Clean Hydrogen Production in Patagonia Argentina

S. Raballo, J. Llera, A. Pérez, J. C. Bolcich

This document appeared in

Detlef Stolten, Thomas Grube (Eds.):
18th World Hydrogen Energy Conference 2010 - WHEC 2010
Parallel Sessions Book 3: Hydrogen Production Technologies - Part 2
Proceedings of the WHEC, May 16.-21. 2010, Essen
Schriften des Forschungszentrums Jülich / Energy & Environment, Vol. 78-3
Institute of Energy Research - Fuel Cells (IEF-3)
Forschungszentrum Jülich GmbH, Zentralbibliothek, Verlag, 2010
ISBN: 978-3-89336-653-8

Clean Hydrogen Production in Patagonia Argentina

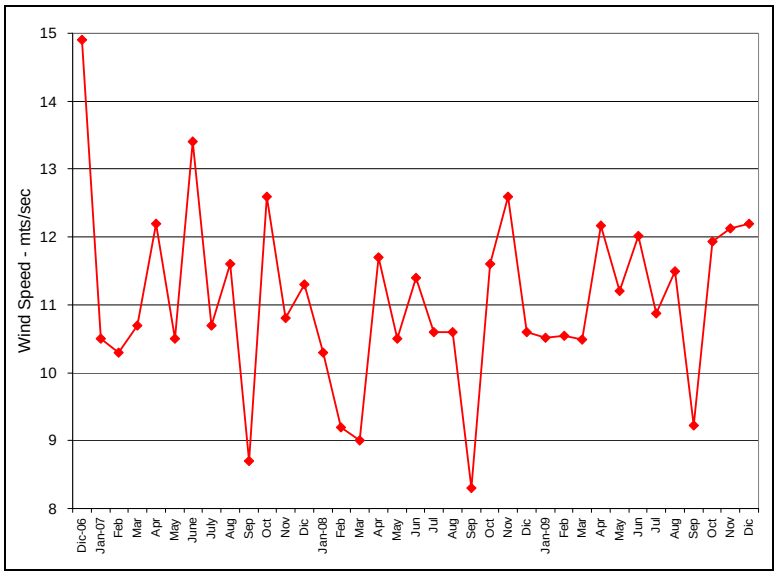
Sergio Raballo, **Jorge Llera**, **Ariel Pérez**, **Juan C. Bolcich**, Hychico S.A., Argentina

Hychico is a company part of the CAPSA – Capex Argentine group, this group has been engaged in the Exploration and Exploitation of Oil and Gas and in the production of Electric Power and Liquefied Petroleum Gases in the Argentine Patagonia for over 30 years.

Focused on renewable energies, Hychico's objective is Hydrogen production from wind energy in Patagonia. The company's vision is that hydrogen will play a significant role in world energy demand as an energy vector, and that industries belonging to the energy sector must turn their efforts and resources towards the development of sustainable energies.

Hychico's Hydrogen Plant started operating in January 2009. It is located in the outskirts of the City of Comodoro Rivadavia, Province of Chubut, and it is the first phase of the "Large Scale Clean Hydrogen Production in Patagonia Argentina" pilot project. The second phase, which will start shortly, will be the start-up of a 6.3 MW wind park which will feed 0.8 MW to the hydrogen plant, the remaining output will be sold to the national interconnected electric system.

The significance of the wind resource in Patagonia [1], recorded in our measurement towers equipped with instruments meeting international standards, can be appreciated in Figure 1.

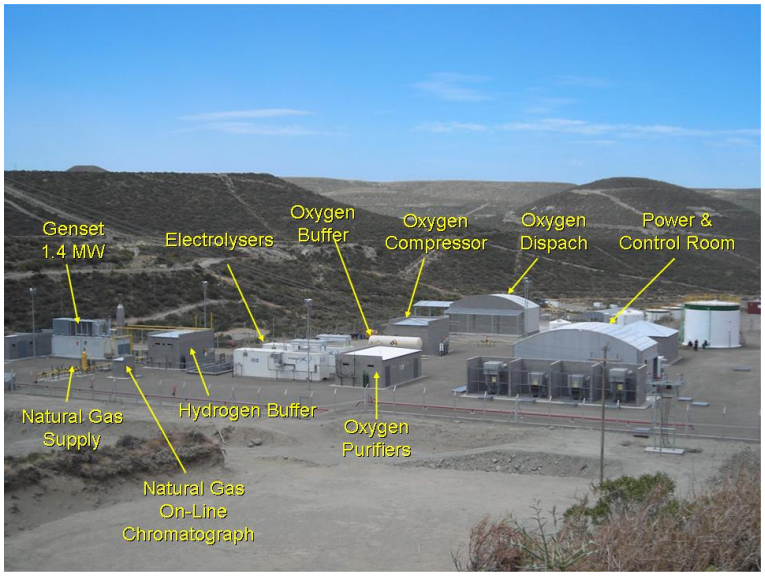


- Wind speed measured at 50m.
- 3-year Monthly Average Speed (Dec. 06 - Dec. 09): 11.1 m/sec., with a maximum of 14.9 m/sec.
- Net Average Capacity Factor: 47 %

Figure 1: Patagonian wind resource.

1 Hydrogen Plant

The plant has 2 hydrogen-producing electrolysers; this hydrogen is mixed with natural gas and used as fuel in a 1.4 MW Genset. In addition, there is a high pressure oxygen dispatch plant (220 bar) which supplies the local market.



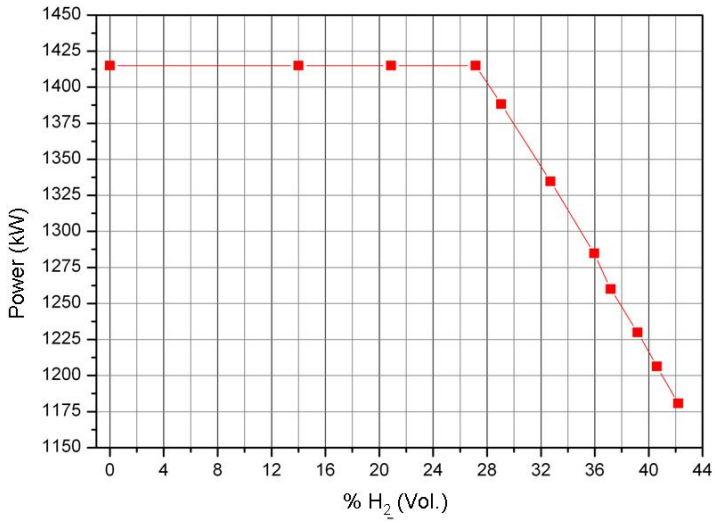
Both 325 kW electrolysers can operate up to a 10-bar pressure, producing a total flow of 120 Nm^3/h of H_2 and 60 Nm^3/h of O_2, both of them high purity gases (99.998 %). The produced H_2 is suitable to be used both in Internal Combustion Engines (ICE) and in Fuel Cells.

Figure 2: General view of the hydrogen plant.

The Genset has an ICE designed to operate with gases from biomass, pyrolysis, etc., and has been specially adapted to operate with rich and/or poor gas – hydrogen mixtures. It is worth mentioning that gases used are raw gases extracted from the Field, with no previous treatment. The rich gas has a 90% Methane content and the poor gas has a ~40% CO_2 content.

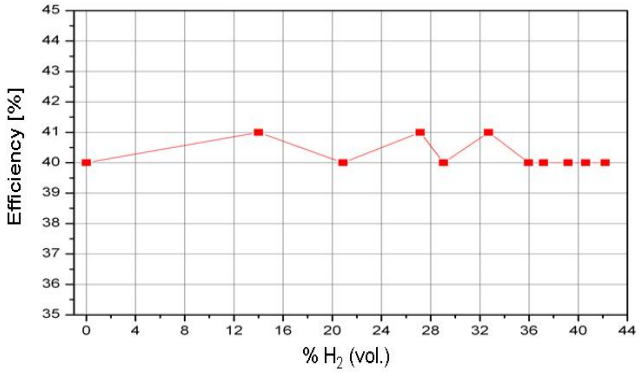
2 Results of the First Year of Operation

Genset: Rich Gas/H_2 Mixtures were used as fuel in the range 0-42% H_2 (vol).



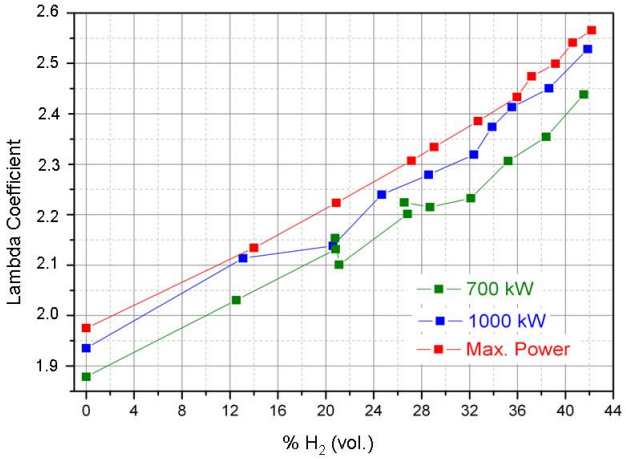
- In the range 0-27% H_2, the equipment was able to run at full power (1,415 kW).
- In the range 28-42% H_2, power was progressively reduced from 1,415 to 1,180 kW to avoid knocking.
- We consider that Max. Power (1,415 kW) could be increased at a higher (than 27%) H_2 content.
- We consider a higher (than 42%) H_2 content could be used.

Figure 3: Maximum Power vs. H_2 content.



- An average thermal efficiency of 40-41% at maximum power was achieved.
- Everything indicates efficiency remains constant to H_2 incremental contents in the mixture.

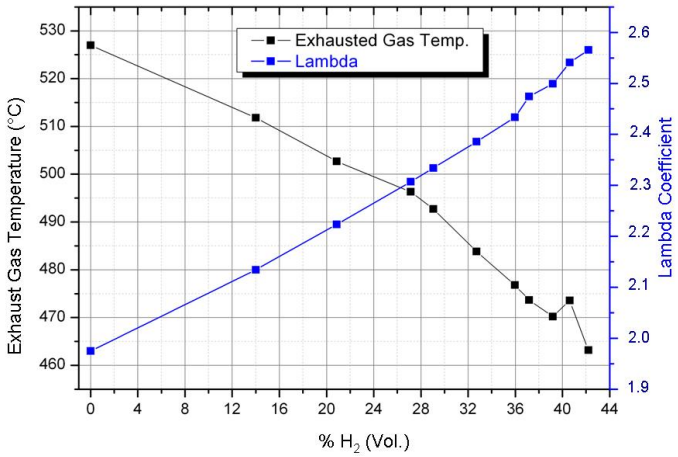
Figure 4: Efficiency vs. H_2 content.



- H_2 content increase requires a greater amount of air in order to slow down flame speed and avoid knocking [2].
- Work was carried out within a 1.9-2.6 Lambda range.
- Lambda coefficient is proportional to H_2 content.
- For the same H_2 %, Lambda coefficient is higher at incremental powers.

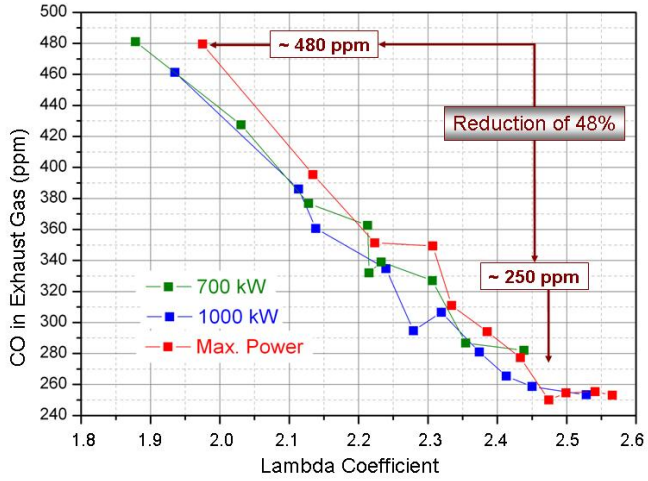
Figure 5: Lambda vs. H_2 content.

We consider that higher Lambda values may be reached and consequently the H_2 content could be increased.



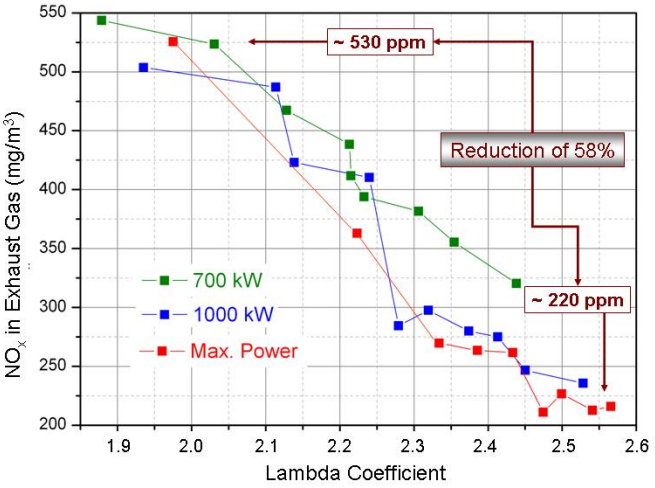
- Lambda incremental value (greater amount of air) with H_2 content means a reduction from 530 ºC to 460 ºC in exhaust gases temperature at maximum power.
- Exhaust gases temperature reduction allows the decrease of NOx and CO concentration [3].

Figure 6: Lambda vs. influence in exhaust gas temperature (max. power).



- Exhaust gases temperature reduction due to Lambda coefficient increase has brought about a 48% CO content reduction in exhaust gases.
- This CO content reduction is observed throughout the range of powers.

Figure 7: Lambda & its influence on CO reduction.



- Exhaust gases temperature reduction as a result of Lambda coefficient increase has brought about a 58% NOx content reduction in exhaust gases.
- Such NOx reduction is observed in the tested powers, i.e. 700 kW, 1,000 kW and Maximum Power.

Figure 8: Lambda vs. NOx reduction.

- As we approach the engine's rated power, a greater NOx content reduction is verified.

3 Genset: Conclusions and Next Steps (Year 2010)

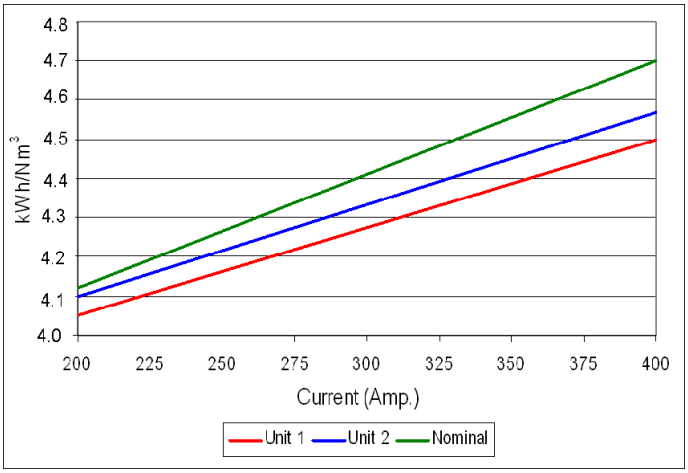
- Rich Gas/H_2 Mixtures were used as fuel in the range 0-42% H_2 (Vol.).
- In the range 0-27% H_2 the equipment was able to run at full power (1,415 kW).
- In the range 28-42% H_2, power was progressively reduced from 1,415 to 1,180 kW.
- An average efficiency of 40% was achieved.
- The replacement of methane for H_2 in the mixture means a CO_2 reduction of approximately 1,000 Tons/year and a NOx reduction of approximately 15 Tons/year.
- Based on the technical possibility of further increasing Lambda coefficient, tests will be run aimed at:

- Keeping Genset Maximum Power even with mixtures with over 27% H_2 content.
- Increasing H_2 content above 42%.
- Reducing exhaust gases emissions.

- Tests will continue with Poor Gas and Hydrogen mixtures in order to evaluate the effect of higher CO_2 content in gas on the Genset's powers and emissions.
- The possibility of incorporating Pure Oxygen (from electrolysis process) in the Genset air feed, in order to observe its effects on efficiency and emissions, will be evaluated.

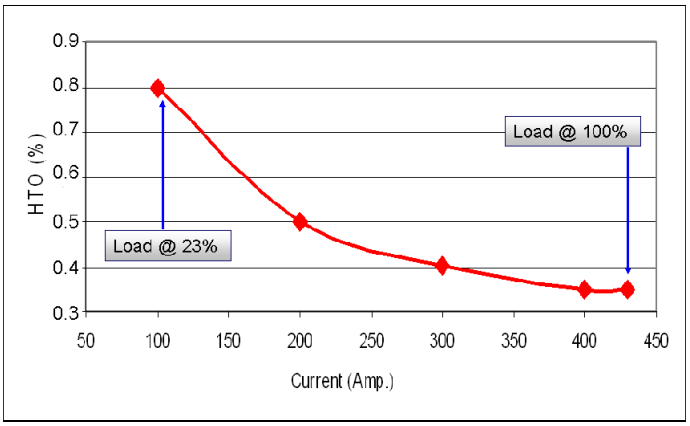
4 Electrolysers

- Electric consumption measurements were carried out on each cell stack.



- The linear correlation among hydrogen production, current and consumed power is verified [4].
- Electrolysers' performance is obtained by integrating that of all cell stacks.
- 4.1 - 4.6 kWh/Nm3 specific consumption range.
- Electrolysers have shown a better performance to the one defined by the manufacturer.

Figure 9: Electrolysers average specific consumption.



- Electrolysers are able to operate in the 23-100% range of maximum production.
- Cross contamination measurements are carried out (H_2 in O_2 and vice versa) in order to guarantee optimum quality and safety standards [5].
- Wide equipment Turn Down is favourable for Wind Turbine-power fluctuations.

Figure 10: Hydrogen concentration in oxygen line (HTO) in terms of production ratio.

5 Electrolysers: Conclusions and Next Steps (Year 2010)

- Specific consumption of 4.1 - 4.6 kWh/Nm^3 was achieved.
- H_2 and O_2 are produced at 99.998% purity, being H_2 suitable to be used both in ICE and Fuel Cells.
- A 90 Nm^3 H_2 buffer proved to be advantageous to this application, aimed at "softening" the electrochemical process inertia.
- 23-100 % Turn Down capacity was tested and we believe it could be increased considering HTO values obtained at lower production ratios.
- Equipment behaviour and gas purity will be determined in the whole range of operation.
- Available 3-year wind resource measurements will be used as input signal to the electrolysers, in order to simulate wind park behaviour.

6 General Conclusions and Hychico Goals

- Hychico has started up a high purity H_2 and O_2 production plant using electrolysis.
- Equipment applications and power match industrial scale with state-of-the-art technology.
- Hychico will continue to gather experience in H_2 state-of-the-art technology operation, also seeking to:
    - Carry out the Wind Park construction and its connection to electrolysers.
    - Develop Strategic Partners with Technology Expertise, thus assuring the concretion of ambitious projects.
    - Achieve a competitive advantage for Argentina, in a market that will be CLEAN and SUSTAINABLE energy-demanding in the medium term.

References

[1] K. Mönnich et ál. Wasserstoff aus Windenergie in Ost-Patagonien – Eine Machbarkeitsstudie-. DEWI Magazin N° 23, August 2003.

[2] L. Das. Hydrogen-Oxygen reaction mechanism and its implication to hydrogen engine combustion. Int. J. Hydrogen Energy. Vol. 21, N°8, pp. 703-715, 1996.

[3] F. Ma et ál. An investigation of optimum control of a spark ignition engine fueled by NG and hydrogen mixtures. Int. J. Hydrogen Energy. Vol. 33, pp. 7592-7606, 2008.

[4] H. Wendt and G. Bauer. Water-splitting methods in Hydrogen as an energy carrier: technologies, systems, economy by Carl-Jochen Winter and J. Nitsch, Springer-Verlag 1988.

[5] ISO/TR 15916. Basic considerations for the safety of hydrogen systems