DON QUICHOTE
hydrogen out of wind turbine energy

Wind Energy, Hydrogen, Forklifts and Smart Grid at a Large Logistic Centre

(Colruyt Group, Belgium)

"We are preparing for a future where hydrogen fueling becomes very normal"

(CEO Jef Colruyt)

The Don Quichote project (**D**emonstration **O**f **N**ew **QU**alitative **I**nnovative **C**oncept of **H**ydrogen **O**ut of wind **T**urbin **E**lectricity) demonstrated that the use of hydrogen as a large scale renewable energy storage solution is not "tilting windmills" anymore, but has technical and economic viability. It represents an interesting commercial opportunity to connect intermittent renewable electricity to transport applications.

ABOUT DON QUICHOTE

The Don Quichote demonstration plant was implemented at a large logistic centre of Colruyt Group in Halle, near Brussels (BE).

The plant at this centre is interconnected to an existing hydrogen refuelling facility that supplies hydrogen to a fleet of material handling vehicles. It receives energy from renewable energy sources: wind and solar power.

In the project, components of an existing hydrogen refuelling system were replaced by innovative, more efficient components, and integrated with a renewable energy source, thereby realizing a renewable energy storage capacity based on hydrogen.

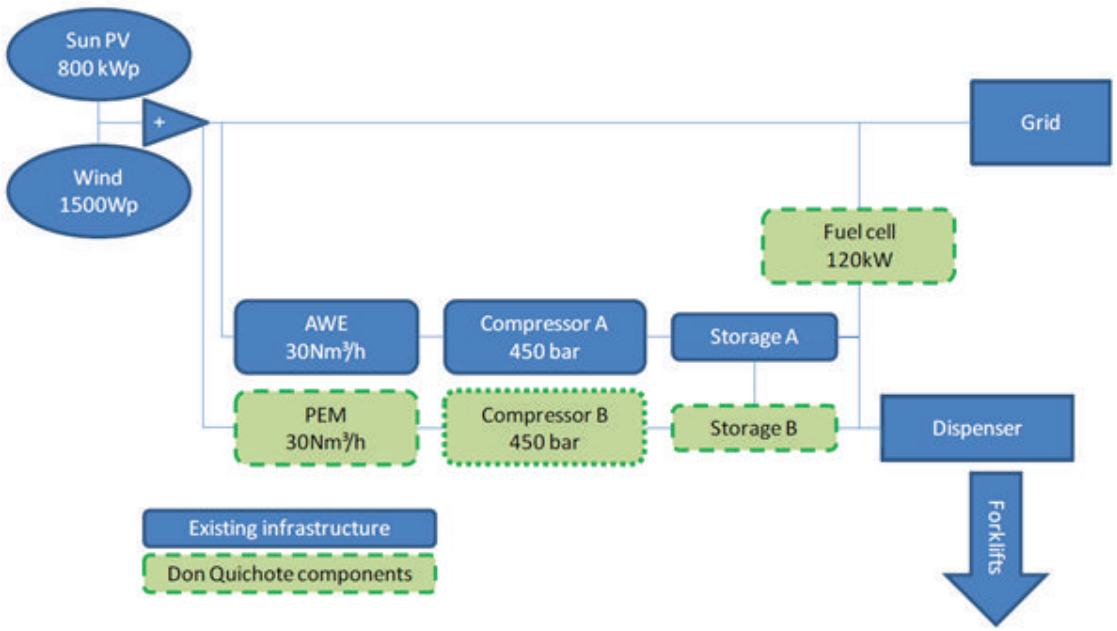
By storing excess renewable electricity in large quantities in the form of hydrogen, renewable energy can be effectively used for mobility, grid balancing and fuel cell material handling vehicles.

By demonstrating the impact on efficiency and costs of the operations of a large logistics centre, the project demonstrated the market readiness of the components needed for storing renewable energy in hydrogen.

OBJECTIVES

- **Doubling the hydrogen capacity** compared to existing systems by adding a very efficient and dynamic **PEM-electrolyser**, 130 kg/day.
- **Developing, testing, demonstrating and validating the coupling** between wind turbine (1,5 MW) and solar panels (800 kW) and the electrolyser technology.
- **Scaling up** of hydrogen applications (e.g. additional forklifts) in this refuelling station

3 PHASES



1 **Phase 1:** The existing hydrogen refueling infrastructure at Colruyt in Halle (BE), equipped with alkaline electrolyser, mechanical compressor, one storage at maximum 450 bar, a hydrogen dispenser at 350 bar and 2 material handling vehicles (number of MHV's from the start in 2015) as end user, was tested throughout the full duration of the project. In the meanwhile, a very efficient PEM electrolyser, its control system and a PEM fuel cell were being developed. Once relevant regulations, codes and standards were identified, a permitting dossier and a safety report have been prepared.

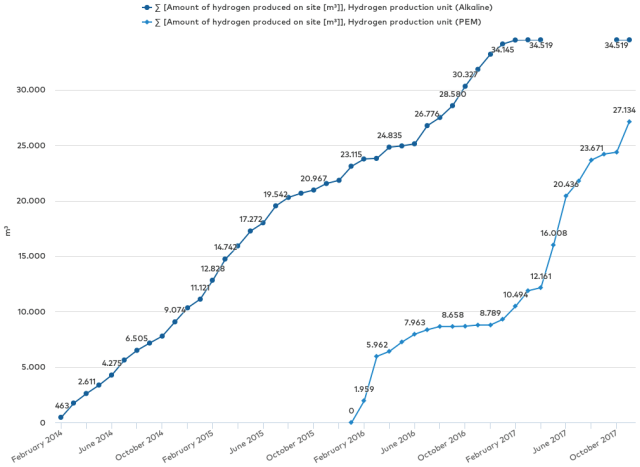
2 **Phase 2:** In this phase the PEM electrolyser has been assembled at Hydrogenics and installed at the demonstration site. The PEM Fuel cell system and the PEM electrolyser stack undertook the certification process. The existing equipment is interconnected to the phase 2 equipment to form a smart grid solution, which is able to supply hydrogen to vehicles, mainly material handling equipment, to store energy in the form of hydrogen from renewable electricity and to re-electrify hydrogen to electricity by means of the fuel cell and supply it to the grid at economical favorable conditions. The complete system for phase II has been built and commissioned, tested and monitored. Report on TCO and LCA have been produced and the assessment of feasibility/impact of large scale implementation performed.

3 **Phase 3:** A new compressor has been installed. The compressor will be used at Colruyt Group in the after life of the Don Quichote project.

FIGURES

H2 Produced

Total H2 production
(Feb 14 – Nov 17): **61.653 Nm³**
Highest monthly production
by PEM el. (June 2017): **4.428 Nm³**
Average monthly production
(Feb 14 – Nov 17): **1.011 Nm³**



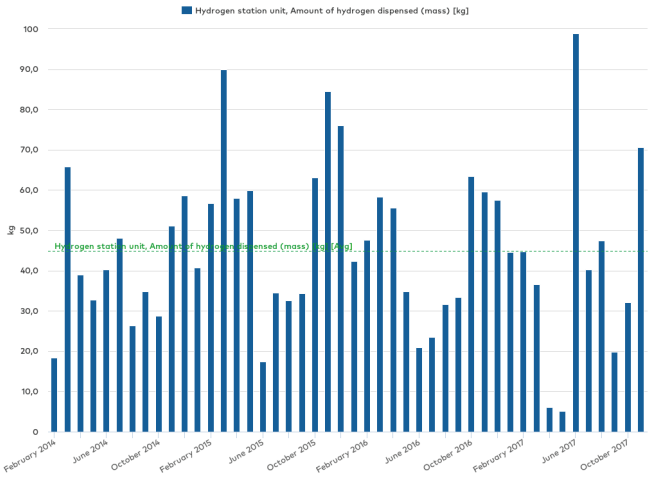
In this graph, the cumulative amount of hydrogen produced by the alkaline and PEM unit is shown. The alkaline electrolyser already existed from the project start and generated data. The PEM electrolyser became operational as of September 2015 and first data became available as of February 2016.

**Graphs are exported from Sofi System of Thinkstep*

thinkstep
SoFi

H2 Dispensed

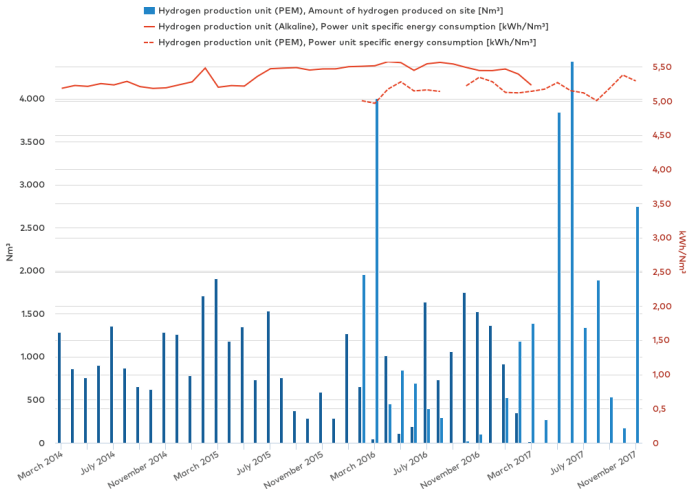
Amount of H2
dispensed From
(Feb 14-Nov 17): **2066 kg**



Is this graph, the monthly amount of hydrogen dispensed is shown which averages around 45kg. Hydrogen is mainly dispensed to fuel cell material handling vehicles. The variation in demand mainly depended on the operational situation at the site of Colruyt Group and the growing number of material handling vehicles.

Electricity consumption (average)

Alkaline:
5,38 kWh/Nm³
PEM:
5,18 kWh/Nm³
➤ 7 % lower energy consumption for PEM



In this graph, the monthly hydrogen production for alkaline and PEM unit is shown together with the specific energy consumption. First data for PEM became available as of February 2016. Alkaline data stopped in April 2017 due to decommissioning for a technical upgrade. Specific energy consumption varies. From these findings it is clear that there is a substantial 'overhead' deficit when there is little demand for the hydrogen. The full potential can only be achieved in a continuously operational plant generating hydrogen continuously.

KEY ACHIEVEMENTS

- At the Colruyt Group site in Halle (Belgium) a unique European project, covering two types of electrolysers (alkaline and PEM), two types of compressors (centrifugal and membrane), a fuel cell system and a dispenser, has been realised and demonstrated.
- The hydrogen produced by the Don Quichote-system is a strong example of sector-coupling, connecting green electricity with hydrogen production, used for logistics (material handling equipment), mobility (cars, trucks) and power (fuel cell, grid services).
- The demonstration is successfully integrated in an existing 'distribution centre', resulting in knowledge/ experience on permitting procedures and safety regulations in operation.
- The connection of the fuel cell to the power grid, in order to be able to deliver grid services, has been approved by the local electric utility.
- A high share of renewable electricity is crucial for environmental benefits of using hydrogen as energy carrier: this is the case at the Colruyt site where >80% of the used electricity for hydrogen has been produced by wind and solar.
- Benchmarking of 'mature' alkaline electrolyser with 'first of a kind' PEM electrolyser showed already a higher efficiency of the PEM towards the alkaline electrolyser.
- PEM-electrolyser technology is evolving rapidly: during the timeframe of Don Quichote, the need for precious metal catalyst already reduced by 50%.
- The Life cycle analysis (LCA) results of both electrolysers are clearly dominated by the utilisation grade (full load operating hours, lifetime, electricity consumtion, source of electricity).The comparison of the life cycle results reveals benefits for the PEM electrolyser due to the lower specific electricity consumption during the utilisation and better LCA results for the manufacturing of the system.
- An upscaling exercise for Belgium, Germany and Iceland learned that at sufficiently large scale, hydrogen will be able to compete with fossil fuels in the near term – given that fossil fuels will pay for environmental impact caused by their use.
- TCO calculations within the Don Quichote project learned that the hydrogen cost is still high for a small installation with a low utilisation factor, but at a higher load and scale, the TCO can be optimised to a level that enables a positive business case in combination with the material handling case.
- The GreenHouse Gas (GHG) emissions of the demonstrated alkaline and PEM electrolyser are below the threshold of 36.4 g CO2eq/MJ (www.certifhy.eu) when using 100% electricity from renewable energy sources (i.e. from wind turbine and/or PV panels). This is the case at the Colruyt site were electricity is produced by e.g. solar, wind.
- Don Quichote received worldwide attention by delegations coming from Europe, United States, China and Japan.
- After ending the European financial support, the built hydrogen infrastructure will be continued in operation and will be expanded, with increased capacity (+ 30 Nm^3/h) of the electrolyser, the storage, a significant increase of the material handling fleet (75 forklifts, indoor dispensing) and an additional possibility for 700 bar public fuelling (in the framework on the Interreg project 'Hydrogen Region 2.0').

PARTNERS

COLRUYT GROUP

EUROPEAN HYDROGEN ASSOCIATION EHA

SCIENZA TECNICA FAST
Federazione delle associazioni scientifiche e tecniche
fondata nel 1897

European Commission

ÍSLENSK NÝORKA ehf
ICELANDIC NEW ENERGY Ltd.

HYDROGENICS
SHIFT **POWER** | **ENERGIZE** YOUR WORLD

thinkstep

TÜVRheinland®
Precisely Right.

WaterstofNet

The project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement N° 303411

Contact: Wouter van der Laak wouter.vanderlaak@waterstofnet.eu +31 6 20 94 31 04