Task 24: "Wind Energy and Hydrogen Integration"

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Task 24: “Wind Energy and Hydrogen Integration”

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1 Purpose

The purpose of Task 24 is:

- Explore in detail all possible issues (technical, economic, social, environmental, market and legal) related to hydrogen production using electrolysis with wind energy.
- Explore in detail possible applications for hydrogen produced using electrolysis with wind energy, with special emphasis on wind and hydrogen integration by means of hydrogen storage and electrical conversion that balances the original wind energy production.

2 Framework

There is currently a broad interest in hydrogen production by means of renewable energy sources, as hydrogen is expected to be one of the main energy carriers in the near future. The IEA HIA has studied several possible renewable energy sources for hydrogen production. Within the current set of possibilities, water electrolysis by means of wind energy ranks high as a competitor to fossil fuel in terms of technical and economic feasibility.

Today, both water electrolysis and wind energy technologies are considered mature, although R&D efforts are still undertaken to enhance performance and cost savings in both technology fields. In principle, however, water electrolysis technologies were not conceived for such variable input conditions as those inherent to the nature of wind resources. Therefore, the current state of the art must be upgraded largely to avoid redundant power electronics. System integration improvements are expected to increase efficiency and reduce capital and O&M costs.

Although hydrogen applications are virtually unlimited, transportation and early markets in portable applications are expected to be near-term drivers for advancement of the hydrogen economy. At the same time, there is an interesting stationary application that arises related to wind energy and other renewable energies such as solar PV. Their inherent variable nature presents integration problems for market and grid operators. These conditions may retard their development in certain markets (e.g., wind energy in Denmark, Germany or Spain), where market penetration has already occurred. Storage systems can provide a solution to this problem by allowing wind energy to be stored closer to conventional energies, thereby increasing wind energy’s capability to follow demand, guarantee a desired amount of energy, offer a flat curve or a more smoothened curve, etc.

The fully integrated wind and hydrogen application connects wind technology with various hydrogen related technologies such as electrolyses (for production), hydrogen to electricity converters (for utilization), and storage systems.

If wind farms can be coupled to energy storage systems, wind energy will become available to offset the growth in network capacity. Furthermore, wind farms would become multi-purpose, decentralized producers of either electricity or hydrogen for fuel when the automotive industry enters mass production of hydrogen-fuelled vehicles. In the short term, marginal but significant benefits can be obtained by improving dispatch ability and offering reserve power and grid services. In any case, the goal is to enhance the value of wind electricity itself.

Another important niche market will be off-grid systems relying solely on renewable energy sources. It makes sense to include these systems in the scope of this annex due to the inherent high cost of off-grid power systems; their role as an early adopter application; and the reality that most current operational wind/hydrogen applications are serving off-grid applications. Projects have been developed or proposed in various countries. These represent a good starting point for learning experience since they include very different stakeholders from every segment of the value chain, including research institutions, equipment manufacturers, and utilities.

3 Members

Two new participants joined during 2009: Statoilhydro (Norway) and Hydrogenics (Canada), both of them electrolyze companies, so nowadays the group in compound by 24 members listed in the table below:

Table 1: Actual Task 24 Members.

	EXPERT NAME	INSTITUTION NAME	Country
1	Luis Correas (Operagent Agent)	Aragon Hydrogen Foundation	Spain
2	Ismael Aso	Aragon Hydrogen Foundation	Spain
3	Rupert Gammon	Bryte Energy Ltd	England
4	Ken-ichiro OTA	Yokohama National University	Japan
5	Mila Rey	Gas Natural	Spain
6	Pablo Fontela	Endesa	Spain
7	Klaus Stolzenburg (Subtask C Leader)	PLANET GbR	Germany
8	Claus Jorgensen	RISO	Denmark
9	Ernest Burkhalter	IHT	Switzerland
10	Eli Varkaraki	CRES	Greece
11	Javier Pino	Seville University	Spain
12	Rafael Ben	Ariema	Spain
13	Aaron Hoskin (Subtask A Leader)	Natural Resources of Canada	Canada
14	Raquel Garde (Subtask D Leader)	CENER	Spain
15	Salvador Suarez	ITC	Spain
16	Kevin Harrison (Subtask B Leader)	NREL	USA
17	Allan Schroeder	RISO	Denmark
18	Sam Miyashita	NEDO	Japan
19	Dennis Krieg	Juelich	Germany
22	Stein Trygve Briskeby	StatoilHydro	Norway
24	Dirk Van den Heuvel	Hydrogenics	Canada

Task 24 is divided into four subtasks which are explain in more detail in points below.

Subtask A: State of the Art

Subtask Leader: Mr. Aaron Hoskin, Natural Resources of Canada

In this subtask, the goal is to conduct an in-depth review of the current state of the art in wind turbines, electrolysers, and and the power electronics which allow for system integration,. A detailed review of recent and on going wind-hydrogen installations will also be performed that includes the current state of the art as well as lessons learned relative to hydrogen production using wind energy and fully integrated wind energy & hydrogen technology.

Subtask B: Needed improvements & system integration. Technology development on main equipment and system integration concepts

Subtask Leader: Mr. Kevin Harrison , Natural Renewable Laboratory (USA)

In this part of the study, the scope is focused on the two main components for hydrogen production, the wind turbine and the electrolyses, as well as the intermediate connecting components. The in-depth analysis will research a future technical optima. The goal of this subtask is not to provide an enhanced design for either equipment but to develop proper specifications.

This subtask has to address the following issues:

- The dynamics
- Electrolyses durability under a very dynamic workload
- Development of specific wind turbines

Subtask C: Business concept development

Subtask Leader: Mr. Klaus Stolzenburg, PLANET GbR (Germany)

This subtask categorises wind-hydrogen systems with regard to their main purpose (such as electricity storage or vehicle fuel production) and plant size. It looks into the regulations on electricity and on alternative fuels in various countries to assess the possible opportunities and obstacles they may generate for hydrogen derived from wind energy.

Subtask C analyses countries by region with respect to the potential that they could provide for operating commercial wind-hydrogen systems in the future. Current and completed R&D and demonstration projects are introduced and examined with respect to costs and with regard to learnings made.

Subtask D: Applications. Emphasis on wind energy management

Subtask Leader: Ms. Raquel Garde, CENER (Spain)

In this subtask, near term applications for the hydrogen produced shall be studied, with a special emphasis on one of the main applications pointed out in subtask C. This application is wind energy management within the wind & hydrogen full integration concept. Given the noticeable synergy between hydrogen and wind energy regarding their integration for a further approach of renewable energy sources with inherent non continuous and random nature, it is considered appropriate to deal with this application in a separate subtask.

It is important to note that hydrogen used as an energy storage system to manage wind energy has many other competitor technologies which can be used in a wide power and energy range and can cover several energy functions.

In this subtask we are going to describe briefly the different energy storage systems that can compete with hydrogen in wind power management services. We will take into account the problems of the grid due to high penetration levels of wind power in order to analyse and characterize the better use for hydrogen in this stationary application or other added value chains, compared to other technologies.

Finally, we will analyse in detail the components and performance of some demonstration projects listed below.

4 Activities and Results in 2009

4.1 Fourth Meeting

It was hold during the 15/17 th of April 2009 in Denver (USA) hosted by NREL (National Renewable Laboratory http://www.nrel.gov/) with the attendance of 11 members from 8 countries.

Figure 1: Attendees at fourth Meeting – NREL Facilities.

4.2 Fifth Meeting

The fifth meeting took place in Oldenburg (Germany) during 21-23 October, hosted by PLANET GbR (www.planet-energie.de) with attendance of fifteen members.

Figure 2: Attendees at Fifth Meeting – Oldenburg.

5 Case Wind-Hydrogen Project Studies

Main wind/hydrogen projects worldwide are being studied (Utsira (Norway), RES2H2 (Greece), Ramea and Prince Edward (Canada), Wind2H2 (USA), etc, and some results are shown below:

5.1 Sotavento Project (Spain)

This project was born thanks to a framework agreement between Gas Natural SDG and the Department of Innovation, Industry and Trade of the Xunta de Galicia for the development of renewable energy. In 2008 an agreement with the National Renewable Energy Center (CENER) was signed by Gas Natural to study, analyze and characterize the plant.

This facility is one of the largest global capacity where hydrogen is used in the energy management of a wind farm. Therefore, it could be used as a platform for the development of tests and studies in this type of facilities.

The facility uses the surplus electricity generated by the wind farm in an electrolyzer. This, from water and using electricity in four cells stacks, generates H_2 and O_2 (electrolysis).

The O_2, that is not going to be used in this process is released to the atmosphere and the H_2, produced at a rate of 60 Nm^3/h and a pressure of 10 bar, goes through a process of purification and drying to obtain a purity higher than 99.99%.

To increase storage capacity, the H_2 generated is compressed to 200 bar in two compressor groups supporting up to 61.8 Nm^3/h at 4 bar.

The storage system at 200 bar is composed by 7 blocks of 28 bottles each, with a maximum capacity of 1.725 Nm^3. These blocks are interconnected in two groups of H_2 storage, with the possibility of isolation of each group.

The storage H_2 can be used in a 55 kW engine in case of energy deficit. The compressed H_2 at 200 bar, is decompressed in a first stage to 14 bar and a second until the suction pressure of engine. The engine has a consumption of up to 70 Nm^3/h of H_2 at a pressure of 25-60 mbar H_2 and produces electricity to the wind farm grid.

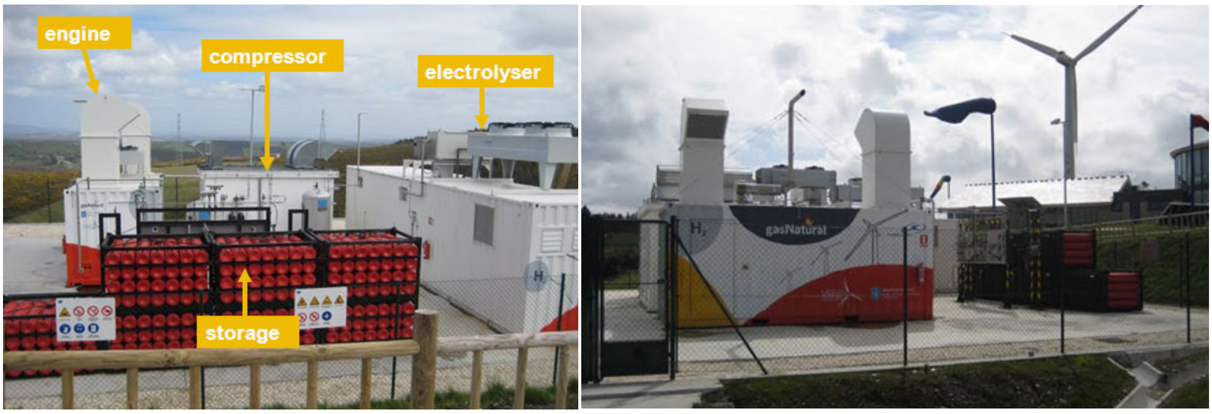

Figure 3: Pictures Sotavento project.

Some experimental results are shown below:

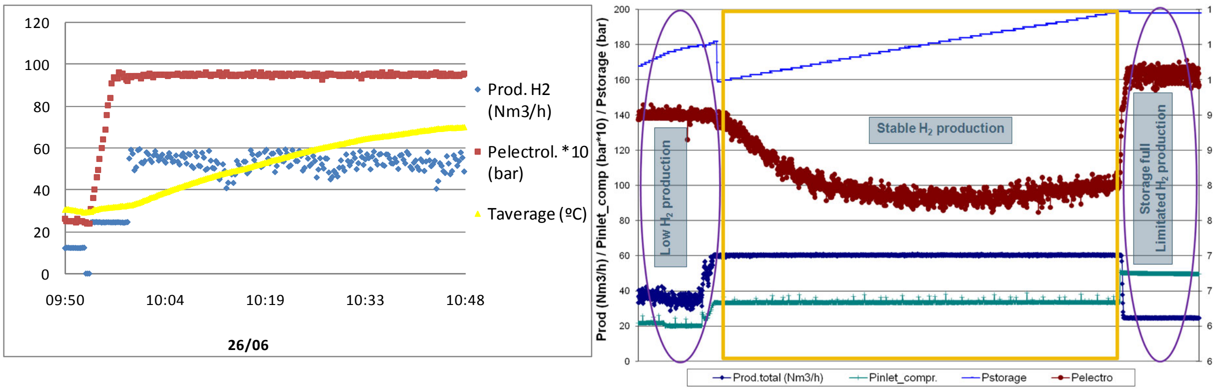

Figure 4: Left: Thermal electrolyser response, Right: Electrolyzer operation.

Lessons learned with the Project:

- Difficulties to obtain licenses because it doesn't exist legislation about this type of facilities.
- There isn't legislation about the sale price of the electricity produced by the engine.
- The control strategy of the equipments is not adequate to work with variable energy resources.
- The system is quite difficult to mode.
- Problems with the electronic power of the electrolyses.
- Harmonics generation

5.2 Hidrólica Project (Spain)

Promoted by Endesa, in Tahivilla wind park (Cadiz, Spain), main goals are:

- Energy optimization in wind farms
- Efficiency and exploitation improvements regarding primary energy
- Technical and commercial assessments of wind hydrogen systems
- Assessment of hydrogen storage and distribution systems
- Assessment of electricity production alternatives by means of H_2
- Technical and economic optimization of wind hydrogen plants
- Integration assessment of wind hydrogen systems in wind farms.

Main components are: PEM electrolyze 6 Nm^3/h, 5.5 Nm^3 hydrogen gas storage, and 12 kW fuel cell. Main lay is show below:

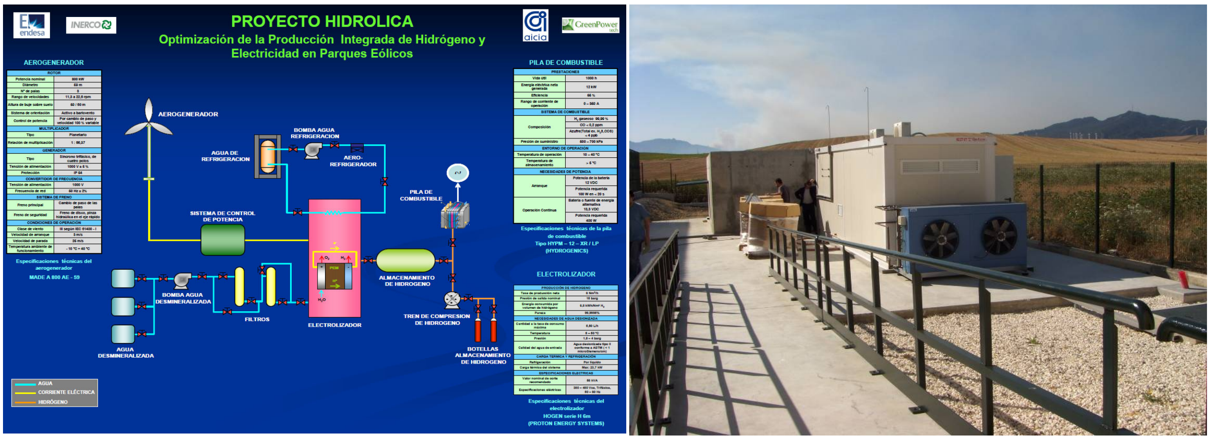

Figure 5: Left: Lay out Hidrolica Project, Right : equipment room.

Lessons learned with Hidrolica project:

- Converter (dc-ac fuel cell): Frequency transformer failure (3 moth delay due to high frequency transformer wrong design)
- Overall control system: Communication problems due to complexity in equipment
- High THD level in wind generator electrical power input
- Electrolyser : Deionised water feed pump failure (water leakage due to reversed draft)

Main conclusions are list below:

- A wind-hydrogen plant was tested and its viability demonstrated.
- Equipment time response has been quite good and more than enough to absorb wind farms variable output.
- Plant systems must be designed to keep a high efficiency working at all loads.
- Overall efficiency is around 14% which is too low (primary resource to electricity step is not considered). It is necessary to increase efficiency

5.3 ITHER Project (Spain)

The ***ITHER project, "Technology Infrastructure for Hydrogen and Renewable Energies***", promoted by the Foundation for the Development of New Hydrogen Technologies in Aragon, comprises a whole test and demonstration facility for photovoltaic, wind energy and hydrogen. This **4 M€** project developed during the last three years, has been completed in phase one in early 2008. Since December 2007 hydrogen from the sun is being produced.

The facilities display a complete picture of current PV and wind technology, consisting of a **635 kW wind farm** with three different turbines, a **100 kW grid connected photovoltaic** installation (three panel technologies, four different sun-tracking systems), and an isolated 2.7 kW photovoltaic application (1 kW concentrated PV, 1.7 photovoltaic roof with two advanced panel materials thin film and amorphous). The facility includes hydrogen production by a PEM and an alkaline electrolyser, storage (low pressure and high pressure) and fuel cells. Up to date, it is the only renewable-to-hydrogen project in the world that includes so many different technologies.

The hydrogen produced is used for mobile applications, for two end users: **20 hydrogen bikes**, and to feed a **hydrogen kart,** which take part in *FormulaZero* racing. *FormulaZero* (FZ) is an European racing that promotes a zero emissions karts championship based on fuel cell technology. The championship begins with a college edition, starting from bases and material support for teams (an 8 kW PEMFC). Different University teams (England, Holland, Belgium, USA and Spain) must conceive, design and manufacture a kart zero emission based on hydrogen and FC systems, testing their technological capabilities.

The ITHER project serves as showcase for renewable electricity and hydrogen production, for training and researching purposes at the Foundation, as well as for raising awareness on the future energy challenges. Recently, the Foundation for Hydrogen in Aragon and Swiss-based Company Industry Haute Technology signed an agreement to jointly develop wind-to-hydrogen solutions in the range of **MWs.**

Figure 6: ITHER Project: IHT Electrolyser 50 kW, FormulaZero Kart, Hydrogen Dispenser.

6 Next Steps 2010

During 2010, sixth meeting will take place in may in Denmark, hosted by Riso, and last meeting Phase I, will take place in October in Huesca (Spain), Final reports related to Subtasks will be completed and several diffusion activities worldwide will be realized to show results and lessons learned, related to wind/hydrogen initiatives

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