“Improvements to Integrate High Pressure Alkaline Electrolysers for Electricity/H2 production from Renewable Energies to Balance the Grid”

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0 Executive Summary

This report summarizes briefly the main goals, tasks and results in the Elygrid project. The index and scope of the document has been defined in accordance with the requirements exposed in the justification procedure in the point "Publishable summary". This report describes the second period of the project from 01/05/13 to 31/12/14.

All the partners involved in the project have contributed for the preparation of this document.

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1 Summary description of the project

This section will be edited by the Commission as such. This summary report has to be updated at the end of each reporting period.
Please provide a summary description of the project context and the main objectives. The length of this part cannot exceed 4000 characters.

Global demand for the production of H_2 is set to grow exponentially. A further challenge will be a change from the hydrogen production processes based on fossil fuels which generate CO2 as an unwanted by product towards the use of H_2 mass production by electrolysers. This key market is considered strategic for the industrial partners looking towards H_2 as the environmentally acceptable solution to their growing energy needs.

The ELYGRID project, "Improvements to Integrate High Pressure Alkaline Electrolysers for Electricity/H2 production from Renewable Energies to Balance the Grid", aims at contributing to the reduction of the Total Cost of hydrogen produced via electrolysis coupled to Renewable Energy Sources, mainly wind turbines, and focusing on mega watt size electrolyzes (from 0.5 MW and up). The objectives are to improve the efficiency related to complete system by 20 % (10 % related to the stack and 10 % electrical conversion) and to reduce costs by 25%. The work has been structured in 3 different parts, namely: cells improvement, power electronics and balance of plant (BOP). Two scalable prototype electrolyzers will be tested in facilities which allow feeding with renewable energies (photovoltaic and wind).

The Consortium is integrated by a mix of academic, research and industrial partners. Industrie Haute Technologie (IHT) is the industrial partner inside the Consortium which is able to produce high pressure alkaline electrolysers in big size per unit (3.5 MW / 760 Nm3/h). The other partners involved in the project has been Fundación para el Desarrollo de las Nuevas Tecnologías del Hidrógeno en Aragón (FHa), Eidgenössische Materialprüfungs- und Forschungsanstalt (EMPA), AREVA Stockage Energie S.A.S. (AREVA), Forschungszentrum Jülich GmbH (FZJ), Vlaamse Instelling voor Technologisch Onderzoek N.V. (VITO), Lapesa Grupo Empresarial, Instrumentación y Componentes, S.A. (INYCOM or I&C), INGETEAM Power Technology, S.A., Commissariat à l'Energie Atomique et aux Energies Alternatives (CEA).

Figure: Picture of the Type S-556 electrolyser of IHT

The main project objectives can be summarized below:

- Define new operation conditions for improvements in performance and efficiency
- Development (synthesis) of advanced materials for electrolysis cell diaphragms/membranes to be used for field testing.
- Increase the efficiency of the stack by increasing operation temperature and electrolyte concentration
- Identify technical improvements related to the Balance of Plant (BOP) which represents approximately 15% of the CAPEX.
- Redesign power electronics, based on transistor instead of thyristor, less sensible to the electrical grid parameters. Power electronics optimization considering factors like efficiency, harmonics and reliability
- Design, develop and test the concept of converters for 3300 A DC and 800 V
- Field test of new stack with a 1,6 m diameter membrane
- Identification of technological market and local value-chain suppliers
- Outreach, social awareness and promotion of alkaline electrolysis coupled with renewable energy sources through demostration projects, field testing and integration
- Assessment on RCS aspects for electrolyzer technology to facilitate commercialization worldwide
- Comparative Life Cycle Assessment (LCA) studies carried out according to the practice guidance developed by the FCH JTI

2 Description of the work performed and main results

Please provide a description of the work performed since the beginning of the project and the main results achieved so far. The length of this part cannot exceed 4000 characters.

The main results will be listed by work package in the following points.

WP2 – Cell Improvement

The main progresses in this WP have been:

- Stable and durable membranes of the new composition have been manufactured and developed successfully by tape-casting at EMPA and by vertical coating at VITO. The materials investigated for using as composite membranes are synthetic or natural silicate based fillers supported in PPS. On the other hand, different concepts of membranes based on Zirfon have been developed.
- The membranes have shown similar results concerning cell voltage, membrane conductivity and gas purity than asbestos and Zirfon® based membranes. The different membranes have been assessed in the operation conditions (85ºC, 30 bar and 30% KOH) in order to know its chemical stability.
- From the perspective of physicochemical properties of the separator (ionic resistance, pore size and bubble point), the separators show quite promising behavior since they combine low ionic resistance with convenient permeability and bubble point.
- The partners involved in membrane development have looked for companies interested in the production of the best membranes at market scale.

Figure. Test bench electrolyser at EMPA

WP3 – Power Electronics

The main progresses in this WP have been:

- Construction of a prototype for the power electronics converter based on the topology selected in the previous period. The power of this prototype has been 2.6 MW. This new design achieves efficiency improvements round 10% taking into account the operation profile of the electrolyser.
- Complete validation of the unit at Ingeteam facilities. This validation has been carried out according to Ingeteam methodology prior to product commercialization, based on the following stages: initial wiring inspection, isolation and dielectric strength, cooling circuit, main parts of the power stack (busbar, capacitors, etc.) and temperature test.
- Assessment of the design for the "Advanced electrolysers" operating at high current densities. This new design would be based on the previous power stack designed, composed of different units running in parallel depending on the requirements of current and voltage. The conceptual design has been defined, taking into account the main changes in terms of control which should be taken in case a power electronics converter beyond 2.6 MW is demanded.

Figure. Power stack developed and test bench at Ingeteam labs

WP4 – BOP optimization

The main progresses have been:

- New BOP design for a Mega Watt Alkaline Electrolyser (MWAE) in order to decrease the costs of commissioning and erection on customer site. This new design has been conceived as a turnkey unit installed in a container. All engineering documentation has been delivered (P&ID, bill of material, safety analysis, 3D diagram, maintenance and regulation assessment).

- The new BOP cost has been decreased round 20% taking into account the same baseline of the previous technology at the beginning of the project.
- New control system for the electrolyser, including new operation states, warnings, alarms and operating modes coupled to RES. This control system has been completely validated, offering improvements in control quality and broadening the possibilities of electrolyser operation coupled to RES.
- The new BOP design has been modeled by Matlab in order to scale up some components and equipments (gas separators, heat exchangers, pumps, etc) taking into account different operation profiles. Besides, these models have been used to try to assess the behavior of this MWAE in a location with a high penetration of RES.

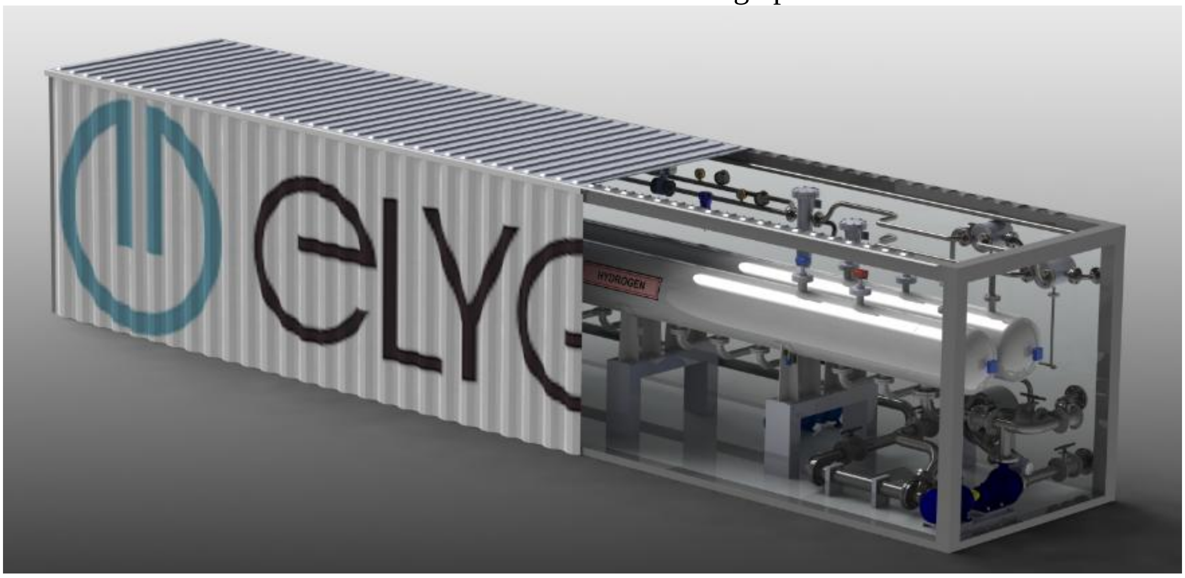

Figure. New BOP design

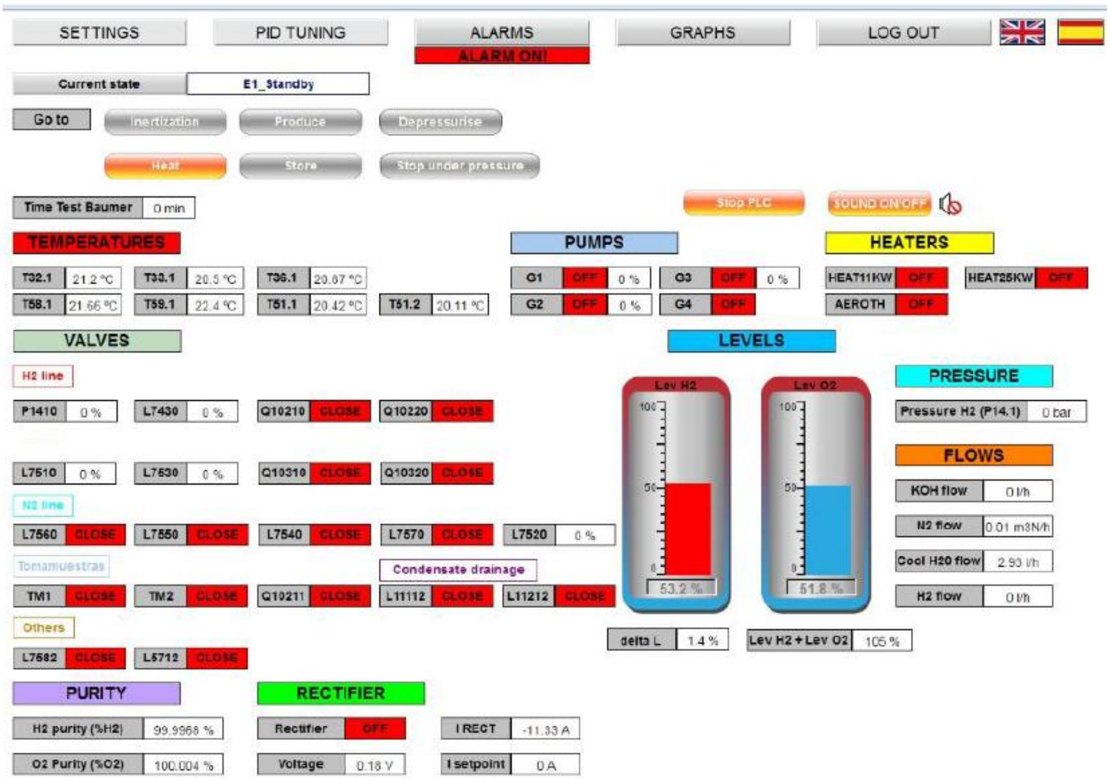

Figure. New control system diagram

WP5 – Field testing

The main progresses have been:

- The whole materials developed by the Consortium have been tested in the IHT test bench (130 mm membrane diameter) at real operation conditions (33 bar, 85ºC). Most of the materials have shown good chemical stability, values of voltage per cell and promising gas purities.
- The new cell topologies have been tested in the FHA test bench (1600 mm membrane diameter) with the goal of obtaining the most information as possible in the market size of this technology. This installation can operate also at real conditions (33 bar, 85ºC).
- The new cell topologies tested have increased an 8% the efficiency of the stack at the same current density of the previous technology. The gas purities of the unit are inside the safety range and enable to use the hydrogen in a fuel cell.
- The electrolyser at Walqa has been coupled to the renewable energy system (635 kW wind energy and 100 kW photovoltaic), providing good performance in terms of fast reaction in stand-by mode operation, quick changes in loads and good operation of the control system.

Figure: Picture of the electrolyser of IHT at FHA facilities

WP6 – Market preparation and dissemination

The main progresses have been:

- The RCS applied to an electrolyser in the European Union have been assessed so that this regulation can be taken into consideration for the project improvements.

- The cost of the megawatt electrolysers have been assessed before (1.6 tons H2/day per unit) and after (3.0 tons H2/day per unit) the project, showing a potential reduction of the cost of about 30%. Prices for large scale production plants have also been estimated.

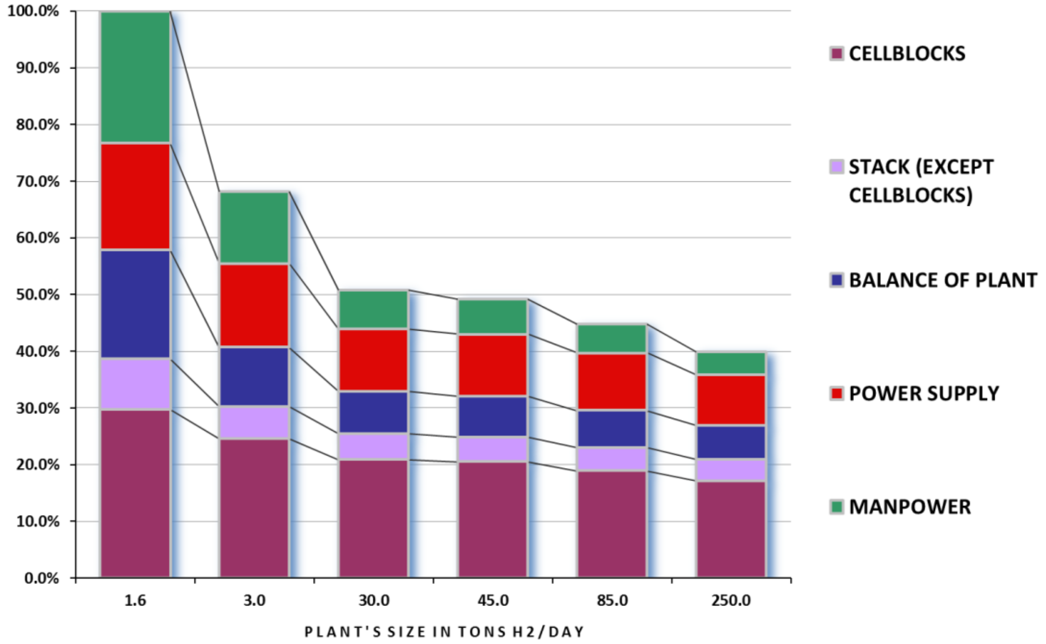

Figure. Assessment on cost reduction

- A Life Cycle Assessment has compared the environmental effects of the technology before and after the project, showing better performance the electrolyser after the project.

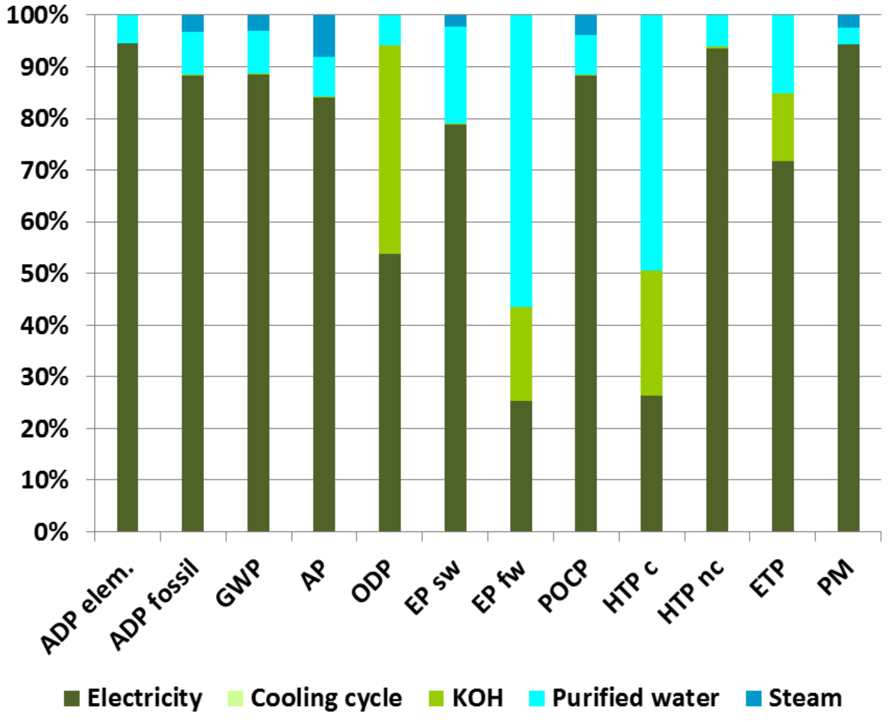

Figure. LCA results showing the relevance of electricity source

- The manufacturing process has been analyzed and a production facility has been proposed in order to manufacture both new stack and BOP design.
- The market studies have been focused on energy storage market. This market has been segmented in 4 segments and 9 applications.

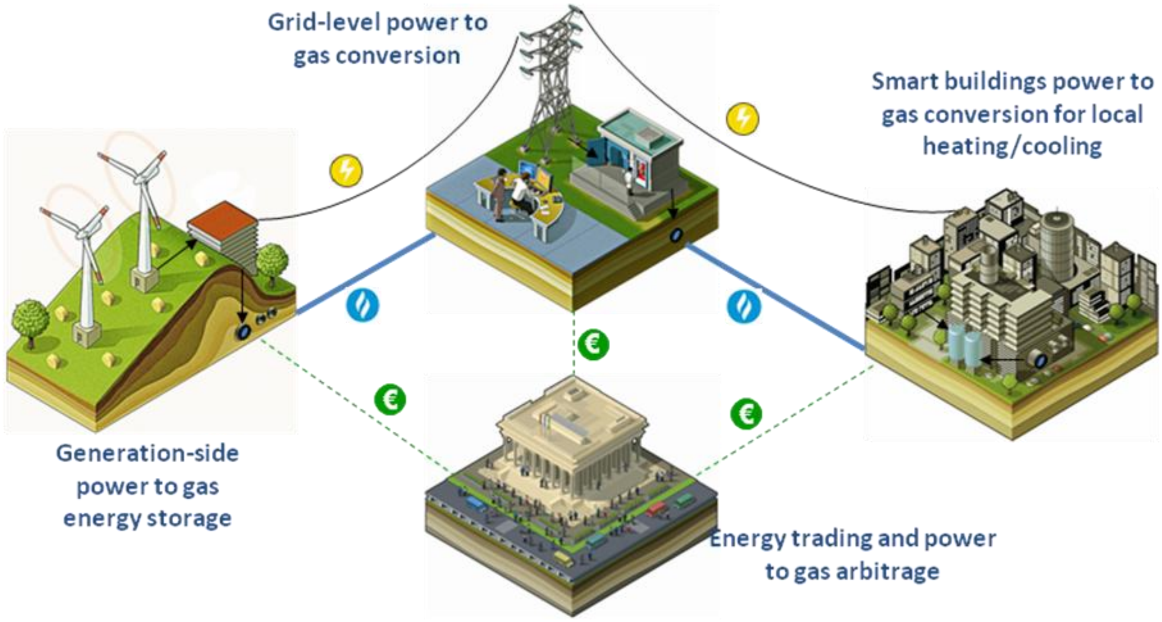

Figure. Market studies focused on energy storage

- The project has been disseminated in different conferences (22), events (3), publications (6), mass media and website (more than 60.000 visits in three years).

3 Expected final results and potential impact

Please provide a description of the expected final results and their potential impacts and use (includind socio-economic impact and the wider societal implications of the project so far). The length of this part cannot exceed 4000 characters

The project has achieved significant results in all the fields. A new cell topology has been developed with better efficiency and working at higher current densities. By using this, more hydrogen per unit can be produced, decreasing the total cost of the hydrogen produced. As well as this, the new cell topology shows better values of efficiency and therefore will improve the value of operation costs.

To increase electrical efficiency, new power electronics have been designed, based on IGBTs with the capability of working properly and with good efficiency coupled to renewable energy sources. This will improve efficiency during operation and therefore decrease the operation costs.

A new BOP has been designed which includes all the components of a MW electrolyser in the same container. It will decrease costs during the erection and commissioning of the electrolyser and will therefore provide a more competitive unit. A new control system has also been validated in order to work properly alongside renewable energy.

Field-testing has been carried out with successful results. The main goal has been to test the standard market sized electrolyser (1600 mm of membrane diameter) in order to pave the way for future commercialisation. The electrolyser has been working properly at double current density showing good values of V/cell and gas purities.

Much work has been carried out in order to aid market preparation and dissemination. The Regulation Code and Standards (RCS) to put an electrolyser in the market have been analysed. A cost assessment has been done, showing an overall cost reduction of 30% in comparison with the technology at the beginning of the project. A life cycle assessment (LCA) has also been done, showing that the new technology is less harmful in terms of environmental performance.

To summarize, the project has been success on testing a new cell topology with 70% stack efficiency, design a new BOP electrolyser with a capacity of 2.98 t/d and with a global cost of much less than the FCH2-JU objective for 2020 of 2M€/(t/d).

As regards the exploitation of the results, the project has a well oriented market approach with the leadership of IHT. These big units producing hydrogen at high pressure (33 bar) could be used to produce large amounts of hydrogen for power-to-gas applications, helping the hydrogen fuel cell vehicles deployment or for classical industrial applications. Therefore, they can have a direct application and market once the project has finished.

On the other hand, the different improvements achieved during the project (cell topology, power electronics, BOP, control system) could be directly integrated in the IHT technology, increasing their competitiveness and broadening their potential possibilities in the different short-term hydrogen markets. In this regard, the project has been working on building strong business alliances between partners which will make easier the future technology exploitation.

The project has been focused on the production of hydrogen coupled to RES and ambitious targets have been set for the EU regarding the introduction of RE sources. The most immediate goal is achieving 20% of share of energy from RE sources by 2020. However, a massive introduction of these intermittent and difficult to predict technologies in the current conditions could lead to several problems like mismatch between generation and consumption or expensive grid expansion to ensure stability and security of supply. Therefore, the results obtained in the project could be very useful for the development of the EU at this level, as it is envisioned that large amounts of hydrogen produced by renewable energy sources could be part of the solution to decrease the European energy dependence and environmental problems.