Energy Storage – Hydrogen Injected into the Gas Grid via Electrolysis Field Test

by **Jesper Bruun[1], Thomas Graf[2], Henrik Iskov[3] and Bjarne Koch[4]**

In order to fulfil the Danish objective of 100% renewable energy in 2050, it is necessary to increase the focus on conversion between various energy sources and on storage of large quantities of energy. Surplus renewable electricity can be converted into hydrogen and stored in the gas infrastructure.

1. Introduction

Achievement of the Danish goal of 100% renewable energy by 2050 makes it absolutely necessary to focus on conversion between different energy sources and on the opportunity for storing large amounts of energy. Here, the natural gas grid and electrolysis play a crucial role. Power from wind and solar can be converted by electrolysis into hydrogen which can be stored in the gas grid (Power-to-Gas) [1].

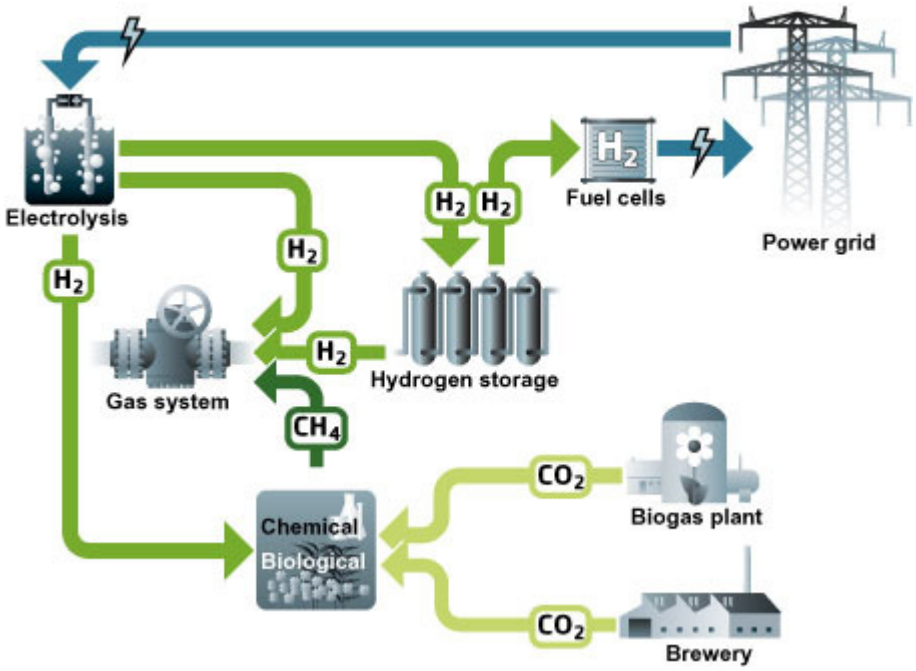

Figure 1 *Potential in integration of the electricity and gas systems through hydrogen [2].*

This project brings together key players in the Danish natural gas infrastructure, Energinet.dk, Dong Gas Distribution and Danish Gas Technology Centre, in a unique collaboration with IRD Fuel Cells to examine the consequences of injecting hydrogen directly into the natural gas grid via meter and regulator (M/R) stations.

[1] Jesper Bruun, jbr@energinet.dk, Energinet.dk
[2] IRD Fuel Cells
[3] Danish Gas Technology Center
[4] Dong Energy

1.1 Pilot projects with hydrogen in the network

Several projects are currently investigating the possibilities of mixing hydrogen with the gas transported in the network [3]. The Danish Gas Technology Centre has participated in a number of analyses, which show that:

- The steel pipes in the gas system can handle large quantities of hydrogen (approximately 10-15%), but there is limited experience with the impacts over an extended period.
- Other elements of the infrastructure would require modification, and it must be taken into account that hydrogen reduces the calorific value and Wobbe index of the gas.
- A lower Wobbe index may create problems for some gas-powered appliances.

In cooperation with the Danish Gas Technology Centre and IRD Fuel Cells, Energinet.dk and Dong Gas Distribution demonstrate what happens to the gas system when exposed to hydrogen over a long period of time. The project's objective is to determine whether the Danish natural gas infrastructure can be operated stably and safely with varying concentrations (up to 15%) of hydrogen.

1.2 Technical setup

In the project, a closed loop between two M/R stations is established. An electrolysis plant for on-site production of hydrogen is installed adjacent to the M/R stations and hydrogen is injected directly into the closed loop. The M/R stations' ability to handle large amounts of hydrogen (up to 15%) will be examined and the necessary modifications will be conducted. The electrolysis system will be developed as a stand-alone production unit with associated user interface, monitoring and smart-grid-ready control systems.

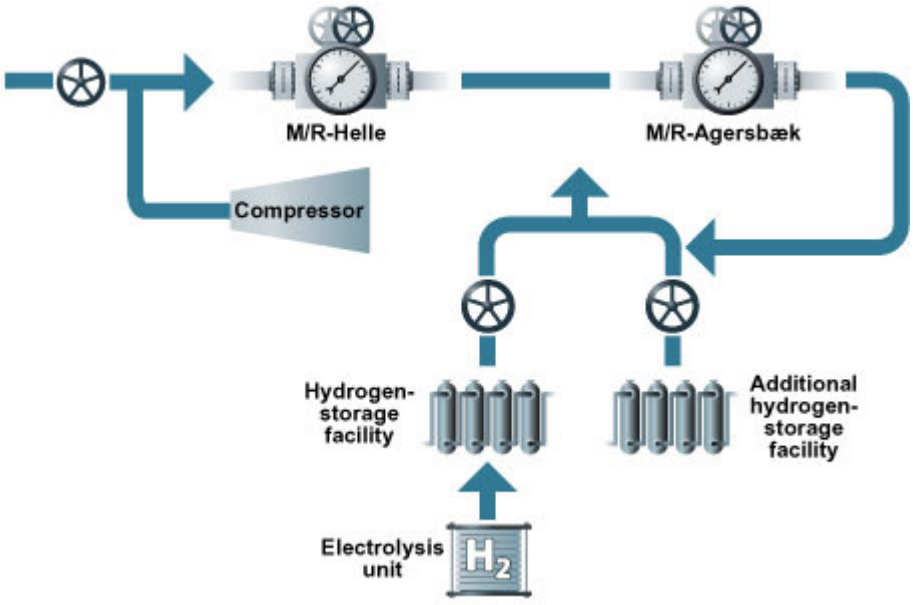

Figure 2 *Test setup for the Helle M/R station and the Agerbæk M/R station [4].*

A lengthy test period of 24 months allows for a comprehensive test program in which the interaction between electrolysis plant and M/R stations is investigated. The test phase also includes lifetime testing of critical components in both electrolyser and M/R stations.

2. The facilities

The entire Danish gas grid is established for natural gas transport and distribution without foreseeing future hydrogen admixture. Because of that the systems tolerance for hydrogen is yet unknown and is the key question for this project.

2.1 The meter and regulation stations

The tests in the project are conducted at the Helle M/R station (Energinet.dk) and the Agerbæk M/R station (Dong Gas Distribution). Both M/R stations have been decommissioned and are no longer used for natural gas transport, because the consumers are supplied from another branch of the gas grid. At the same time, they are both standard M/R stations similar to those which are used all over the country. It will therefore be possible to transfer the results direct to all other Danish stations.

Figure 3 *Helle M/R station (left) and Agerbæk M/R station (right).*

2.2 How is it done?

A closed system is established between the Helle M/R station and the Agerbæk M/R station which resembles the existing gas network structure as show at Figure 2. Today, there is a connection between the two M/R stations, and a new connection is to be established from the Agerbæk M/R station back to the Helle M/R station. Here, the pressure will be increased from about 4 bar to 80 bar by means of a compressor. At the Helle M/R station, the pressure will be reduced to approximately 40 bar, and further reduced to 4 bar at the Agerbæk M/R station. This test setup is similar to the existing network with its various process equipment.

A gas chromatograph is to be installed in the test loop to monitor the hydrogen content. This measurement will be used both to identify hydrogen leakage and to control the hydrogen content that can be increased by Energinet.dk's gas control center by an actuated valve.

2.3 The electrolysis plant

IRD Fuel Cells develops and manufactures electrolyzer and fuel cell systems based on hydrogen. Both the electrolyzer, an E1050, and the fuel cell, a µCHP, are used in the electrolysis plant.
IRD Fuel Cells has long time experience with developing Membrane Electrode Assemblies, known as MEA, which is best described as the heart of the fuel cells and electrolyzers. The company has also built complete Fuel Cell systems for many years.

The electrolyzer plant transforms electrical wind- or solar power to clean hydrogen which is introduced into the gas grid. The system can also transform hydrogen back to power by the installed µCHP.
The electrolyzer E1050 is prepared for the smart-grid, which makes it possible to generate hydrogen in case of excess power from renewable energy sources or in general when the price of the power is low, and power can be transformed to hydrogen in a meaning full time pattern based on the smart grid.
In the same way a smart grid ready µCHP is installed in the electrolysis plant. This device will transform hydrogen to electrical power when the net is short on electrical power and the power price is high.

The electrolyzer plant consist of one electrolyzer, E1050 and one fuel cell µCHP, which are shown in figure below. The electrolyzer needs clean water, which is split into oxygen and hydrogen. Hydrogen is stored in a composite storage cylinder at 50 bar. The electrolyzer can generate hydrogen directly at this pressure. Both demineralization system and the tank are part of the electrolysis plant as well.

The gas net will be able to introduce hydrogen from the cylinder whenever needed. The pressure for the gas net is transformed from max. 50 bar to 4 bar right after the cylinder.

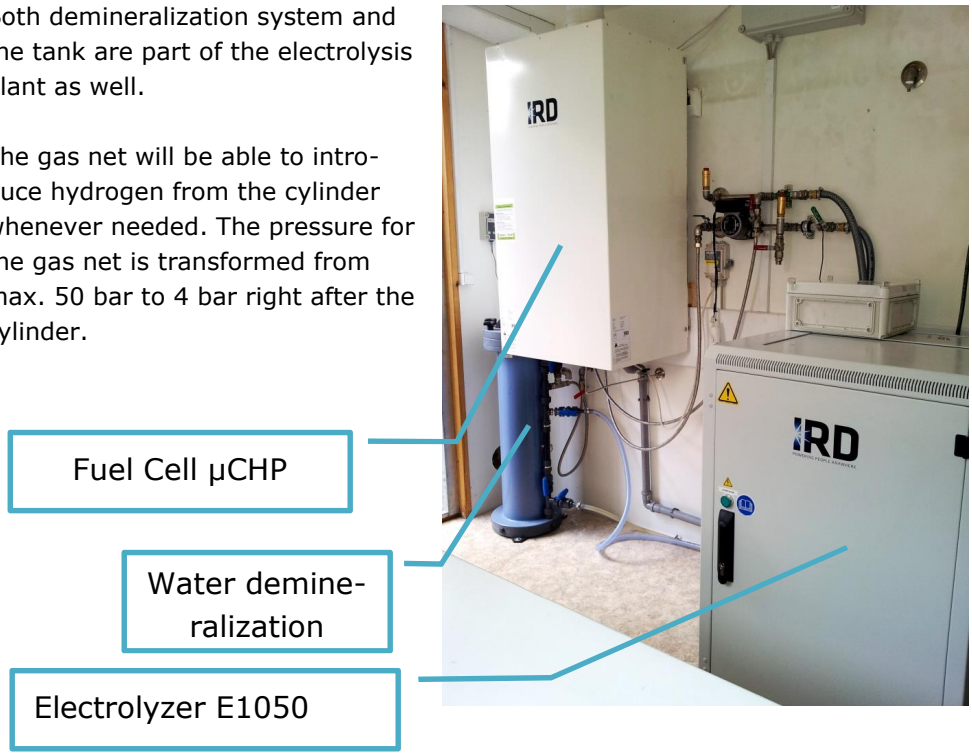

Figure 4

For years, IRD Fuel Cells has shown that renewable power can be transformed to hydrogen or in the opposite way from hydrogen to power. IRD Fuel Cells has been testing the µCHP system in ordinary households in the village Vestenskov. We believe the fuel cell µCHP and the electrolyzer E1050 to be a vital key to creating a totally renewable energy system.

Figure 5

Outlook:
The initial market for such fully renewable energy systems consisting of wind turbines and or solar PV farms could be places where the primo power sources are limited or unstable because of a weak grid e.g. islands using diesel or natural gas generators for power production.

Read more about IRD Fuel Cells at: http://www.ird.dk/

3. The project

The project is divided into three phases:

- The first phase will be a preliminary study, with the first adaptation measures being recommended on the basis of a review of the M/R stations.
- The second phase will cover the construction work and the establishment of the test loop.
- The third phase will be the test phase, with the stations being operated with natural gas and hydrogen mixes containing up to 15 % hydrogen.
- When the test installation is established in the beginning of 2015, the test will run over a 24-month test period with varying natural gas and hydrogen mixes.

3.1 Project plan

During 2014 the documentation of the MR stations has been worked through and possible weak points regarding hydrogen tolerance are being handled. A leakage test with formier gas (90 % N2 and 10 % H2) is being performed for the methane tight installations. A HAZID workshop of the total test setup is being performed to ensure that a safe and robust test setup is being established.

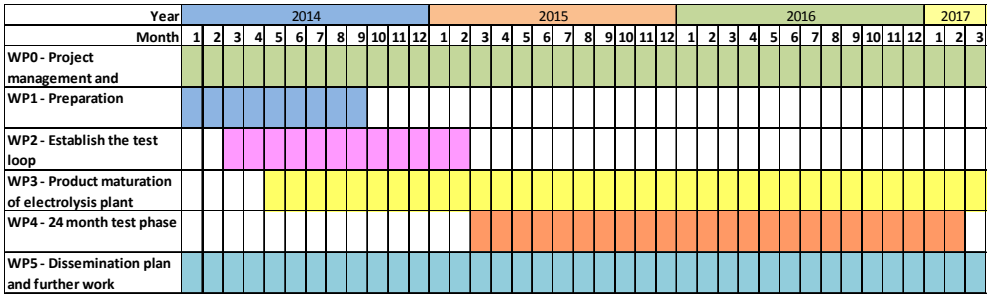

Figure 6 *Detailed project plan.*

4. Expected results

Through the project, knowledge will gained on what it will cost to prepare the stations for handling hydrogen.

The past ten years have seen both national and EU projects which have examined infrastructure components such as pipes, meters, process equipment, gas storage facilities and end-user installations to discover their suitability for hydrogen and natural gas operation. However, the Agerbæk/Helle project is the first to test such high hydrogen concentrations over a two-year period.

If the hydrogen impact causes damage to the material, the damage may not be visible until the material has been exposed to hydrogen over a long period of time. On project completion, the projects partners will know how the gas system is to be maintained in the future and how a reliable green gas system can still be ensured.

5. Project deliverables

The project results in a practical, public guideline that describes how the M/R stations and gas grid must be adapted to handle the injection of hydrogen in the natural gas grid, including consequences for regulatory approvals and operation & maintenance.

References

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Annex 1. Projects partners

Active Partners	
Energinet.dk	
Danish Gas Technology Centre (DGC)	
Dong Energy/ Dong Gas Distribution	
IRD Fuel Cells	
Additional Funding	
Energy Technology Development and Demonstration Program (EUDP)	EUDP Energiteknologisk udvikling og demonstration