

Large scale PEM electrolysis: technology status and upscaling strategies

Denis THOMAS, Hydrogenics
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The HyBalance project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 671384. The Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation program. www.fch.europa.eu. The HyBalance project has furthermore received funding from the Danish EUDP program, which is administered by the EUDP Board.

HyBalance

Hydrogenics in a nutshell



ON-SITE HYDROGEN GENERATION

Electrolyzers

Industrial Hydrogen supply



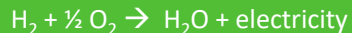
POWER SYSTEMS

Fuel cells

Stand-by Power

Mobile Power Modules

MW Power Plants



RENEWABLE HYDROGEN

Energy Storage

Hydrogen for Refueling Stations

Power-to-X

Grid balancing services



Hydrogenics, a daughter company of Cummins and Air Liquide

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Cummins takes over fuel cell maker Hydrogenics

AIR LIQUIDE | CANADA | CUMMINS | FUEL CELL | HYDROGEN | HYDROGENICS CORPORATION | USA



The US engine manufacturer Cummins has taken over the Canadian fuel cell manufacturer Hydrogenics Corporation. However, Air Liquide will remain on board as an investor in Hydrogenics.

Cummins announced that the company will acquire all shares of the Canadian fuel cell and hydrogen technology developer and manufacturer, with the exception of the shares Air Liquide acquired in Hydrogenics earlier this year. Cummins will pay \$15 per share, equivalent to \$290 million in shareholder value.

Further details on the deal and its impact on both companies will be announced by Cummins CEO Tom Linebarger later this year: "Upon closing, we will share more details about the acquisition and our strategy to offer a broad portfolio of power solutions to meet our customers' needs." According to the announcement, Cummins expects the transaction to close in the third quarter of 2019.

The US manufacturer Cummins was previously known for its diesel engines, but over the last two years has already made a number of significant and decisive acquisitions in the field of electrically powered vehicles. After presenting the prototype of an electric truck in 2017, Cummins acquired the former electric motorcycle manufacturer and current battery specialist Brammo, followed in February 2018 by the acquisition of Johnson Matthey's UK division specialising in electric and hybrid vehicles. Just a few months later in July of 2018, Cummins also acquired Efficient Drivetrains, as well as joining the Hydrogen Council. Now, with the acquisition of Hydrogenics, the US firm is setting itself up for rapidly growing markets in zero-emission technologies.

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Source: <https://www.electrive.com/2019/07/01/cummins-takes-over-fuel-cell-maker-hydrogenics/>



80%

20%

Joint Venture

Atlantis AcquisitionCo Canada Corporation

100%

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Tipping point for the hydrogen industry

From niche

First products and demo projects
kW market
Workshop mode
Immature supply chain
Only small Industrial market is commercial
"Hydrogen is a hype"

Upscaling

Product evolution (alkaline, PEM)
MW market
Project manufacturing
Supply chain development
1st commercial energy applications
"Why not Hydrogen ?"

To mainstream

Product standardization
GW market
Product manufacturing
Optimized and competitive supply chain
Full commercial market deployment
"We always believed in hydrogen"



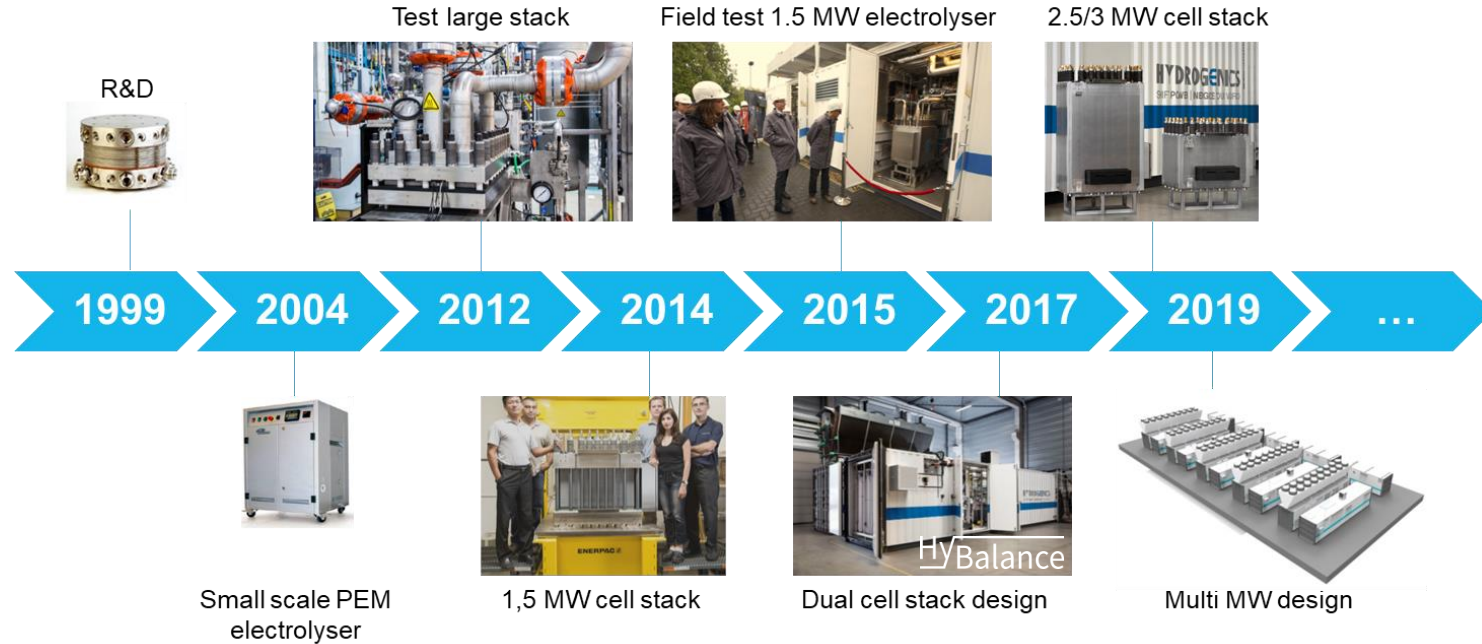
2015

We're Here

2020-2025

Regulation change

PEM water electrolysis- Key milestones

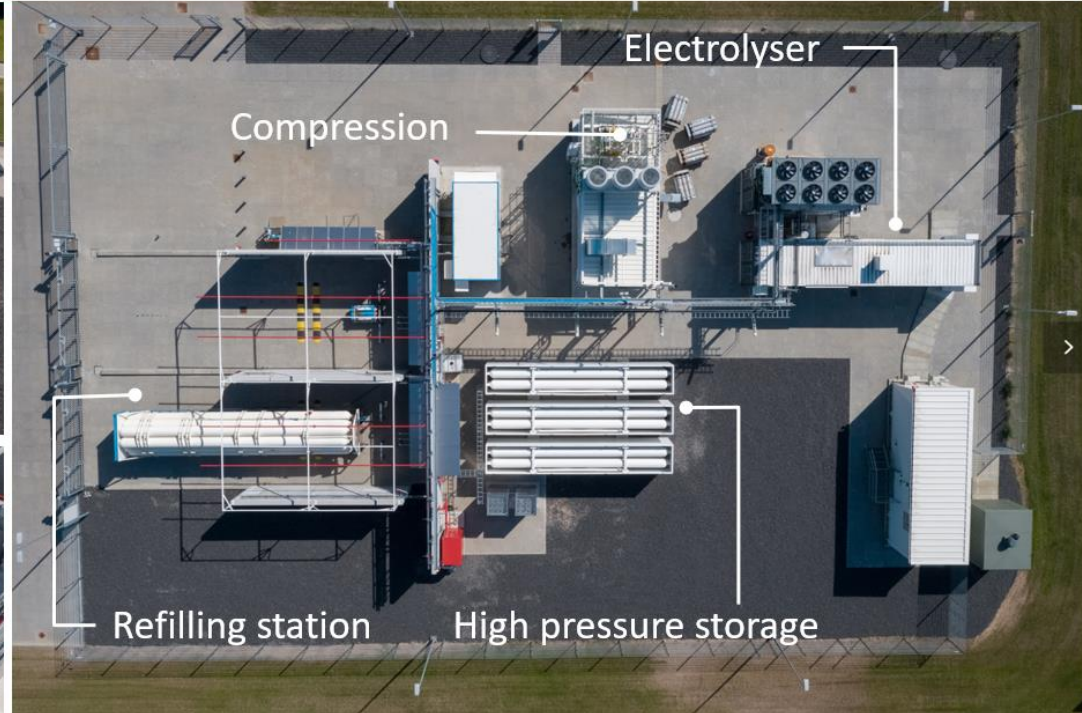


2014

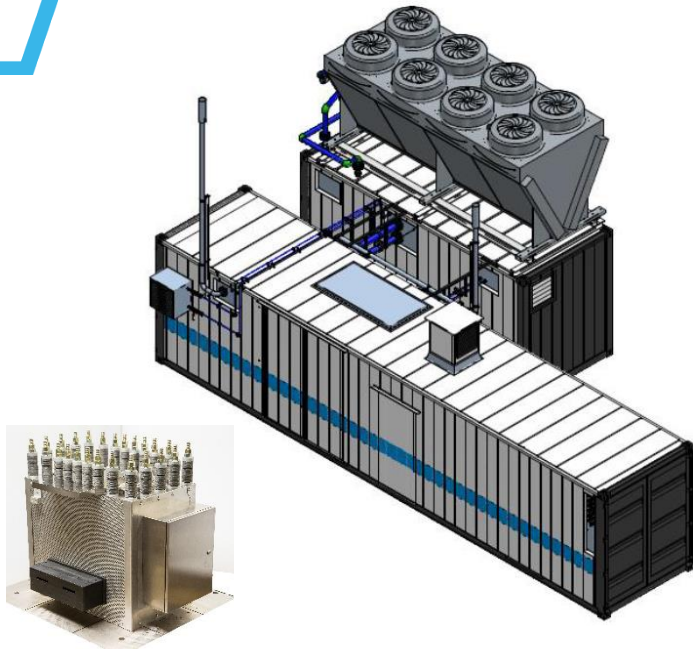
First commercial large stack



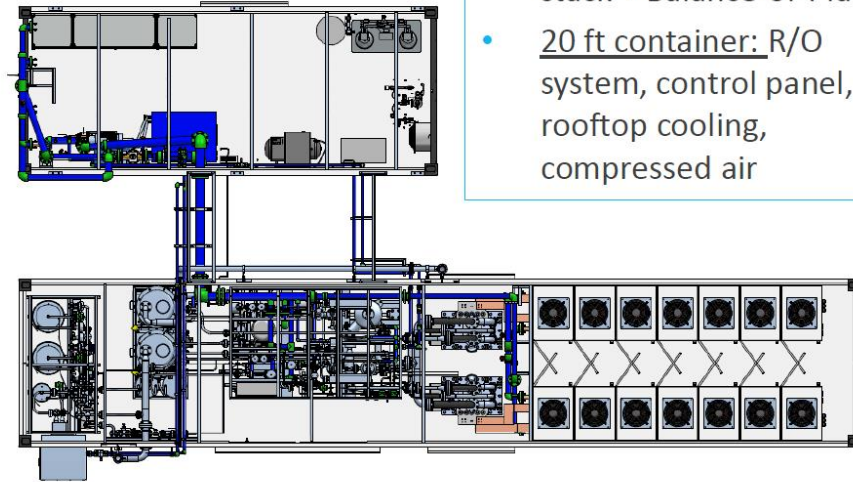
HyBalance project: top view



HyBalance project: 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



2017

HyLYZER® 230-30 – dual stack
5.0 kWh/Nm³



Air Liquide, HyBalance, Hobro, Denmark

2017

HyLYZER® 230-30 – dual stack
5.0 kWh/Nm³

HyBalance

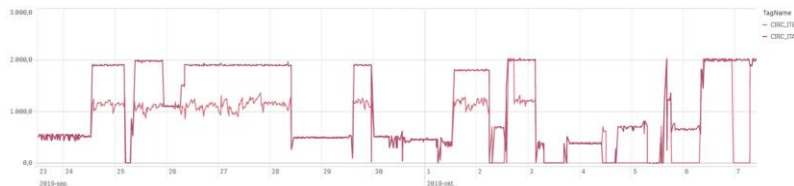
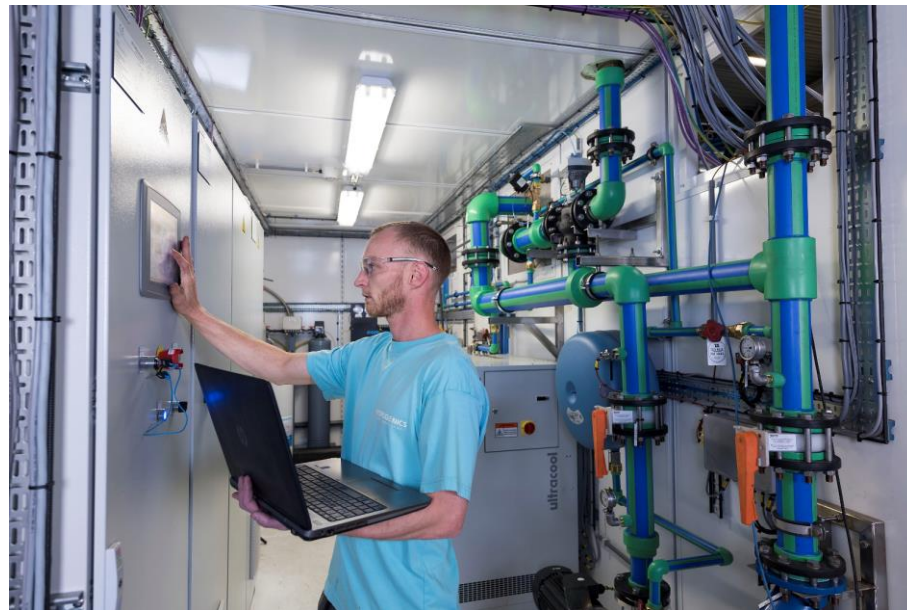
Air Liquide, HyBalance, Hobro, Denmark

Return of experience from Hybalance on the electrolyser

- '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

Return of experience from Hybalance on the electrolyser

- **>70 tons** of hydrogen produced
- **>7000 hours** of operation
- Operational availability: **>95%**
- Cell stacks can be operated asymmetrical



Lessons learnt from other P2X projects

Country	Project	Size	Year	Electrolyser technology	Power	Gas	Industry	Mobility	Fuel
Canada	AL Becancour	20 MW	2019	PEM			•		
New Zealand	Halcyon Power	1.5 MW	2019	PEM				•	
Germany	HRS Wuppertal	1 MW	2019	PEM				•	
Belgium	HRS CMB	1 MW	2019	PEM				•	
Norway	Haeolus	2 MW + 100 kW FC	2018	PEM	•		•		
Germany	MefCO2	1 MW	2018	PEM					•
Germany	WindGas Brunsbuttel	2.4 MW	2017	PEM		•			
Thailand	EGAT	1 MW + 300 kW FC	2017	PEM	•				
Canada	Embridge P2G	2.5 MW	2017	PEM		•			
Denmark	HyBalance	1.2 MW	2017	PEM			•	•	



Main conclusions from these projects:

1. Hydrogen **technologies work fine** and deliver according to expectations.
2. There is still room for further technical improvement but **no technology breakthrough is expected**.
3. There is a important potential for further **cost reduction**: going from project manufacturing to product manufacturing.
4. Energy **regulatory framework is no suited** for these applications and **business operation** of these projects **remains very challenging**.

New Benchmark in PEM Water Electrolysis, 3MW 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

Smallest footprint on the market

6

Reduced Maintenance

Limited and optimized

2019

2014

Power Input: 3.0 MW
Hydrogen Output: 1,330 kgpd
620 Nm³/h
Design Pressure: 40 bar

Power Input: 1.5 MW
Hydrogen Output: 670 kgpd
310 Nm³/h
Design Pressure: 40 bar

2019

HyLYZER® -1000-30
5 MW PEM Electrolyser



- Containerized design & compact footprint: 2 x 40 ft
- Plug&Play modular design based on 2 x 2,5 MW cell stacks
- Fully tested & certified @ Hydrogenics's factory

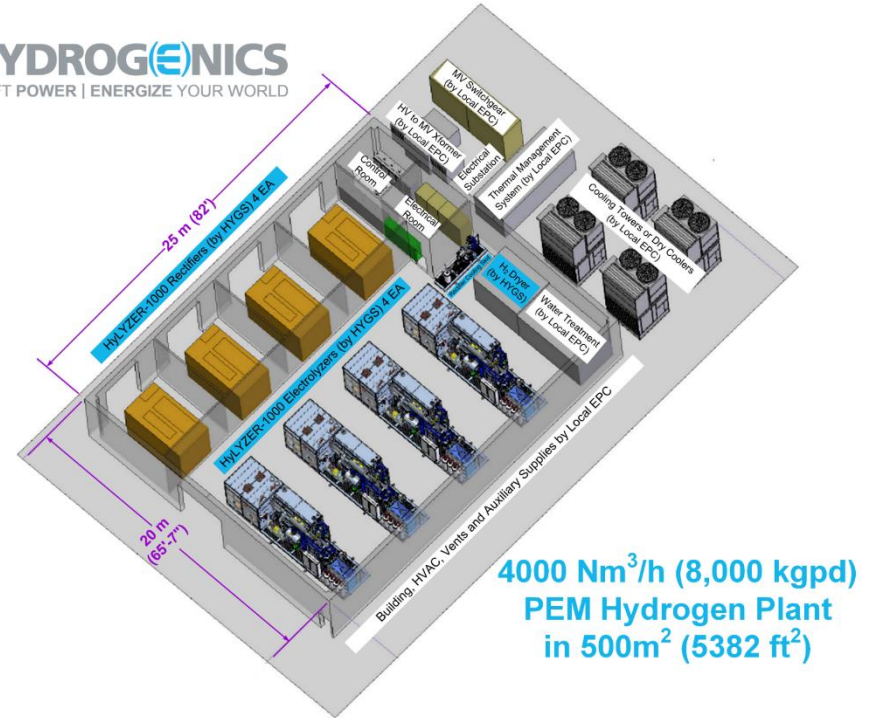


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Layout for 4000 Nm³/h indoor plant (20 MW)



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Electrolysers : product's line

Alkaline

PEM (Proton Exchange Membrane)

HyBalance

	HySTAT®-15-10	HySTAT®-60-10	HySTAT®-100-10	HyLYZER® -300-30	HyLYZER® -1.000-30	HyLYZER® -5.000-30
Output pressure	10 barg (27 barg optional)			30 barg		
Number of cell stacks	1	4	6	1	2	10
Nominal Hydrogen Flow	15 Nm³/h	60 Nm³/h	100 Nm³/h	300 Nm³/h	1.000 Nm³/h	5.000 Nm³/h
Nominal input power	80 kW	300 kW	500 kW	1.5 MW	5 MW	25 MW
AC power consumption (utilities included, at nominal capacity)	5.0 to 5.4 kWh/Nm³			4.4 to 4.8 kWh/Nm³		
Hydrogen flow range	40-100%	10-100%	5-100%	1-100%		
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	1 x 40 ft	2 x 40 ft	10 x 40 ft
Footprint utilities (optional)	Incl.	Incl.	Incl.	1 x 20 ft	1 x 20 ft	5 x 20 ft

Conclusions

- **Pressure on governments** to deliver solutions to fight climate change is **increasing** rapidly
- **Hydrogen**, Sector coupling, Power-to-X are now **clearly recognized as key** technologies to deliver high decarbonization solutions in power, transport, heating and industry.
- International & national **policies are clearly driving the demand for hydrogen** technologies and first regulations are coming
- The **HyBalance** project has **allowed Hydrogenics to develop and validate its dual PEM cell stack platform** for MW-scale projects
- Hydrogenics is now building the **largest 20 MW PEM electrolyser plant**
- **Hydrogenics is part of strong group** (Cummins and Air Liquide), **ready for the 'GW Era'** of hydrogen technologies

Thank you for your attention



hybalance.eu



in HyBalance



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