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Zero–HyTechPark Project: Reducing CO_2 Emissions with H_2 RES Applications

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Abstract. The Zero-HyTechPark project aims to put measures in place to achieve more sustainable technology parks via optimum energy management by means of systems based on hydrogen technologies and renewable energies. Thus, the objectives of the project focus on three areas: sustainable mobility promotion, dissemination of hydrogen technologies to the industrial and public sectors and achieve a zero emissions building. To complete these objectives, prototypes integrated with renewable energies such as a connected grid fuel cell, a fuel cell based cogeneration system, a fuel cell powered forklift balance of plant performing or the conversion of a battery electric vehicle to a fuel cell electric vehicle, among others have been developed.
As a result, the CO_2 emissions in the building under study have been reduced over 8 Tn of carbon dioxide.

Key words

Renewable energies, hydrogen, CO_2 zero-emissions systems, fuel cell, sustainable mobility, zero-emissions building

1. Introduction

Hydrogen as an energy carrier is understood as a system capable of storing energy for a later use in a controlled manner. Surplus electricity from renewable energy serves for green hydrogen generation via electrolysis (production stage). Once produced, the hydrogen is stored (storage step) for later consumption. This consumption can be performed directly, as a gas (hydrogen injection to the gas grid in the so called Power – to – Gas systems) or may be used in a fuel cell (an electrochemical device that directly converts the fuel, hydrogen in this case, to electric power obtaining as additional products heat and water) (consumption stage) using this electrical energy in various applications or directly injecting it back into the power grid (Power – to – Power) when the demand is higher than the power generation, thereby completing the "hydrogen cycle".
The inclusion of fuel cell systems as a means to reduce CO_2 emissions is being implemented more and more every day [1]
On the other hand, public institutions are developing mobility programs that encourage greener cars and propose alternative means of transport [2], [3], [4].
In Spain 25 % of all energy consumed is for the transport sector [5].
The residential sector takes 14% of total energy consumption. At European level, the work is focused to reduce this consumption, in order to achieve in 2020 almost zero emissions buildings according to Directive 2012/27/UE [6], [7].
The Zero- HyTechPark project combines all these aspects, trying to reduce CO_2 emissions level technology park and transforming the Aragon Hydrogen Foundation building into a zero emissions building.

2. Objectives

The aim of the Zero-HyTechPark project, funded by the Environmental LIFE+ Program of the European Commission, is to achieve more sustainable technology parks. The project budget is 1.3 million euros and the project duration is four years (from 1 January 2010 to 31 December 2013).
The project partners are the Walqa Technology Park (Huesca), Andalusia Technology Park (Málaga) the Technology Park of Bizkaia (Zamudio) and the Foundation for the Development of New Hydrogen Technologies in Aragon (Huesca). The coordination of the project and the technical activities are in charge of the Foundation for Hydrogen in Aragón.
The main project objectives are the promotion of sustainable mobility, dissemination of hydrogen technology to industrial and public sectors and achieve a zero emissions building with the use of renewable energy and hydrogen technologies.
Regarding the first objective a number of prototypes based on fuel cells electrical technology such as the transformation of a battery electric vehicle into a fuel cell electric vehicle, implementation of an assisted fleet bicycle in Walqa Technology Park as a means of transportation for the Park workers and balance of plant development for the operation of an electric fuel cell powered forklift have been developed.
Related to the other two main objectives there are included: a hydrogen station filled by green hydrogen produced from surplus renewable energy supplies the mobility applications associated, also the hydrogen produced is used in an UPS (Uninterruptible Power

System) a cogeneration system and a grid-connected fuel cell.
Finally, an off-grid electrical energy installation is included in order to reduce electricity consumption of the building to achieve zero emissions, hereinafter Object Building, which is the Aragon Hydrogen Foundation building. Also a thermal water preheating of the heating installation circuit and a hydride metal hydrogen compressor are incorporated to the energy reduction consumptions.

3. Results

The tasks carried out are included here below with its corresponding CO_2 emissions reduction and consumption savings.

A) Sustainable Mobility

The main problems the battery-powered electric vehicles present are high battery reload time and low autonomy. Therefore, a battery electric vehicle (REVA) [8] has been transformed and homologated as a fuel cell electric vehicle [9], [10] which incorporates a 12 kW fuel cell, giving it 1.4 kg storage 350 bar hydrogen capacity which provides autonomy for approximately 130 km. This vehicle has been tested on a street circuit and a trunk circuit, achieving increased range of up to 50% and reduced recharge time from 8 hours with the battery system to 3-4 minutes with the hydrogen one.

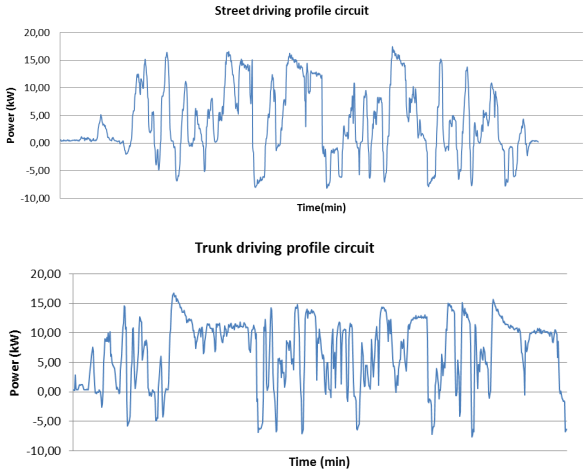

Fig. 1. Street and trunk driving profile circuits.

Vehicle currently serves on the Object Building, with a total of 100 $kgCO_2$/year avoided emissions. Additionally, a totally novel heating system has been incorporated into the vehicle, which takes advantage of the fuel cell cooling, generating up to 4 thermal kW, replacing the electric resistances usually incorporated into electric vehicles, increasing its autonomy to 21%.

Fig. 2. Fuel cell powered vehicle.

The homologation of this vehicle has been carried out concerning the Regulation (EC) N79/2009 the European Parliament and of the Council of 14 January 2009 also Directive 2007/46/EC.

Twenty-assisted bicycles fleet has been assigned to Walqa Technology Park in order to facilitate the workers mobility in the park, reaching 50 $kgCO_2$/year avoided emissions. These bikes are powered by an electric battery that gives them a range of 80km, with the next features: cannot exceed 25 km/hour, a brake application or stop pedaling cut the power to the electric motor incorporated.

Fig. 3. Assisted bicycles fleet.

The electric fuel cell powered forklift which involves the development of a balance of plant (a complete system-level design and integration of a hydrogen fuel cell (PEM) power pack), is still on its testing phase. The fuel cell stack balance of plant consists of an air supply subsystem (fan, intake filter, ducting, compressor, and humidifier), fuel supply subsystem (purge valve, anode recirculation blower) and controls (optimal stack operation). With this type of truck the refueling time is reduced by 87%, increasing productivity.

Fig. 4. Forklift hydrogen fuel cell power pack.

B) Zero emissions building

The object building incorporates an electrolyzer with two clear objectives: provide energy storage in order to support the integration of renewable energy in the building and fuel supplying also for vehicles (through a hydrogen station) and hydrogen applications.
This electrolyser has a delivery capacity of 25 kg h_2/day at 350 bar, with the possibility to supply hydrogen at the hydrogen filling station to hydrogen buses (TK25 connection) and hydrogen vehicles (TK16 connection).

Fig. 5. Electrolyzer

A metal hydride hydrogen compressor system has been incorporated in the installation. This system can be integrated with solar thermal energy thereby increasing the compression performance eliminating electrical-grid consumption.

Fig. 6. Hydride hydrogen compressor.

The building's server room has a PEM (Proton Exchange Membrane) fuel cell based UPS (Uninterruptible Power Supply) of 1.7 kW. With this equipment, the autonomy increases from 15 minutes with the battery power supply to 6 hours and 15 minutes, which allows improving the performance and the energy storage possibilities.

The building also has a PEM fuel cell based cogeneration system; this is a system in which there is a simultaneous use of electricity and heat.
With this equipment a production up to 4 electric kW and 3.7 thermal kW from the fuel cell cooling can be reached. As a result, a 150 liters water deposit can be heated up to 60ºC.

Fig. 7. PEM fuel cell cogeneration system.

The hydrogen cycle is shown with a 10 kW fuel cell grid-connected. This fuel cell close the “hydrogen cycle” by using the exceed hydrogen in the electrolyzer testing.
It is a modular stack which allows adjusting the power to the available hydrogen power, increasing in this way the system efficiency.

Fig. 8. Fuel cell grid-connected.

C) Additional actions

Additionally, the building reduces CO_2 emissions mainly with the development of two systems.
The first one is an isolated electrical system, which consists of 3.6 kW peak power photovoltaic systems, a bank of 2000 Ah lead acid batteries and a 2 kW PEM fuel cell.

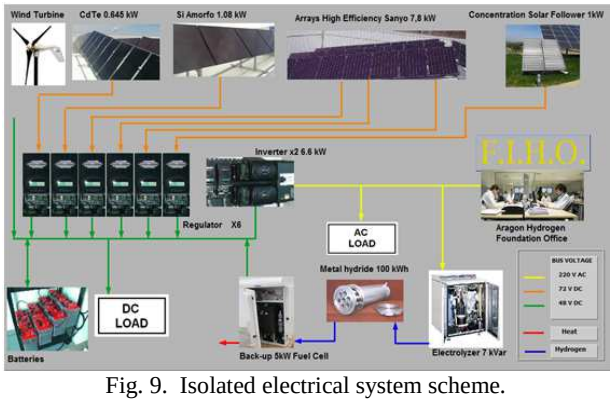

Fig. 9. Isolated electrical system scheme.

This system covers 100% of the electricity consumption of the building object office, which is roughly equivalent to 9700 kWh/year, achieving a reduction in CO_2 emissions of up to 2.5 tons annually.

The second system is a heating system based on solar thermal system, installed on the roof of the building. The objective of this system is to preheat the return water from the existing heating system in order to reduce the consumption of propane. With this facility, a generation of up to 5400 kWh/year is reached (20% of total heating consumption), equivalent to a reduction of 1300 kg of CO_2 per year.
The installation consists of 25 flat thermal solar collectors with an accumulation of 3000 liters and a total power of 45 kW_{th}. The heating system includes two boilers, condensing one, with a total output of 145 kW.

Fig. 10. Solar thermal system.

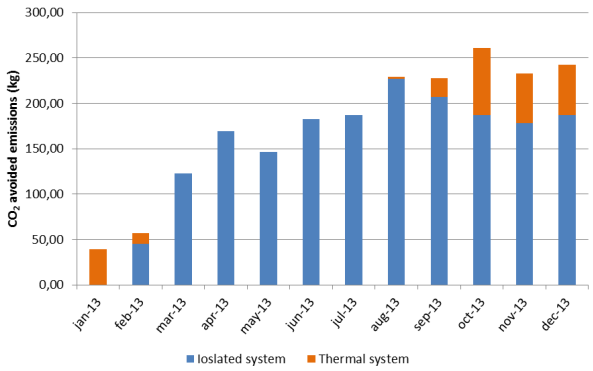

Fig. 11. CO_2 avoided emissions in 2013 with the isolated and thermal systems.

Finally, a web application has been designed for the control and monitoring of different temperatures, faults, etc [11], [12].

4. Conclusion

The Zero-HyTechPark project with the development of all the prototypes presented here has avoided 8 Tn of CO_2, of which 44% corresponds to the heating system, 36% of the isolated electrical system, 18% to measures undertaken in sustainable mobility and the remaining 2% corresponding to the contribution to the creation of a CO_2 sink.
It should be noted that the results have not yet reached 100% of development, since, for example, not accurate data of the isolated heat system has been logged simultaneously for a period of one year. Whit this action it is expected to reduce CO_2 emissions in the coming years by up to 25%.

The viability of fuel cell based systems has been also demonstrated including the integration of renewable energy systems.

Acknowledgement

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