scope of Supply

Supplied by Cummins

Optional Supply by Cummins

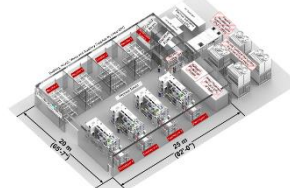
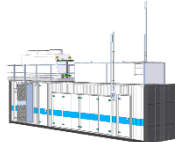
Supplied by Others (Local EPC)



WATER ELECTROLYZERS : PRODUCT LINE

Alkaline

PEM (Proton Exchange Membrane)



	HySTAT®-15-10	HySTAT®-60-10	HySTAT®-100-10	HyLYZER® -500-30	HyLYZER® -1.000-30	HyLYZER® -4.000-30
Output pressure	10 barg (27 barg optional)			30 barg		
Design	Indoor/outdoor	Indoor/outdoor	Indoor/outdoor	Indoor/outdoor	Indoor	Indoor
Number of cell stacks	1	4	6	2	2	8
Nominal hydrogen flow	15 Nm³/h	60 Nm³/h	100 Nm³/h	500 Nm³/h	1.000 Nm³/h	4.000 Nm³/h
Nominal input power	80 kW	300 kW	500 kW	2.5 MW	5 MW	20 MW
AC power consumption (utilities included, at nominal capacity)	5.0 to 5.4 kWh/Nm³			≤ 5.1 kWh/Nm³	DC power consumption: 4.3 kWh/Nm³ ± 0.1 (at nameplate hydrogen flow)	
Turndown ratio	40-100%	10-100%	5-100%	5-100%	5-125%	
Hydrogen purity	99.998% O2 < 2 ppm, N2 < 12 ppm (higher purities optional)			99.998% O2 < 2 ppm, N2 < 12 ppm (higher purities optional)		
Tap water consumption	<1.4 liters / Nm³ H2			<1.4 liters / Nm³ H2		
Footprint (in containers)	1 x 20 ft	1 x 40 ft	1 x 40 ft	2 x 40 ft	(LxWxH) 8.4 x 2.3 x 3.0 m	20 x 25 m (500 m²)
Utilities (AC-DC rectifiers, reverse osmosis, cooling, instrument air, H2 dryer)	Incl.	Incl.	Incl.	Incl.	Optional	Optional

CONCLUSIONS

- The HyBalance project has allowed Cummins-Hydrogenics to develop and **validate its dual PEM cell stack platform** in an industrial environment
- There were **many learnings** during all phases of the HyBalance project and those have been translated in incremental improvements of the HyLYZER®-500 electrolyzer platform (now a commercial product)
- **The HyBalance unit will continue its operation** after the end of the funding period
- Cummins-Hydrogenics is now building the **largest 20 MW PEM electrolyser plant** based on the HyLYZER®-1000 platform with individual PEM cell stacks of 500 Nm³/h (~2,5 MW each)
- Cummins-Hydrogenics is getting **prepared for the ‘GW Era’ of hydrogen technologies**
- Big **THANK YOU** to all HyBalance project partners and to the funding authorities: the FCH-JU and the Danish EUDP program



THANK YOU

Contact: Denis THOMAS, EU Regulatory Affairs & Business Development Manager Renewable Hydrogen
Email: denis.thomas@cummins.com - Mobile: +32 479 909 129