

# From wind power to **GREEN HYDROGEN**



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 programme. [www.fch.europa.eu](http://www.fch.europa.eu). The HyBalance project has furthermore received funding from the Danish EUDP programme, which is administered by the EUDP Board.

**Hy**Balance





Tube trailer to transport hydrogen to refueling stations and industrial clients in Denmark.

# HYBALANCE

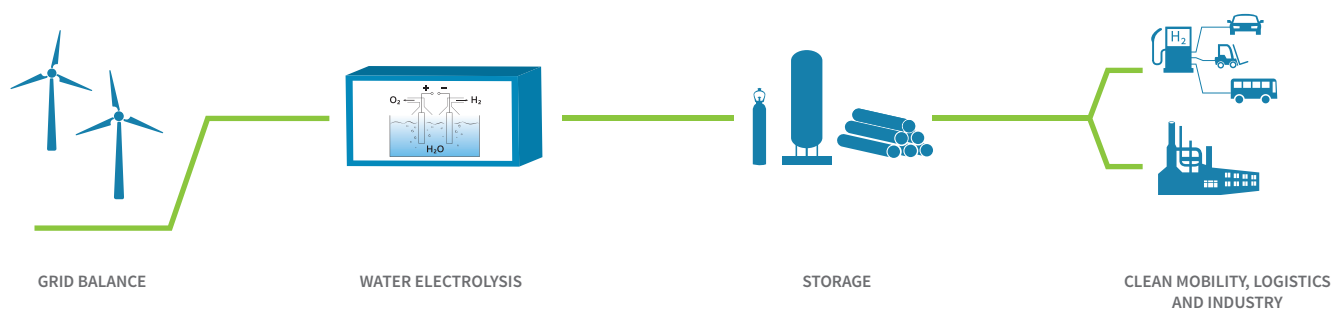
In 2018 the *HyBalance facility* was inaugurated. Located in the North of Denmark, the plant produces hydrogen on a larger scale from water electrolysis and is the first of its kind in Europe.

The facility is the focal point of the *HyBalance project*, which aims to demonstrate the use of renewable hydrogen in energy systems. It is a technology showcase for sustainable development pathways in Europe and one of the initiatives to help transform energy systems from fossil dependency to relying on renewable and local energy sources by utilizing the potential of hydrogen. For this reason, it has received both European and Danish funding – through the Fuel Cells and Hydrogen 2 Joint Undertaking and the Danish EUDP programme.

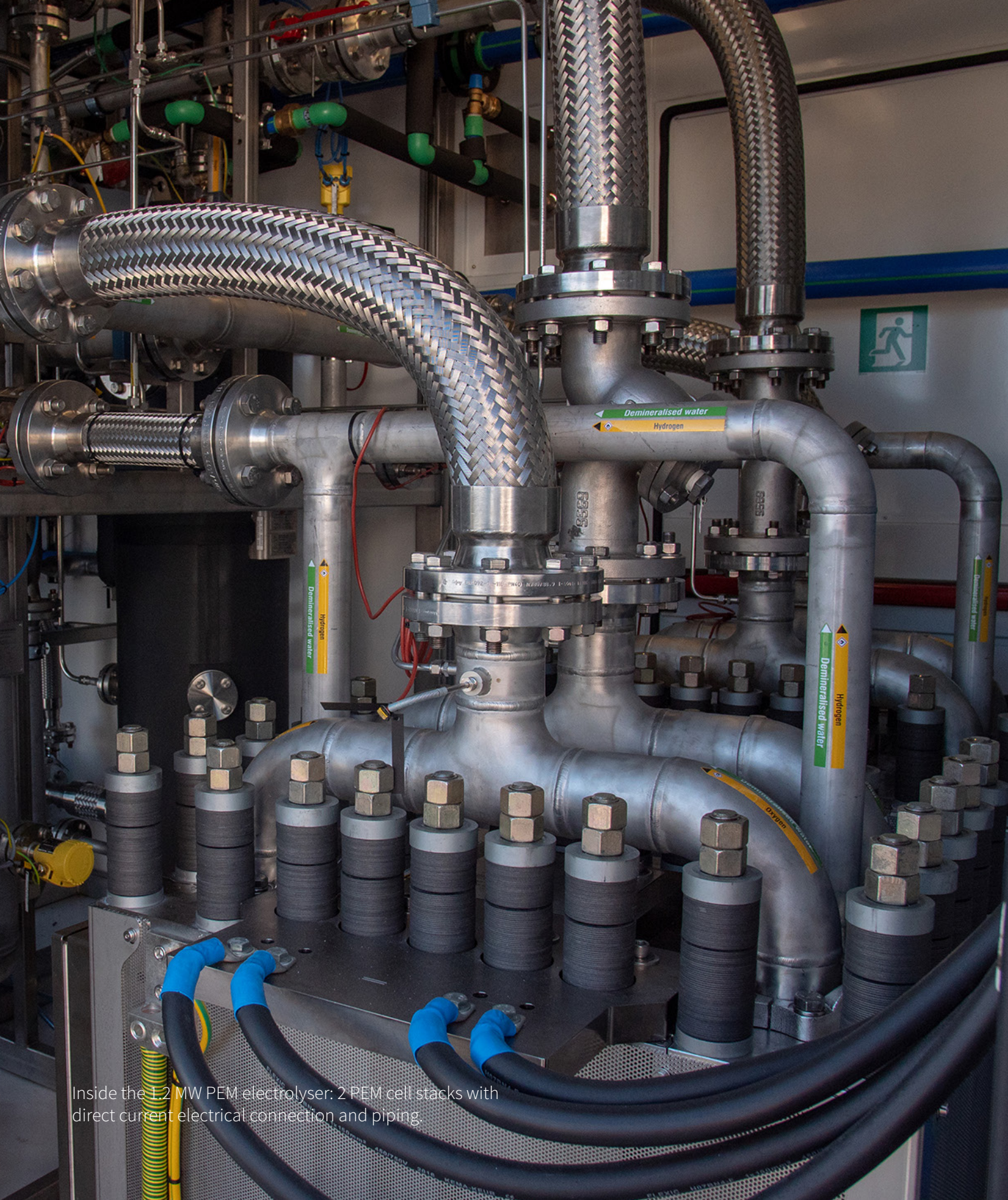
## The project has demonstrated that

1. it is possible to store electricity on a larger scale in the form of hydrogen
2. the PEM electrolysis technology achieves a high level of availability and efficiency
3. hydrogen production can help balance the electricity grid
4. the hydrogen can serve clean transport and industry.

Behind the project is a consortium, led by the main investor Air Liquide and encompassing Cummins (formerly Hydrogenics), Centrica Energy Trading (formerly NEAS Energy), Ludwig-Bölkow-Systemtechnik and Hydrogen Valley.







Inside the 1.2 MW PEM electrolyser: 2 PEM cell stacks with direct current electrical connection and piping



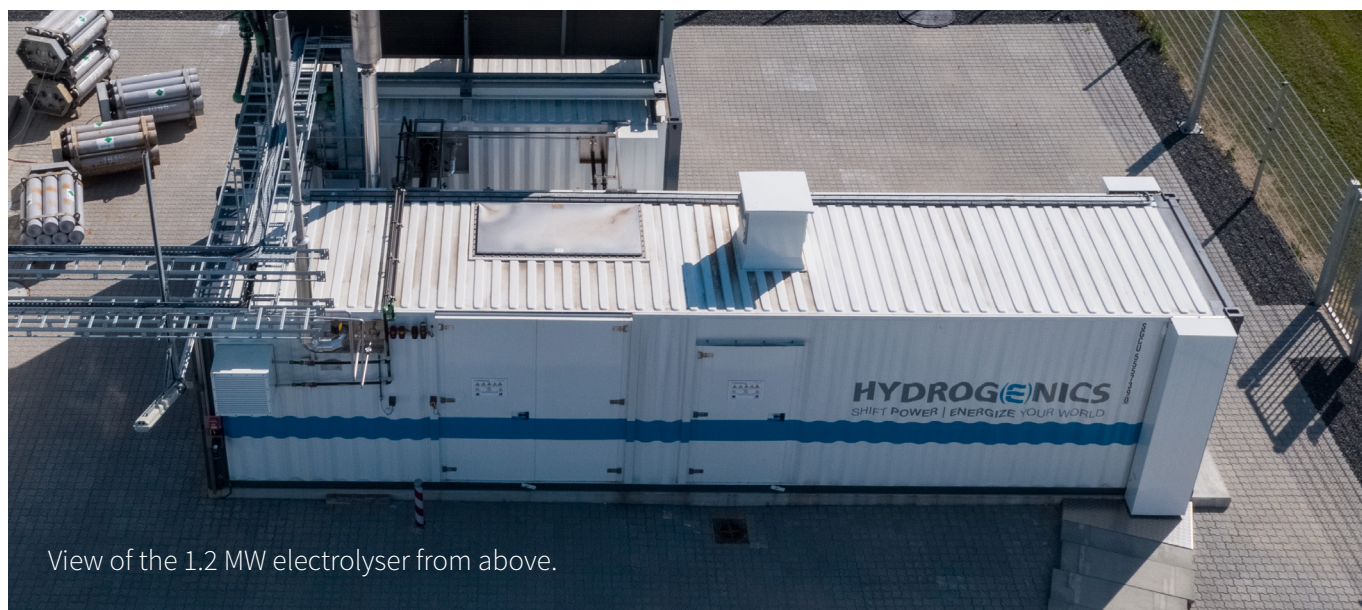
# PEM ELECTROLYSIS

The HyBalance facility produces hydrogen by leading power from the grid into a 1.2 MW PEM electrolyser that splits water into hydrogen and oxygen.

The PEM (Proton Exchange Membrane) is a relatively new technology which is characterized by a high efficiency (more hydrogen produced per kWh of electricity), a smaller footprint (more kg of hydrogen produced per m<sup>3</sup> of cell stack) and better capability to operate under flexible operations. These characteristics make PEM technology an excellent candidate to balance renewable power, and the PEM technology presents a high cost reduction potential through mass production.

The 1.2 MW PEM electrolyser at the HyBalance facility has demonstrated a very high availability, considering the pilot nature of the installation.

This stability has enabled production of hydrogen 24/7 for an industry complex nearby, delivered through a pipeline.



View of the 1.2 MW electrolyser from above.







# GRID BALANCING

The HyBalance facility has demonstrated how hydrogen production can help balance the electricity grid.

The PEM electrolysis unit has delivered the required reaction-time and flexibility to ramp up and ramp down production in less than 10 seconds as demanded by the Danish energy authorities in order for the facility to deliver balancing services.

A short ramp up time makes it possible to increase the consumption of electricity from the grid when it is desirable to regulate electrical frequencies. A short ramp down time makes it possible to quickly interrupt

or reduce the production of hydrogen and thus the consumption of electricity. This may be needed during peak demand in the evening when cooking, laundry, etc. put a strain on the electricity grid.

The plant has been approved by the Danish energy authorities as a bidder in all electricity markets and especially on the primary reserve containment where few power installations are able to react.







# CLEAN HYDROGEN FOR MOBILITY AND INDUSTRY

By September 2020 the HyBalance facility had delivered 120 tons of hydrogen.

As wind and sun energy makes up 49 percent of the consumed electricity in Denmark, much of the hydrogen produced by HyBalance derives from a renewable source.

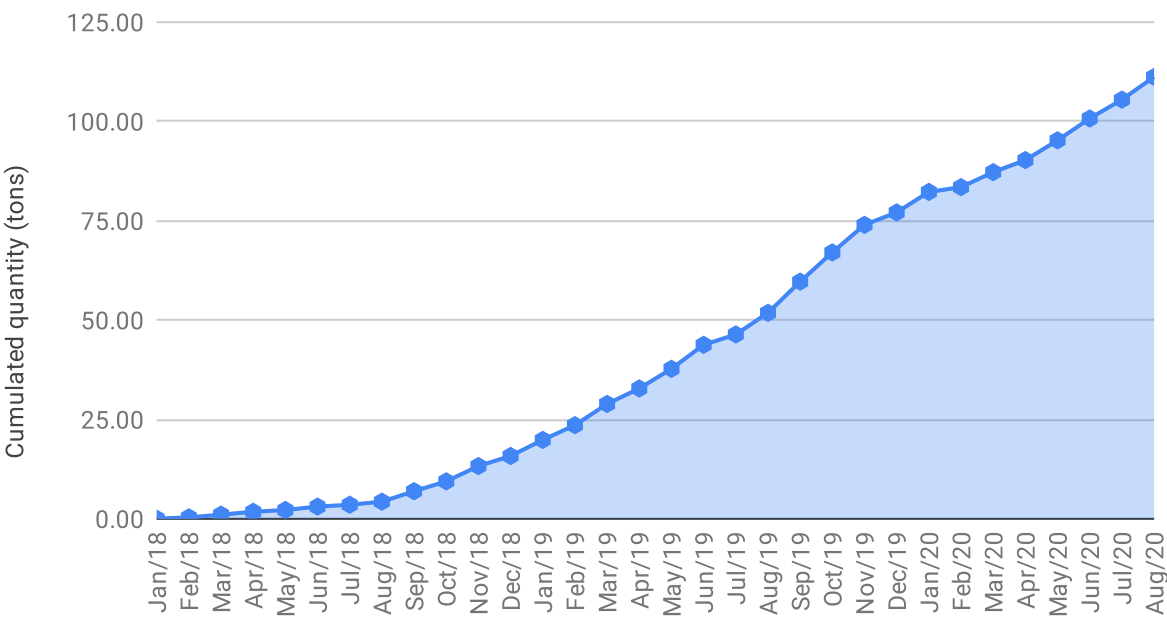
50% of the hydrogen has been delivered through a pipeline for an industrial complex close to the facility. The remaining 50% of the hydrogen has been delivered by tube trailers to other industries and for clean transportation.

Among vehicles fuelled by HyBalance is a fleet of Fuel Cell Electric Vehicles (FCEVs) taxis in Copenhagen.

The benefits of FCEVs are that they enable a reduction of greenhouse gas emissions as they do not produce any local pollutant emissions (fine particles etc.), they can be quickly fuelled and have a long range autonomy compared to electric cars.

The purity of the hydrogen produced at the HyBalance facility is much higher than hydrogen produced by steam reforming of natural gas for instance. For this reason, the hydrogen from HyBalance can be utilised for many applications.

H<sub>2</sub> volumes delivered by HyBalance







## FACTS

- Approximately 14.000 hours in service
- Production Rate: 230 Nm<sup>3</sup>/h
- H<sub>2</sub> purity above 99.998%
- Efficiency (Specific energy consumption) 56.5 kWh/kg - includes the electrolyser and its ancillaries
- Very high electrolyzer availability with regards to the pilot nature of the project
- Flexibility: Hydrogen production rate adjustable at any level from 10% to 100% of the nominal in daily operation mode
- Reactivity : Hot idle ramp-up and ramp-down in less than 10 seconds with a continuous hydrogen production flow, where requirements of the grid operator are from 15 to 30 seconds.



# PERSPECTIVES: FROM PILOT PROJECT TO OPERATIONAL PLANT & MODEL

The HyBalance facility is the first of its kind in Europe. It has demonstrated that power-to-hydrogen is a valid path to balance the grid, to store renewable energy and to transfer it into clean transportation and industry.

This success story will lead the plant to keep delivering hydrogen to customers (while proofing the equipment over a long period of time), and is already a model for larger scale PEM electrolyzers around the world (eg. Bécancour).

## Grid balancing

With the share of renewable, fluctuating energy from wind and solar growing in the energy mix, grid operators need to identify ways to ensure the perfect balance in the electricity grid which are economically more attractive than halting wind turbines or exporting excess capacity.

The HyBalance project has demonstrated that from a technological point of view, hydrogen production can offer balancing services on the primary, secondary and tertiary containment reserve. In the perspective of larger PEM electrolysis plants, the grid revenues will represent an important leverage to decrease the share of electricity in H<sub>2</sub> production costs.

## Clean mobility and industry

The HyBalance project has demonstrated that it is possible to store power on a larger scale in the form of hydrogen.

This of course also applies to renewable power, and thus renewables can be transferred into other industries through hydrogen and act as a substitute for fossil based alternatives. This can be within industry as well as within mobility.

Transportation has become a critical issue in decarbonizing the economy. Fuel Cell Electric Vehicles running on hydrogen emit nothing but water and are in that perspective clean. If the hydrogen is produced from renewable sources, the emission of CO<sub>2</sub> when producing the fuel is close to zero, as the electrolysis process itself does not emit any CO<sub>2</sub>.

Whether transportation will grow a major demand for hydrogen depends on the market development for FCEV's but also on the perspectives in converting hydrogen into electrofuels like methanol and ammonia. Long distance transport within shipping and aviation is looking for alternatives to fossil based fuels, and electrofuels are among those being investigated.






## CONTACT INFORMATION


Marie-Louise Arnfast

Communications Manager,  
Hydrogen Valley

+45 40 56 34 36

arnfast@hydrogenvalley.dk

 [hybalance.eu](https://hybalance.eu)

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[www.airliquide.com](http://www.airliquide.com)



Centrica Energy Trading, owned by Centrica PLC, is an international energy asset management company and operates in power, gas and energy certificate markets across Europe.

[www.centrica.com](http://www.centrica.com)



CUMMINS (formerly Hydrogenics). Leading manufacturer of water electrolysis solutions (for onsite hydrogen generation) and hydrogen fuel cell systems (for heavy-duty electric vehicles including buses, trucks and trains). Cummins is present in 190 countries and employs more than 60,000 employees.

[www.cummins.com](http://www.cummins.com)



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Danish business incubator acting as a driver in the hydrogen and Power-to-X industry in Denmark. Hydrogen Valley develops Power-to-X concepts, facilitates and bring them to life in solid business cases.

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