For more information, check http://www.don-quichote.eu/

This project is co-financed by funds from the European Commission under FCH JU 2011

Grant Agreement number 303411

Project Information	
FCH JU GA N°	**303411**
Acronym	**Don Quichote**
Title	**Demonstration of new qualitative concept of hydrogen out of wind turbine electricity**
Funding Scheme	**Collaborative Project**
Duration	**1 October 2012 – 1 October 2017**

Deliverable Information	
Title	**Publishable summary**
Responsible	**Hydrogenics & WaterstofNet**
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Status	**Final**
Level	**Public**
Date	**August 2015**

Inhoud

1. General

The EU, recognizing the need to step up efforts to reach its renewable energy objectives, agreed on mandatory targets of 20% renewable energy for electricity production and 10% renewable energy in transport, including hydrogen produced by renewable sources (COM 2009/144). The EU Energy 2020 Communication (COM 2010/639) indicates that the EU intends “re-establishing Europe’s leadership on electricity storage (both large-scale and for vehicles). Ambitious projects will be developed in the fields of hydro capacity, compressed air storage, battery storage, and other innovative storage technologies, such as hydrogen. These will prepare the electricity grid at all voltage levels for the massive uptake of small-scale decentralized and large-scale centralized renewable electricity.”

The use of hydrogen as a clean energy carrier, able to store large quantities of energy for longer periods of time, could significantly contribute to reach these goals by balancing intermittency and enabling a more efficient use of renewable energy production, as well as linking renewable produced electricity to clean innovative transport solutions. Several components of a renewable energy storage system using hydrogen, including the electrolysis of water by using renewable electricity, hydrogen compression and distribution have seen important improvements in performance and reduction of costs.

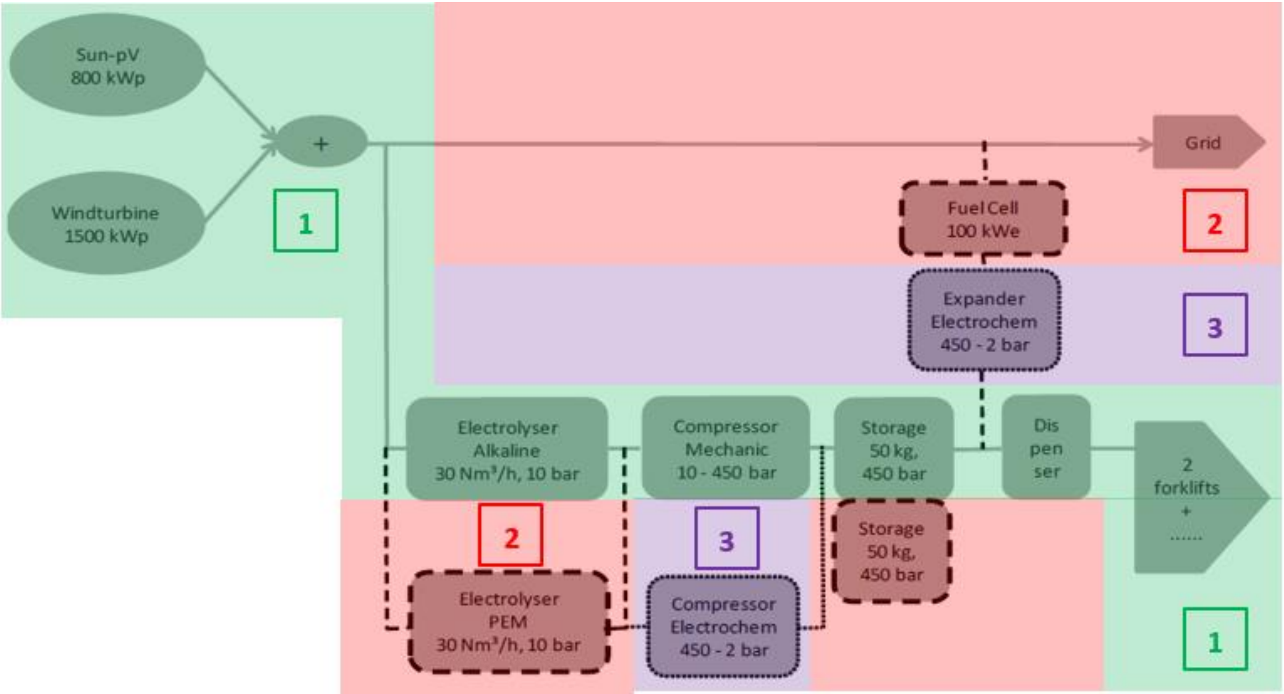
The Don Quichote project (Grant Agreement N°: 303411; starting date: 1 October 2012; project duration: 5 years; partners: Hydrogenics, HyET, WaterstofNet, Colruyt, TUV Rheinland, Joint Research Centre, Thinkstep (PE International, Icelandic New Energy and FAST/European Hydrogen Association) aims to contribute to the Commission efforts to create large scale energy storage projects by demonstrating the market readiness of these components, integrating them into a comprehensive industrial system connected to a hydrogen refuelling facility to supply hydrogen to a fleet of material handling vehicles in a large logistics centre. As such, the Don Quichote project contributes to intensively demonstrate and validate the system level technology readiness and generate further facts based data for the exploitation of renewable electricity to hydrogen fuelled sustainable mobility.

The project stepwise expands components of an existing hydrogen refuelling system with innovative, more efficient components, and integrating it with a renewable energy source, thereby realizing renewable energy storage capacity based on hydrogen. The hydrogen is used to refuel mobile applications or to feed a fuel cell connected to the grid. This project combines the targets on increasing renewable electricity, grid balancing, sustainable mobility and the use of clean hydrogen in a very concrete way.

The schematic below depicts the stepwise implementation and components in three phases:

1. the existing hydrogen refuelling station (phase I): alkaline electrolyser + membrane compressor + logistic applicatons (forklifts fuelled by hydrogen)
2. the existing hydrogen refuelling station is at first complemented (phase II) by PEM electrolyser technology, PEM fuel cell technology and hydrogen storage technologies (black dashed lines
3. in a next stage complemented (phase III) with a electrochemical hydrogen compressor/expander (black dotted lines).

The whole system is extensively tested and evaluated in performance, environmental, regulatory, financial and business potential terms.



2. Intermediate results

2.1 Important achievements until August 2015

In the table we summarised the most important achievements to date.

Project month	Achievements
M1 – M12 (Oct.'12-Sept.'13)	• development and implementation of a control system for the PEM electrolyser • development of PEM electrolyser, fuel cell and electrochemical compressor • testing of existing hydrogen refuelling infrastructure • preparation of permitting dossier and safety report for new components • identification of relevant regulations, codes and standards • scoping documentation of life cycle assessment (LCA) approach • data acquisition specification documentation
M13-M18 (Oct. '13-March. '14)	• PEM electrolyser assembly at Hydrogenics • Fuel cell system and PEM electrolyser stack in certification process • Operational data gathering on existing refuelling station ongoing • Permit request submitted (February 2014) • Additional information request from permitting authorities provided (March 2014) • First data for Sofi software being exchanged • LCA data gathering started
M18-M24 (March. '14- Sept. '14)	• Presentation of first LCA results • CE conformity inverter reached • Operational data gathering on existing refuelling station ongoing • Further development on electrochemical compressor
M25-M30 (Oct.'14-March '15)	• Report on test results and evaluation phase 1 • Concept report of bi-monthly statistics and yearly datasets • Updated report on pricing of renewable electricity and green certificates • Update report concerning progress of PEM electrolyser and fuel cell • Development of registration plan and operational diary for TCO • Operational data gathering on existing refuelling station ongoing • Preparations regarding monitoring phase II, installation phase III system (electrochemical compressor) and regarding TCO analyses
M31 – M35 (April '15 – Aug '15)	• Report on bi-monthly statistics • Installation PEM electrolyser and fuel cell finalised • Preparations regarding monitoring phase II • Operational data gathering on existing refuelling station ongoing • Operational testing of PEM electrolyser started

2.2 Yearly data sets

The Don Quichote project gathered full year data for phase I as of February 2014 till February 2015. The fueling station is fully operational throughout the year, the hydrogen production hours ranging from 20 hours to 70 hours per month. This is determined by the hydrogen demand, corresponding to the operational activity of the fuel cell powered fork lifts. In this way, the electrolyser functions on a non-continuous basis which has a high impact on the efficiency. On average, the electrolyser starts 1 or 2 times a day. Also, a 30 minute start-up period is needed from cold start situation to allow the production to reach the expected hydrogen quality levels. This is the primary reason for the high electricity usage which has been around 92 kWh/kg between January 2014 and 2015 and 112 kWh/kg between January 2014 and October 2014. It is also important to remark that the electrolyser system has to be kept above 0 °C. So, in cold periods with no demand for hydrogen, the electrolyser system has to be heated by electric tracing which requires electricity. A more continuous way of producing hydrogen will improve the efficiency of the hydrogen generation.

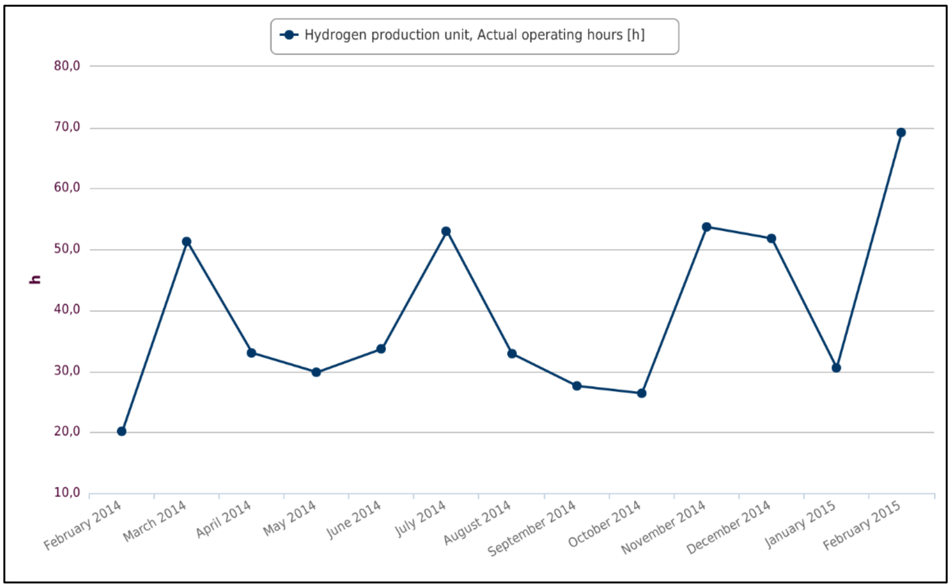


Figure 1: Operating hours of production unit

The amount of Hydrogen produced per month ranges between 41 kg (468 m³) and 153 kg (1707 m³) per month. The highest value of production has been reached in February 2015. Production amounts are stored in the system with daily production values.

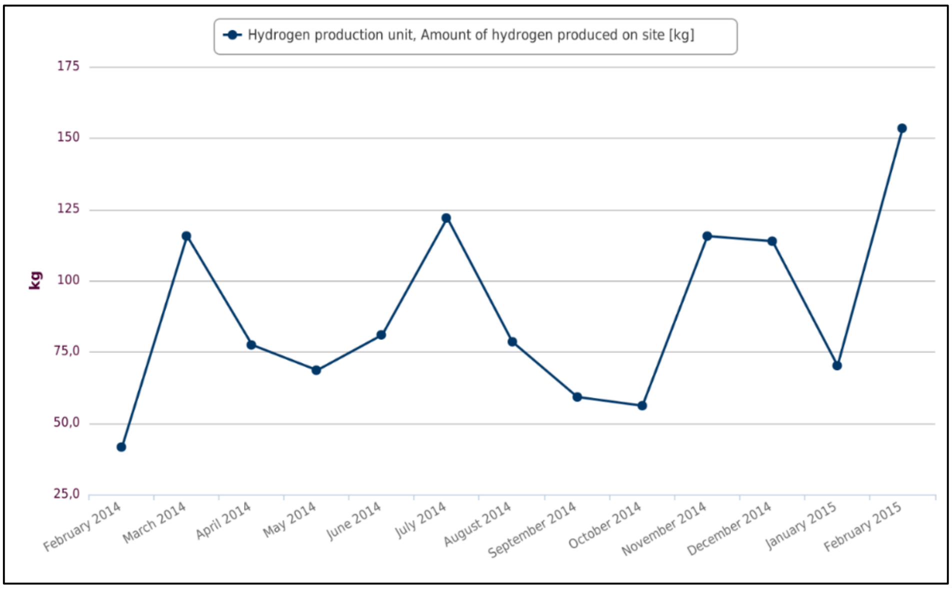


Figure 2: Hydrogen produced on-site

Hydrogen is being dispensed from the dispensing unit to on-site forklifts and a couple of other external vehicles each month. The values include all the dispensing that was conducted. Also difference in values between the produced and dispensed hydrogen has been measured which is a result of the vented and stored Hydrogen on site.

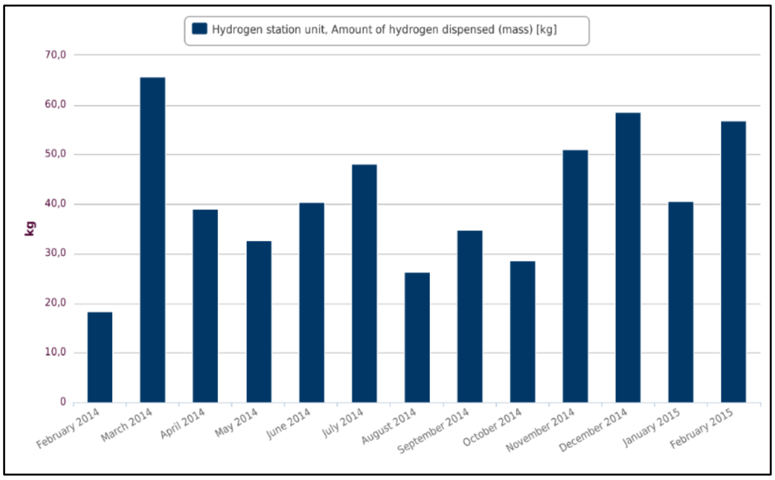


Figure 3: Hydrogen dispensed

Foto 1: Some applications which consume hydrogen

The amount of refuelings has accumulated to 766 times in February 2015 since February 2014. With a record amount of 86 refuelings in December 2014.

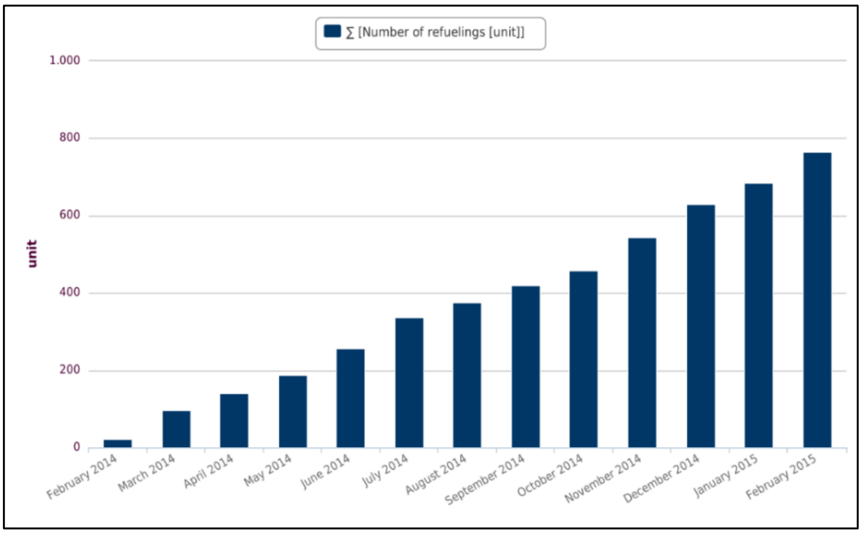


Figure 4: Number of refuelings

Down time information has been imported into SoFi on a monthly basis. Excluding monthly checks and yearly maintenance. The system has been down related to a couple of technical incidents, all of which have been fixed on a timely manner. Some major downtimes have been caused by:

- a leaking hydrogen coupling (May 2014)
- Utility Power Supply (UPS) back-up-batteries in May/June 2014
- A dispenser-screen (touch screen) did not function properly for 60 hours (June 2014). After the installation of a hardwired start button, fuelling has become available again.

Below you can see the technical availability of the system and downtimes with respective incidents.

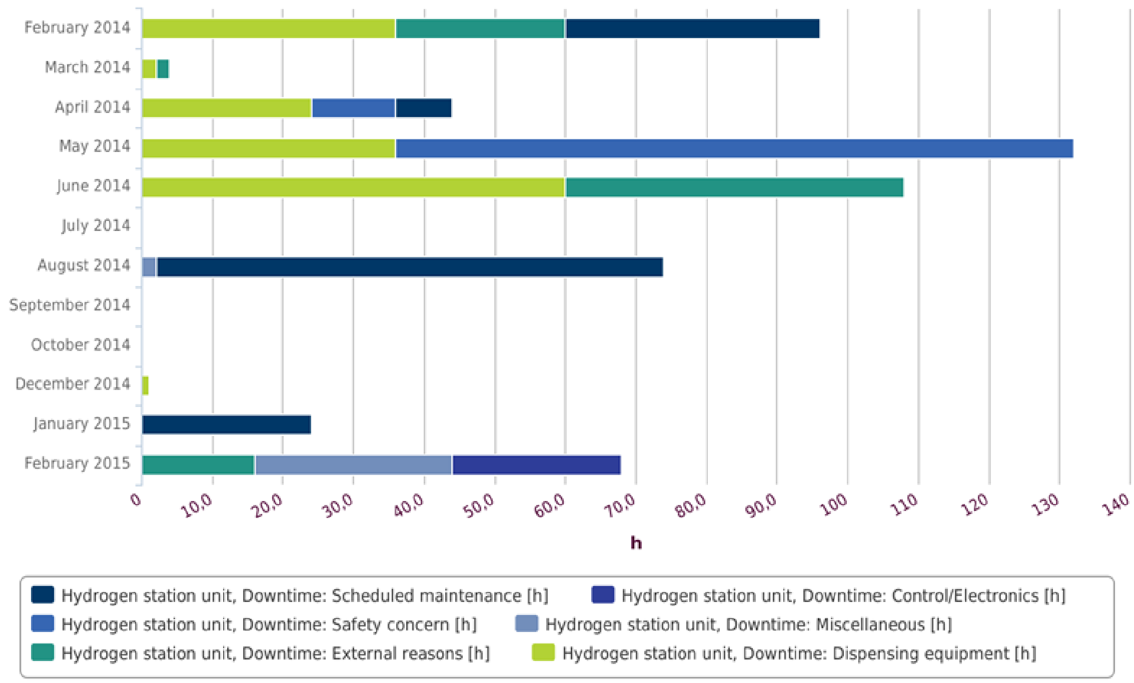


Figure 5: Technical availability and downtime

2.3 Status objectives and deliverables against the DoW

In this table, the status of objectives are presented untill **August 2015**. Where we foresee any problems in achieving the final target, an explanation is given.

Description target	Target	Current status/achievements until Sept. 2015	Probability of final target achievement (%)	Explanation if probability <100%
efficiency (WtT;well to tank)	Electrolyser 69% Compressor 85%	Stack at 77% efficiency (full production). BOP: to be monitored	100%	
cost of hydrogen delivered	<13€/kg	Related to cost of renewable energy. Phase 2 TCO analysis in progress Phase 3 demo cost unclear	80%	Possible higher capital cost of electrochemical compressor
hydrogen quality	ISO/DIS 14786-2 compliant	PEM unit qualified Compressor to be decided in phase 3 of project	100%	
Availability	>95%	Succesful site acceptance test. Measurements phase II starting Q3,2015	100%	
Operation within project	>25000 hrs	To be started	95%	Operational hours to demonstrate availability Amount of hydrogen to be produced will depend on business case for re-electrification
Durability	>10 yrs	Started. Designed for 50khrs operation with proper operational maintenance	50%	Depends on business model – cost of electricity and hydrogen use in order to demonstrate lifetime

2.4 Deliverables until March 2015

A summary about the deliverables until March 2015 is presented in the table. There are 2 deliverables behind schedule in WP 2. This is caused by the delays regarding the development and manufacturing of the PEM electrolyser. The reports will be delivered in Q4,2015. We also foresee that the electrochemical compressor will be delayed for about 6 months. Also, in WP3, 2 deliverables are behind schedule which are coupled with the just mentioned deliverables in WP2 (PEM electrolyser and the fuel cell). Also, in WP2, we expect a delay with the electrochemical compressor.

Deliverable production monitor (March 2015)	WP1	WP2	WP3	WP4	WP5	WP6	WP7
Deliverables total	14	6	6	2	6	4	2
Deliverables need to be delivered according to DOW until March 2015 (month 30)	7	5	4	1	3	1	0
Actual delivered deliverables untill March 2015	5	3	2	1	3	1	0
Deliverables behind schedule	**2**	**2**	**2**	**0**	**0**	**0**	**0**
To be delivered deliverables as of March 2015 (month 30)	9	3	4	1	3	3	2
Forseeable delayed deliverables	**0**	**3**	**4**	**0**	**0**	**0**	**0**

2.5 Project pictures

Foto 2: work in progress on PEM electrolyser (July 2015)

Foto 3: PEM electrolyser and fuel cell are installed (August 2015)

3. Next steps

The next most important steps for the Don Quichote project are:

- Start of phase II test program (Oktober 2015)
- Development of electrochemical compressor completed (December 2015)
- Start of phase III test program (June 2016)
- Continuous monitoring of complete system