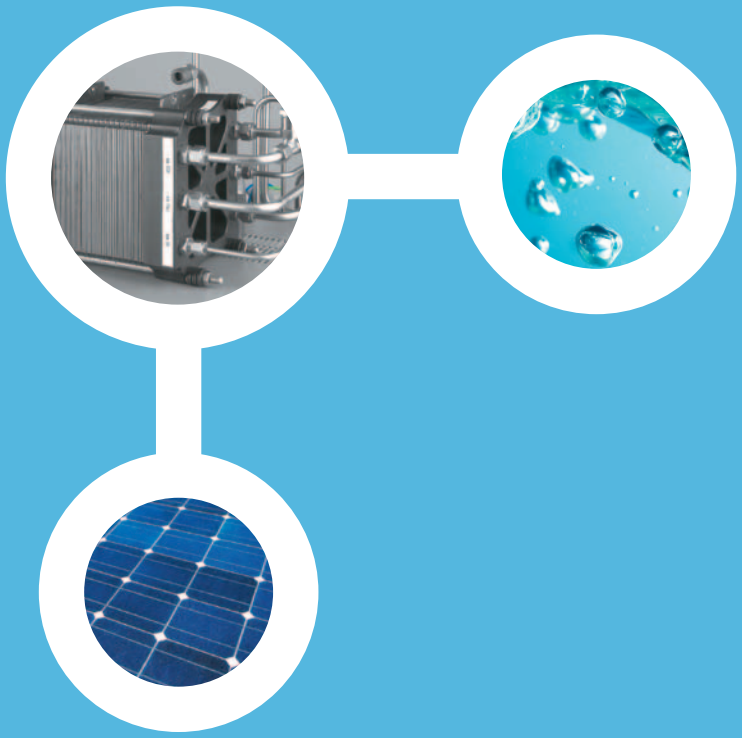
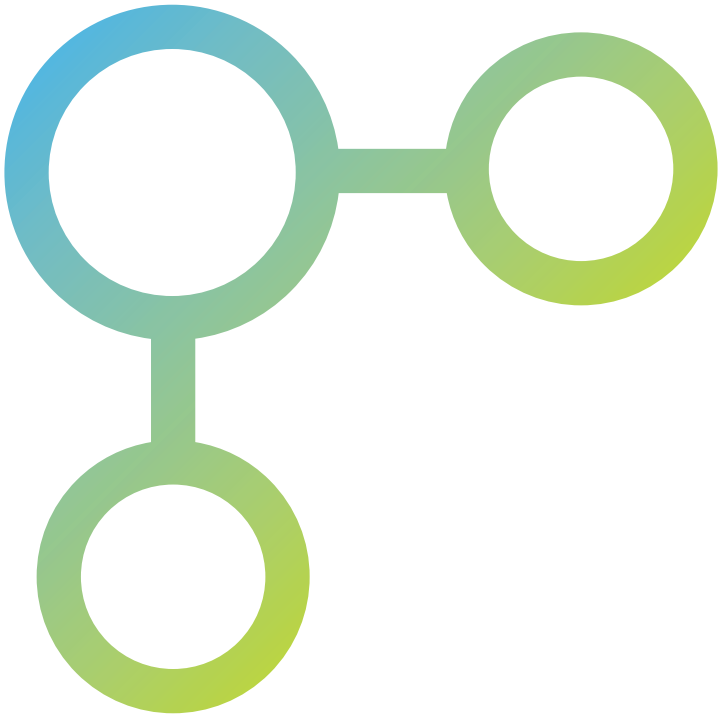


Status of **hydrogen and fuel cell technologies** in Andalusia

JUNTA DE ANDALUCIA

Andalusian Energy Agency
REGIONAL MINISTRY OF ECONOMY, INNOVATION AND SCIENCE



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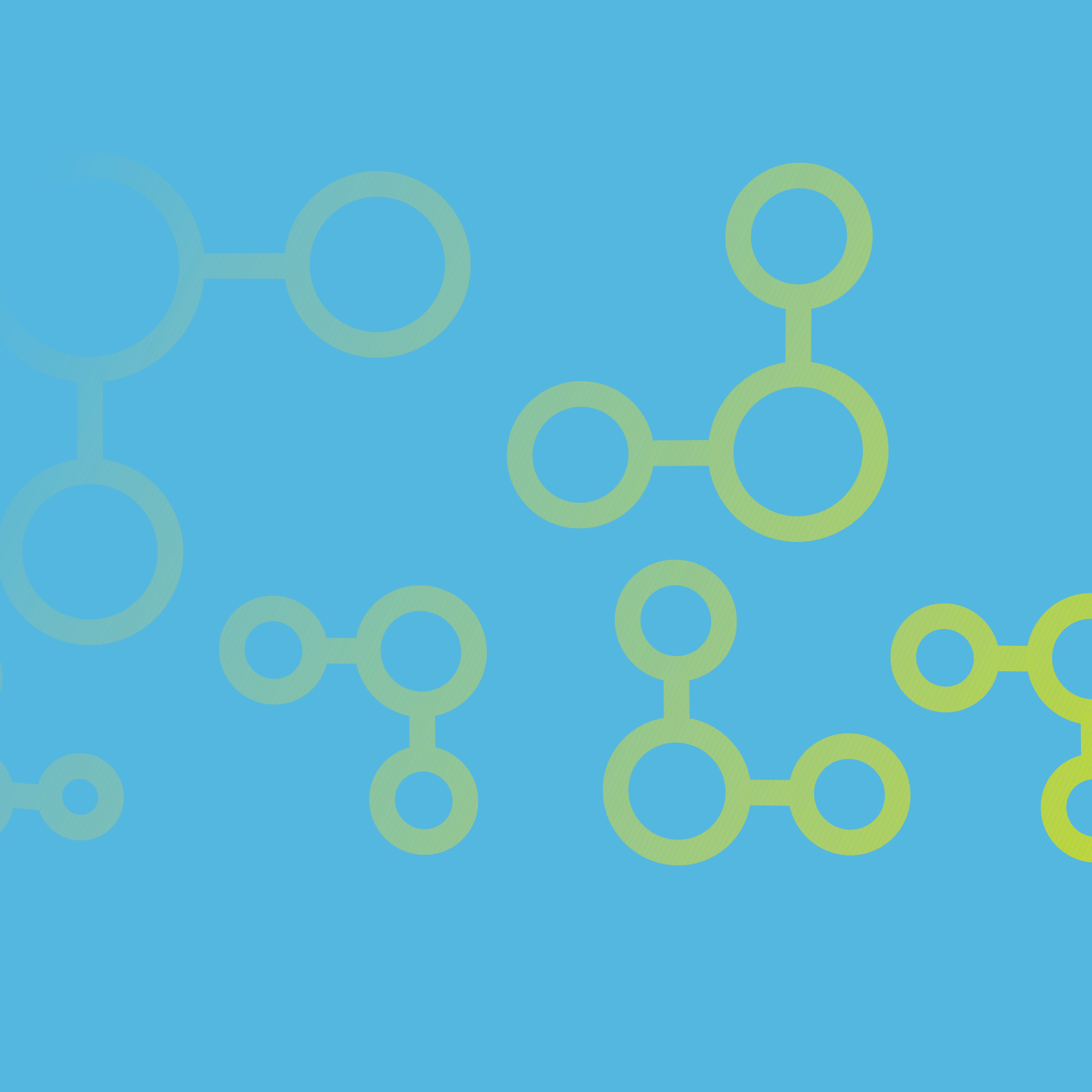
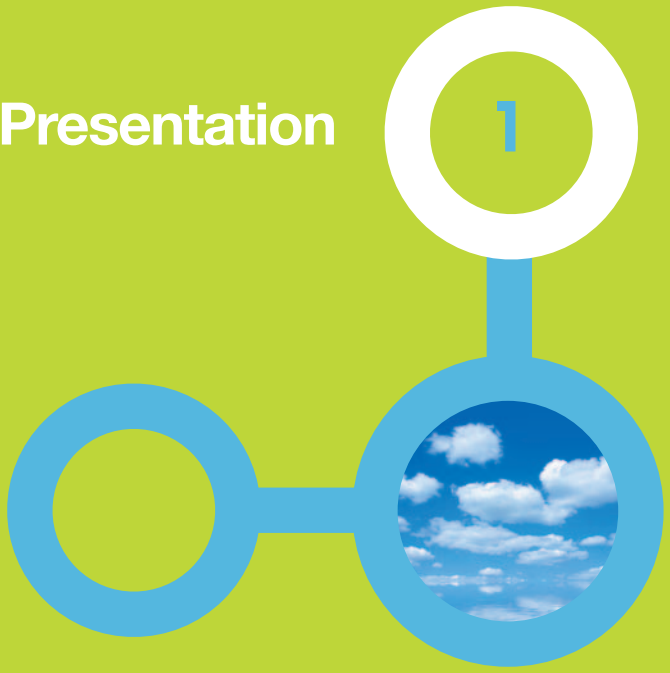


Content

Presentation 1



Presentation /

/ Hydrogen is a clean, sustainable, safe and efficient energy vector that, in the future, will complement electricity when it comes to ensuring the supply of energy to the population, while also increasing the penetration of renewable sources.

This new situation is leading various Public Agencies, institutions and companies to position themselves by preparing strategies and action plans focused on a future that contemplates the use of hydrogen and fuel cells.

The Andalusian Sustainable Energy Plan 2007-2013 (PASENER) pursues an approach to a new energy model that responds to the energy supply needs of Andalusian society without creating environmental, economic and social imbalances, within the context of sustainable development for Andalusia, addressing, inter alia, the following issues:

/ Energy diversification.
/ Security and assurance of supply.
/ Abatement of greenhouse gas emissions.
/ Energy self-sufficiency.

This new development model requires a profound transformation of the existing energy system, for which technological progress, innovation and research are deemed essential, in the renewable energies field above all.

In this respect, hydrogen and fuel cells are considered crucial to the introduction of renewable sources into the energy mix, as their use as an energy storage system eliminates the intermittent nature itself of these resources.

In turn, the transportation sector, at European Union level, is responsible for 30% of greenhouse gas emissions and 33% of final energy consumption. Hydrogen and fuel cell technologies are considered appropriate to curb these emission levels and introduce the use of renewable energies in the sector.

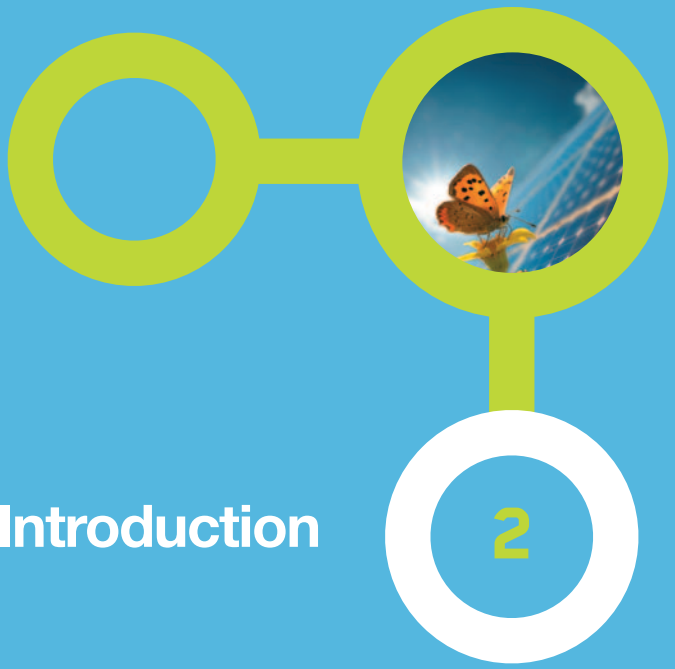
The Autonomous Community of Andalusia has been developing projects and technology in this field for years now, through companies and research centers of renowned prestige. With the “Status of hydrogen and fuel cell technologies in Andalusia” document, the Andalusian Energy Agency aims to disseminate some of the most relevant initiatives. The objective of this publication is to possess a benchmark of the current situation, taking the same as a starting point to chart future actions related with this matter, by showing how, through companies, research centers and social partners, Andalusia is prepared and ready to face this change, by playing a leading role in the development of technology, equipment manufacturing and installation of infrastructures.

To this end, in addition to analyzing the strategic situation at national and international level, an inventory of the projects undertaken in our Autonomous Community is kept, showing the research centers, universities and companies that have been working on hydrogen and fuel cells, or on related technologies.

The result shows that Andalusia has opted for a shift in the energy paradigm, and has put itself, through specific actions, in an optimal position to play a leading role in this sector.

Isabel de Haro Aramberri

President
Andalusian Energy Agency



Introduction

2

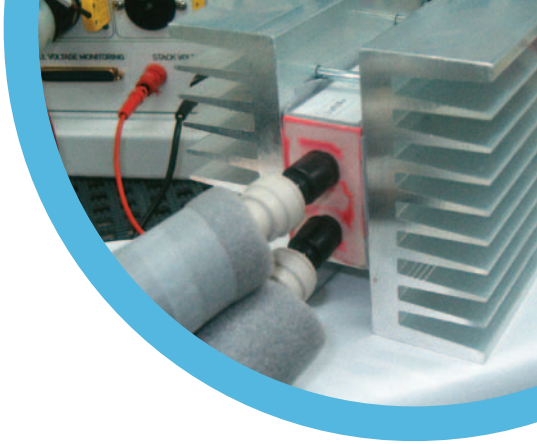
Hydrogen is an energy vector, not a primary energy source.

Its use is clean and safe.

The sustainability of the hydrogen production process depends on the technology utilized.

The *hydrogen – fuel cell* binomial can be used in any application that requires electric energy.

The utilization of hydrogen is not limited to use in fuel cells, and its use in internal combustion engines and turbines is noteworthy.



The nature of hydrogen /

/ Hydrogen is a colorless and odorless gas that, as in the case of natural gas or gasoline, possesses the quality of being a fuel, that is to say, it oxidizes in the presence of oxygen (or air), releasing energy in heat form.

However, unlike other fuels that contain carbon in their molecule, when hydrogen reacts with oxygen it only produces water vapor as waste.

$$H_2 + ½O_2 \rightarrow H_2O$$

Although hydrogen is an abundant chemical element in nature (approximately 75% of the Universe), it is not to be found in pure state in any type of "deposit", and has to be produced, with an energy input, from a raw material that contains it.

Due to the above, hydrogen is not a primary energy source, but an energy vector that is utilized to store and transport energy.

The benefits of hydrogen /

/ The benefits of hydrogen can be included in the following categories:

- **Energy saving and efficiency benefits.**
- **Benefits as regards diversity of supply and energy independence.**
- **Environmental benefits.**

The use of hydrogen as an energy vector opens the door to the use of electrochemical-based technologies, in which the performance of transformation from chemical energy to electrical energy increases compared to systems based on thermal-type transformations (the case of internal combustion engines), achieving improvements in terms of energy saving and efficiency.

The benefits in terms of diversity of supply and energy independence stem from the fact that hydrogen is not an energy resource in itself, but has to be produced using a primary energy source and, therefore, each country, each region, can generate its own hydrogen, its own “fuel”. When said hydrogen is produced from indigenous sources, this results in energy independence, security of supply, improvement in the balance of payments, and the promotion of local economies as jobs are created.

Additionally, the use of hydrogen as fuel and its production, both centralized and distributed, opens the door to “renewable hydrogen”, that is to say, to the possibility of storing and transporting renewable energy (regardless of the source) in a practical and safe manner.

This aspect is of special interest if we consider the ever-increasing difficulty in evacuating electricity generated with renewable technologies. Through the use of hydrogen as an energy vector, an increase in the penetration capacity of these sustainable sources is achieved.

On the other hand, the storage of energy in hydrogen form, and its subsequent use in the transportation sector, sets the scene for the use of renewable energies in said sector.

In terms of environmental benefits, the combustion of hydrogen is a clean process as it only releases water vapor, and therefore the electricity generated from hydrogen will always be emission-free provided the fuel has been produced by a carbon-free process.

Hydrogen generation processes /

/ At present, there are technologies that are at different stages (research, development and commercialization) that allow hydrogen to be produced from different raw materials such as water, biomass, or fossil resources (coal, oil and natural gas) and with an input of primary energy that can come from conventional fuels, nuclear power or renewable sources.

In spite of this range of possibilities, some 94% of the hydrogen currently produced worldwide comes from natural gas (methane) reforming, which consists of splitting the molecule of this gas by combining it with water vapor, which only requires an energy input. The reaction governing this process is:

$$CH_4 + 2\,H_2O \rightarrow 4\,H_2 + CO_2$$

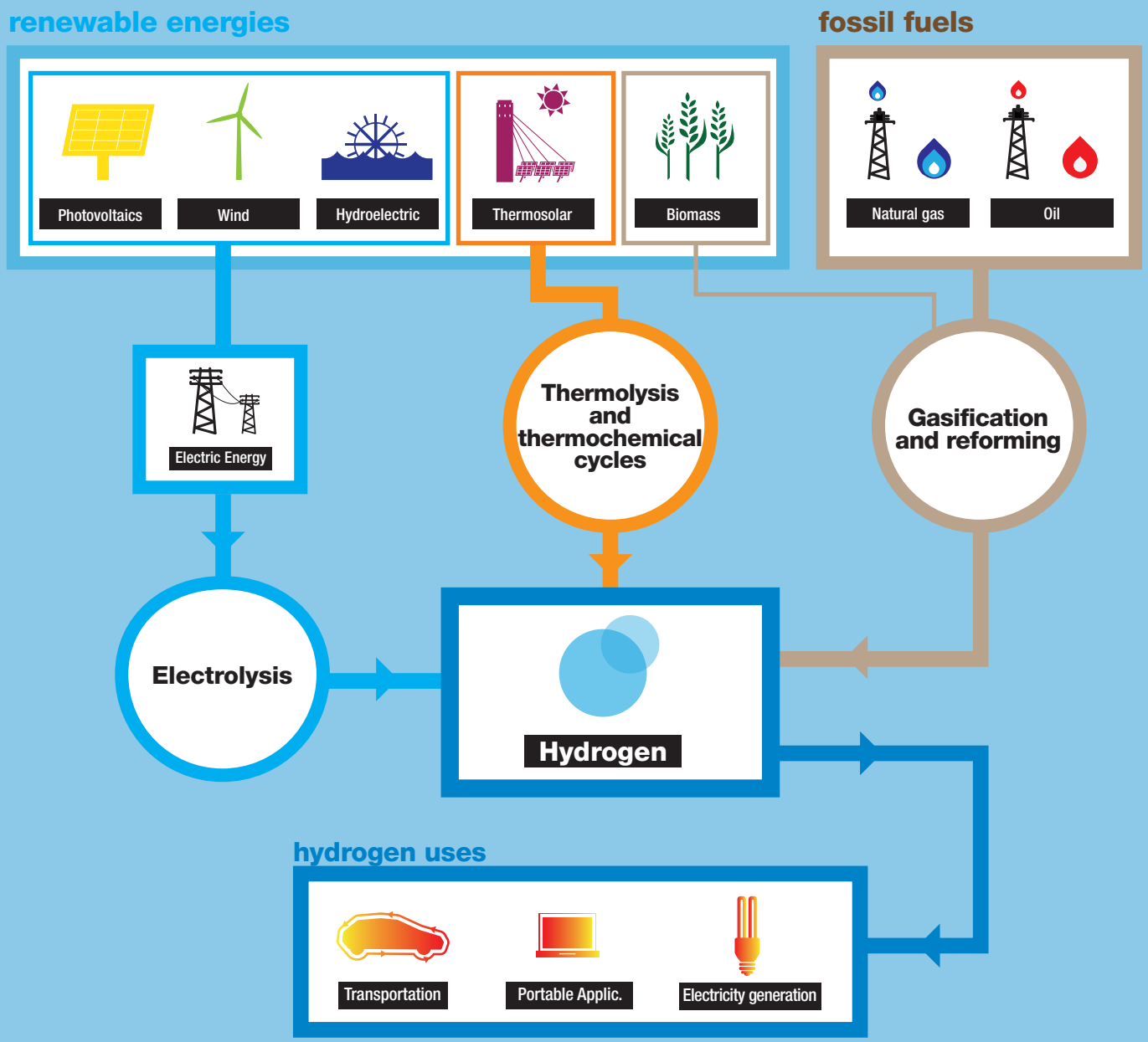
This process has the advantage of being the less costly at large scale but it involves emissions of CO_2 as a consequence of fossil origin raw material being used. These emissions are, in practice, about 7 kg of CO_2 per kg of hydrogen produced.

On the other hand, there is a group of clean processes (electrolysis, thermolysis, photoelectrolysis, etc.) as far as CO_2 emissions are concerned, that are based on water splitting and require the consumption of energy for said purpose, in accordance with the following reaction:

$$H_2O + \text{energy} \rightarrow H_2 + \tfrac{1}{2}O_2$$

Given that all hydrogen production processes require raw material consumption and energy input, sustainability of the same will depend on the technology utilized.

Hydrogen production chain /



Hydrogen storage /

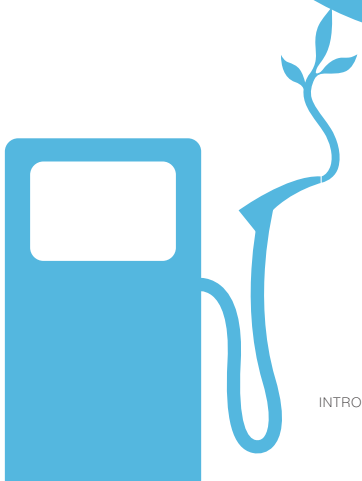
/ There are several, commercially established ways to store hydrogen: pressurized, liquid, and in metal hydrides.

Compressed hydrogen storage is a technology that is being used widely since the early 20th century. Its commercial use has been set at a pressure of 200 atm and its use in the automotive sector at pressures up to 700 atm is foreseen.

The use of liquid hydrogen is associated with its utilization in aerospace or portable applications. This is the favored option when it comes to increasing the energy density of the storage system.

The use of systems based on metal hydrides is associated with stationary applications and it is that which needs the lowest energy requirement.

Safety levels compatible with both industrial and domestic use are achieved with all of them.



Hydrogen uses: Fuel Cells /

/ In addition to its uses as raw material in the chemical industry, hydrogen, as an energy vector, is capable of storing and transporting energy.

Now, to transform the chemical energy contained in hydrogen into another type of energy such as electricity or heat, devices such as fuel cells (integrated or not into combined cycles) or internal combustion engines must be used.

Fuel cells, the operating basis of which was discovered in the 19th century, are based on the principle of reverse electrolysis; that is to say, oxygen and hydrogen combine to form water and electricity:

$$H_2 + \frac{1}{2}O_2 \rightarrow H_2O + \text{electricity}$$

Note: other fuel cell technologies exist, such as those that carry out internal reforming or those that operate with direct methanol.

Structurally, fuel cells are a set or stack of "basic cells", in each one of which the afore-mentioned reaction is carried out. Fuel cells are classified according to parameters such as the electrolyte, operating temperature or the specific chemical reactions that occur in their cells. They will be more suitable for one or another application in accordance with their characteristics.

Currently, the fuel cells that are in commercial development are those for use in the aerospace industry (alkaline technology or AFC), those used in the automotive sector (solid polymer technology or PEMFC) and those used in distributed generation (usually phosphoric acid or PAFC).

In general, the hydrogen – fuel cell binomial can be utilized wherever electric energy is needed. One of their early uses was in the vehicles employed in the space race towards the end of the 60s. The hydrogen and oxygen stored on the ship were combined in a fuel cell to produce the electricity that was required on board.

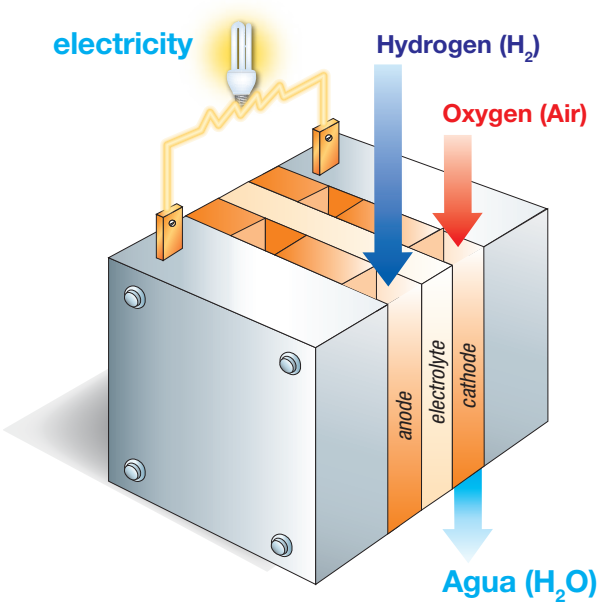
This binomial is currently used in submarines (where it is used to allow them to stay submerged for longer periods), communication systems or portable applications.

→ IN THE FUTURE, TRAINS, PLANES AND CARS WILL BE ABLE TO BENEFIT FROM THEIR USE, TOGETHER WITH OTHER STATIONARY OR PORTABLE APPLICATIONS.

As a consequence, for example, almost all the world's automobile manufacturers have developed prototypes of vehicles powered by hydrogen fuel cells, which is an indication of how the energy vectors of the future will advance. Furthermore, some automobile companies are contemplating the use of pure hydrogen or a hydrogen and natural gas mix in internal combustion engines, thereby achieving higher energy yields than with a conventional engine, without the need for a large investment.

On the other hand, as regards electricity production, integration of high temperature fuel cells in a Brayton cycle (or combined cycle) allows the net energy yield of the system to be increased to values close to 80%.

Operating synthesis



Name	Initials	Applications
Alkaline fuel cells	AFC	Used frequently in spaceships.
Polymeric fuel cells	PEMFC	Automotive and portable applications; communication systems.
Direct methanol polymeric fuel cells	DMFC	Portable applications (microelectronics).
Phosphoric acid fuel cells	PAFC	Stationary applications and occasionally for transport (buses). Distributed generation.
Molten carbonate fuel cells	MCFC	Stationary applications and possibility of cogeneration. Distributed generation.
Solid oxide fuel cells	SOFC	Centralized generation of electricity, integration into combined cycles.

3

The current environment: Spain, Europe and the world

The cornerstones for the development and application of new technologies associated with hydrogen and fuel cells are: US-Canada, Japan and the European Union.

On the national scene, the following agents are of note: the Spanish Hydrogen and Fuel Cell Technology Platform (PTE-HPC), the Spanish Hydrogen Association (AeH_2) and the Spanish Fuel Cell Association (Appice).

The current environment: Spain, Europe and the world /

/ The existing energy scenario is mainly characterized by the following:

Majority share of fossil fuels in the global energy structure. They currently represent about 50% and unless action is taken in this respect, this percentage is expected to reach values of around 80% by 2030.

Indications that oil fields have peaked, adversely affecting the production levels of the same.

Widespread concern about the effects climate change causes.

Notable increase in the demand for energy, driven mainly by emerging economies such as China and India.

Existence of a close relationship between continuity and quality of energy supply, and the socio-economic development of a country.

This situation has led to practically all international programs and business strategies, such as the Joint Technology Initiative (JTI)[1], referring to the importance of innovation, research, development and implementation of new energy technologies that are more efficient, environmentally-friendly, less dependent on fossil fuels and compatible with a distributed generation system, in order to achieve greater energy independence and ensure the quality and security of energy supply.

This is where hydrogen and fuel cells fit in and resolve part of the complex problem. Hydrogen as an energy vector, and a clean, safe and efficient way to store and transport energy and fuel cells as a suitable device for producing heat and electricity

1 The Fuel Cells and Hydrogen Joint Tecnology Initiative (JTI) is a public-private partnership launched by the European Commission in 2008.

from this gas. All indications are that the future lies in the coexistence of two fundamental energy vectors: hydrogen and electricity.

Global positioning, as regards the development of hydrogen and fuel cell technologies, as well as the approach taken to implement a Hydrogen Economy, is determined on the basis of three cornerstones: US-Canada, Japan and the European Union.

There are other countries and regions, apart from these three main players, that stand out in the global framework due to the strategy they have identified and followed to implement a Hydrogen Economy. The case of Iceland is significant as it undertook to harness its renewable resources to ensure energy self-sufficiency, trusting in a Hydrogen Economy that covers the demands of certain economic sectors, such as those of its fishing fleets and tourism.

US-Canada

These countries have taken up a leadership position globally in these technologies, from an economic and market point of view.

The United States Fuel Cell Technologies Program, managed by the United States Department of Energy (DoE), aims to advance the definition and implementation of these technologies at commercial level, to which end it has focused its efforts on development of the following lines:

- **Hydrogen production using own resources.**
- **Centralized hydrogen production and distribution.**
- **Hydrogen storage in vehicles.**
- **Fuel cells.**
- **Technical validation of the systems in real applications.**
- **Preparation of security protocols and hydrogen production, distribution, storage and use standards.**
- **Hydrogen Economy education and training.**
- **Analysis of interactions between components, system costs, energy efficiency, social impacts and the trading system.**

The interest of the United States Departments of Defense and Transportation in this matter is also noteworthy. They have their own development and implementation programs for this technology, in addition to those managed by the DoE.

Canada has drawn up its own roadmap and has supported the creation of technology "clusters" of the Silicon Valley type, where the scientific and industrial sectors (large, and small and medium-sized enterprises) have been installed in a manner in which they cover the complete production chain of a final product, such as the manufacturing of polymeric fuel cells, around the multinational Ballard Power Systems Inc., Vancouver (British Columbia, Canada).

As an example of Canada's commitment to these technologies, the construction of the Vancouver to Whistler "hydrogen highway" within the framework of the 2010 Winter Olympics is cited, and a similar initiative exists in California.

Japan

Japan's objective has always been to ensure its energy supply, clearly limited by its shortage of resources, which has even led it to commit to the creation of industries to convert resources imported from third countries into intermediate components and final products.

Japan was the first country to establish a national hydrogen and fuel cell strategy and it currently leads in the manufacturing of different devices related with these technologies; all this has been achieved, to a great extent, thanks to sustained public and private investment to favor the necessary R&D in the sector.

Furthermore, it has opened new technology markets based on the manufacturing of fuel cells and on the use of these systems in the domestic and industrial sectors, including cogeneration of electricity and heat. Along this line, it has supported the establishment of a single trade name, Ene Farm, under which products based on fuel cells are commercialized, regardless of their manufacturer.

Japan's trade strategy is based on a plan that integrates the development of fuel cells, the production of hydrogen, its transportation and the development of more efficient storage systems with higher energy density, together with demonstration programs and the drafting of legislation and standardization material.

The European Union and Spain

The great diversity that exists among the member states of the European Union makes it extremely difficult to define lines of work with respect to hydrogen and fuel cells, in which the interests of the different member states can be accommodated and unified. In the case of Germany, the objective is to maintain the current leadership of its automobile industry, while other European countries, as might be the case of Poland, seek to cover their needs for tecnological development and jobs, reorganizing the use of their resources (coal basically), so as to comply with the environmental restrictions imposed in the area of sustainable development.

As a link within this diversity, European policy aims at technological development and eco-innovations as one of the pillars of the energetic response to the serious problems facing the current energy scenario. The innovations focus on two aspects: renewable generation and application of hydrogen technology in generation, storage and transport.

In this regard, the European Strategic Energy Technology Plan (SET Plan) includes hydrogen and fuel cells among the technologies required to achieve, by 2020, the objectives of a 20% reduction in greenhouse gas emissions; a 20% share of renewables in the energy structure and a 20% reduction in energy consumption, and to achieve decarbonization of the system in the long term (2050).

On the national scene, different organizations are currently working on the promotion and development of hydrogen and fuel cell technologies. Of note are the Spanish Hydrogen and Fuel Cell Technology Platform (PTE-HPC), the Spanish Hydrogen Association (AeH_2), and the Spanish Fuel Cell Association (Appice). The recent launching of the National Center on Hydrogen and Fuel Cell Technology Experimentation (CNETHPC) in Puertollano (Ciudad Real) is also noteworthy. This center is one of the 24 Scientific Research and Technology Development facilities (ICTS) of the Ministry of Science and Innovation included in the INGENIO 2010 initiative, aimed at scientific and technology research in all fields related with hydrogen and fuel cells.

At regional level, the following autonomous communities are worthy of mention:

/ **Aragon**, which has, since 2007, its own Master Plan in this field, managed through the Foundation for the Development of New Hydrogen Technologies in Aragon. Said Plan includes a series of initiatives and strategic lines of research for the sector, and establishes the action plans and the time horizon required for their development.

/ **Galicia**, whose ENERXE Technology Platform has promoted a panel of experts on hydrogen comprising public administration, research groups, universities and Galician businesses.

/ **Madrid**, where the Energy Madrid Institute for Advanced Studies (IMDEA Energía) includes hydrogen, as a tool for producing sustainable fuels and as an energy storage system coupled to renewable energies, and fuel cells, as highly efficient energy utilization systems, within its lines of research.

Moreover, the weight of the projects related to hydrogen in the call for proposals under the National R&D&I Plan (non-existent until the 2000) is noteworthy.

Agents in the Hydrogen Economy at international level /

US Department of Energy

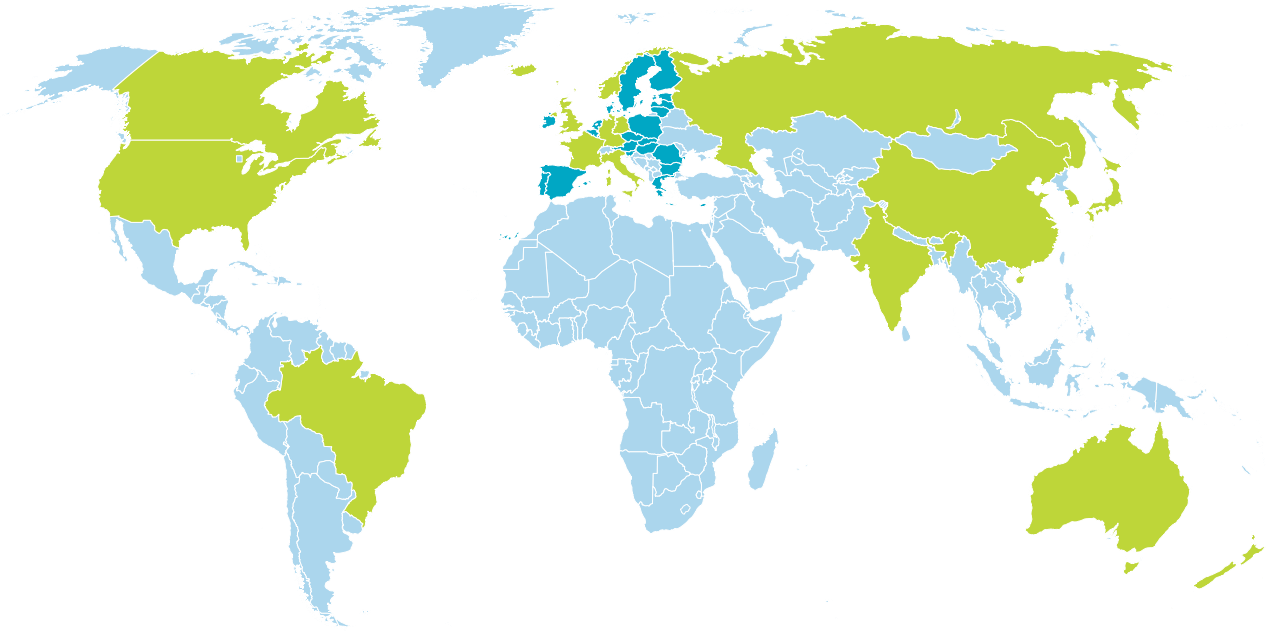
Within the US Department of Energy (DoE), management of the hydrogen and fuel cell program, for which the budget in 2009 was approximately 200 million dollars, is the responsibility of the Office of Energy Efficiency and Renewable Energy (EERE).

The lines of research and development in hydrogen matters covered by the DoE include the fields of fossil energy, nuclear power and basic science in the energy sector. It also has a specific program to promote niche markets that can be covered with fuel cell technology, as is the case of freight handling equipment or energy back-up systems.

International Partnership for the Hydrogen Economy

The International Partnership for the Hydrogen Economy (IPHE) was established in 2003 as an international institution to accelerate the transition to said economy. It currently comprises: Australia, Brazil, Canada, China, the European Commission, France, Germany, Iceland, India, Italy, Japan, the Republic of Korea, New Zealand, Norway, the Russian Federation, the United Kingdom and the United States.

Each of the IPHE partner countries (or groups of countries) is committed to accelerating the development of hydrogen and fuel cell technologies, to improve the quality and security of their energy supply, environment and economy.



IPHE partner countries

Countries represented in the IPHE through the European Commission

International Energy Agency

The International Energy Agency (IEA) is an organization that acts as an energy policy adviser for its 28 member countries, in their efforts to ensure a reliable, economically acceptable and clean energy supply for their inhabitants.

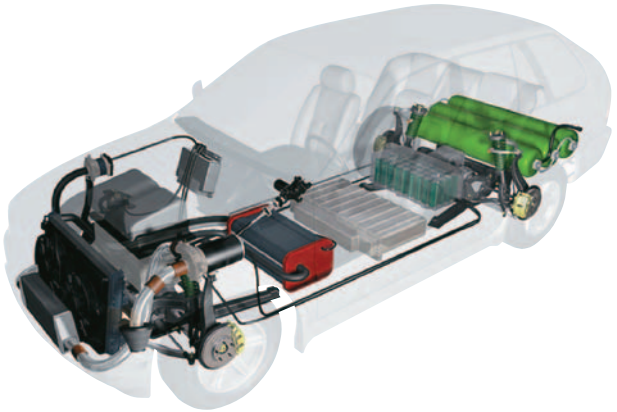
Its current work is focused on developing climate change policies, market reform, cooperation in energy-related technologies and in fostering the interest of the rest of the world, especially of countries that are major energy consumers and producers, such as China, India, Russia and the OPEC countries.

Of note is the establishment in 1988 of the Hydrogen Implementing Agreement, a program structured around what are called “Tasks” that encompass the entire hydrogen chain: production, storage and use in fuel cells, and in which there is Spanish participation.

Hydrogen Economy Agents in Europe /

→ Fuel Cells and Hydrogen Joint Technology Initiative (FCH JTI)

The Fuel Cells and Hydrogen Joint Technology Initiative (FCH JTI) derives from the extinct European Hydrogen and Fuel Cell Technology Platform (HFP). The Platform was created by the European Commission in January 2004 to facilitate and accelerate development and use of, globally competitive, European energy systems based on fuel cells and hydrogen, for use in the transportation sector and in stationary and portable applications.



This Technology Platform, which included members from the scientific community, industry, public authorities, the business community and civil society in general, saw its objectives culminated with the definition of a European strategy (Strategic Research Agenda, Deployment Strategy, Implementation Plan) that served as a basis for establishment of a public-private partnership within the framework of article 171 of the Treaty on European Union: the fuel cells and hydrogen JTI.

The JTI launched by the European Commission in 2008, aims to develop projects, for a period of 6 years, related with hydrogen and fuel cells in the field of basic and applied research, development and demonstration, that allow these technologies to experience major growth in commercialization from 2010 to 2020, and achieve significant access to the mass market by 2020.

The members of the FCH JTI are: The European Commission, the Industrial Group (Industry Grouping – IG) and the Scientific Community (Research Grouping – RG). Spanish companies and organizations are involved in the last two.

Hydrogen Economy Agents in Spain /

Spanish Hydrogen and Fuel Cell Technology Platform

The main objective of the Spanish Hydrogen and Fuel Cell Technology Platform (PTE-HPC) is to facilitate and accelerate the development and use, in Spain, of systems based on fuel cells and hydrogen, in the different technologies, for integration into the transportation sector and into stationary and portable applications. To this end, it takes the entire R&D&I chain into account.

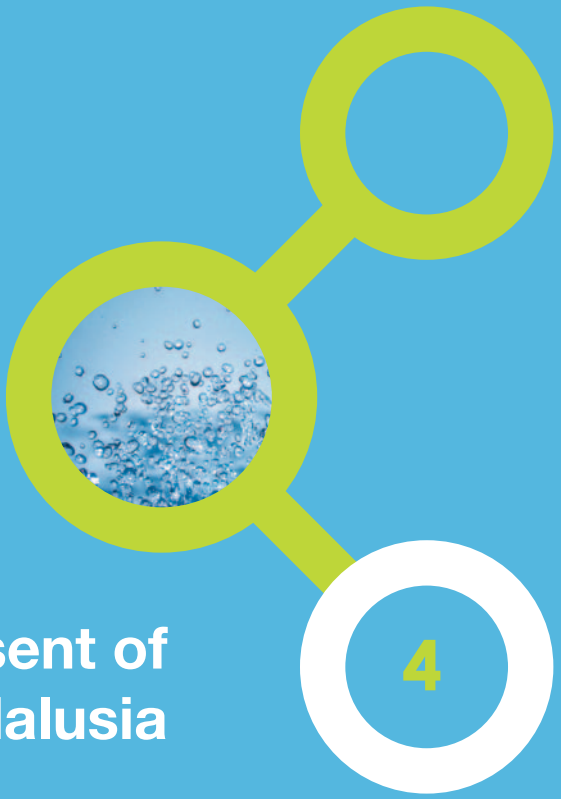
In this regard, the Platform is aware of the need for an operational and dynamic approach that incorporates all elements of the science-technology-enterprise system as well as public administrations, achieving optimal coordination with European and international bodies, which will become a compulsory forum in which administration will put its trust when considering short, medium and long-term R&D&I needs.

Spanish Hydrogen Association

The main objective of the Spanish Hydrogen Association (AeH_2) is to foster the development of hydrogen technologies as an energy vector and promote their use in industrial and commercial applications. It is intended that the principal beneficiary of the achievements of the Association be society as a whole and not the partners themselves, of both the environmental benefits and long-term industrial momentum it expects to achieve.

Spanish Fuel Cell Association

The aim of the Spanish Fuel Cell Association (Appice) is to favor scientific and technical development of this technology, disseminate its potential at national and international levels, and to provide training and information to interested social agents.



4

Past and present of hydrogen in Andalusia

Andalusia commenced hydrogen and fuel cell activities in 1989 through a Cooperation Agreement with the National Institute for Aerospace Technology (INTA).

The Andalusian Sustainable Energy Plan 2007-2013 (PASENER) considers hydrogen an important vector for storing energy from renewable sources and as an alternative with which to achieve sustainable transportation.

Past and present of hydrogen in Andalusia /

/ Activities related to hydrogen as an energy vector and to fuel cells commence in Andalusia in 1989, supported by a Framework Cooperation Agreement between the Regional Government of Andalusia and the National Institute for Aerospace Technology (INTA).

The objective of said Agreement was to make progress in a concept of energy storage and management known as “regenerative fuel cell system”, for aerospace use essentially at that time, but with undoubted potential at terrestrial level for management of energy produced from renewable sources, uncoupling energy production and consumption.

In September 1990, under the aforesaid Agreement, the first Specific Agreement was established to set up a working group to conduct activities related to hydrogen production from solar photovoltaic energy. One of its main achievements was the design, construction, operation and evaluation of the first domestic installation of its kind, and one of the first at world level, where the hydrogen-renewable energy binomial was combined, at the Experimentation Center in El Arenosillo (Huelva).

The interest of the Andalusian Administration in these activities materialized in successive Specific Agreements between the Regional Government of Andalusia and the INTA, developed until 1995, in which aspects of hydrogen storage (through the development of a metal hydrides system) and the use of fuel cells – phosphoric acid fuel cell, taking advantage of internal methanol reforming, and solid polymer fuel cell , using renewable hydrogen– were researched in depth.

In turn, the scientific-technical infrastructure (7 kW solar photovoltaic installation, hydrogen storage devices in the form of 200 bar pressure metal hydrides, PEMFC and PAFC systems, auxiliary installations, etc.) developed by the INTA in the town of Mazagon (Huelva), enabled an Andalusian research team to present, in 2002, the first doctoral thesis[2] associated with this subject. In the same, the production of electrolytic hydrogen from solar photovoltaic energy was analyzed from an energy standpoint as a means of energy storage that contributes to the management of renewable energy sources and to reducing the randomness of the same.

The unit set up and the nature of the Public Research Center that housed it can be considered the germ that has enabled achievement of, through the efforts of companies that became involved later, levels of know-how, knowledge and experience that allow Andalusian entities to participate in national and European R&D projects.

Several universities throughout Andalusia also commenced activities in this field in the 90s: the University of Huelva, which focused its activities on development of inverters and control systems for fuel cells; and that of Seville, which focused its efforts on integration of renewable energy sources and hydrogen production systems, and on development of power systems applicable to fuel cells. These institutions set up new laboratories that joined the existing facilities in El Arenosillo.

From early 2000 to date, several companies, research centers and Andalusian universities have been progressively adding to the total number of players developing activities related with hydrogen and fuel cell technologies in Andalusia, which have resulted in significant innovation, research and development projects in the sector. The list of Andalusian companies, research centers, universities and projects is provided in subsequent sections herein.

In this regard, of note are some Andalusian companies and entities, such as Abengoa (which, in 2003, centralized all its activities related to hydrogen and fuel cells in the company Hynergreen Technologies, S.A.), the INTA and the Almeria Solar Platform, which, in the 90s, created fields of work related to hydrogen and fuel cells that, years later, still exist within the Andalusian business framework operational in the sector.

2 Theoretical and Experimental Study on the production of electrolytic hydrogen from solar photovoltaic energy: design, operation and evaluation of a 1.2 Nm^3 H_2 /h pilot plant for electrolytic hydrogen production.

In 2007, due to the ever-increasing need to attain a more environmentally friendly energy model that favors sustainable development based on less contaminating and more efficient electric energy production, activities related with the preparation of a hydrogen and fuel cell roadmap in Andalusia commenced, under the coordination of the Andalusian Energy Agency, the entity responsible for developing and assessing the measures derived from the energy policy of the Regional Government of Andalusia to optimize the energy supply of our Community.

At present, the Andalusian Sustainable Energy Plan 2007-2013 (PASENER) considers hydrogen a relevant vector to respond to the energy supply needs of Andalusian society, due mainly to its interest in renewable energy storage and as an alternative to achieve sustainable transport.

The efforts made by the Regional Government of Andalusia to promote and support projects and initiatives in the hydrogen and fuel cells sector, from its Ministry of Economy, Innovation and Science through the Directorate General for Universities, the Agency for Innovation and Development of Andalusia (IDEA), the Andalusian Energy Agency, and from the Technological Corporation of Andalusia (CTA), are worthy of mention. This support has contributed greatly to enabling achievement of the status this Autonomous Community now holds.

→ THERE IS A CLEAR OPPORTUNITY FOR GROWTH FOR ANDALUSIA IN THESE TECHNOLOGIES BECAUSE IT POSSESSES GREAT RESEARCH AND BUSINESS POTENTIAL, WELL BALANCED AND KNOWLEDGEABLE OF THE LATEST R&D TRENDS IN THE SECTORS IN WHICH IT OPERATES, AS WELL AS HIGH AVAILABILITY OF RENEWABLE RESOURCES AND EXPERIENCE IN HARNESSING THE SAME, ALL OF WHICH ARE ASPECTS IN ITS FAVOR.

Harnessing and exploitation of this potential by research centers and companies requires a development strategy that favors their positioning at international level in the hydrogen and fuel cells field.

5 Relevant players in Andalusia

There are currently 22 Andalusian research groups that have developed activities related to hydrogen and fuel cells.

50% of these research works are in the field of production technologies, focused mainly on fuel cells.

There are 7 Andalusian companies with projects underway in the hydrogen and fuel cells sector and 46 with potential interest in these technologies.

Andalusia has a business presence in practically the entire hydrogen value chain.

Relevant players in Andalusia /

/ In the analysis of the relevant players in Andalusia that are working in the hydrogen and fuel cell sectors, those belonging to R&D&I groups, on the one hand, and those linked to companies, on the other, have been separated.

Within the former, a distinction is made between universities (or groups attached to the same) and Public Research Bodies (OPI). As regards the companies, they in turn have been subdivided into those that are already working on these technologies and those that have only recently begun to show their interest in the same.

R&D&I Groups /

/ The number of research groups active in this sector has increased remarkably in recent years.

There are currently 22 research groups belonging to, or attached to, universities, included in the Andalusian Plan for Research, Development and Innovation (PAIDI) that have developed activities in this field. These groups are involved in the following areas:

- **Physics, Chemistry and Materials (FQM)**
- **Production Technologies (TEP)**
- **Natural Resources and Environment (RNM)**
- **Life Sciences (CVI)**
- **Social, Economic and Legal Sciences (SEJ)**

The variety of areas demonstrates that hydrogen and fuel cell technologies are interdisciplinary lines of research, where not only are the energy (TEP) or catalysis and material (FQM) aspects taken into account, but also aspects relating to natural resources (RNM), hydrogen production via biological process (CVI) and economics (SEJ).

The data analysis concludes that 50% of these research groups conduct their activity in the area of Production Technologies, focusing in most cases on study, design, and modeling of PEMFC and SOFC, while also including lines aimed at the use of hydrogen as a storage system and management of energies from renewable sources.

Physics, Chemistry and Materials occupies second place, with a 36% share. These groups work mainly on the development of catalytic materials for hydrogen production and conductors for use in fuel cells. The theoretical studies within this area, on hydrogen storage in nanotubes, being conducted by the Department of Physical, Chemical and Natural Systems of Pablo Olavide University in Seville, are worthy of mention.

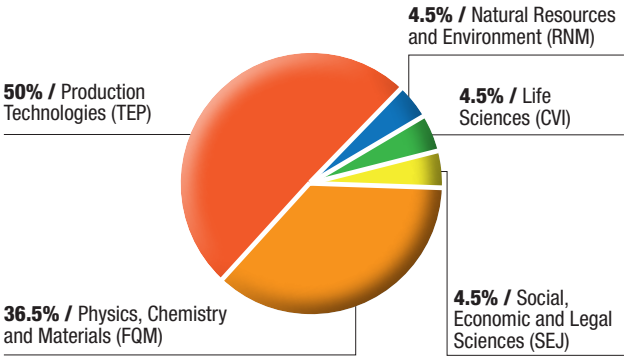
This university's Department of Economics, Quantitative Methods and Economic History is the only department that conducts its activities in the area of Social, Economic and Legal Sciences. In the same, an economic analysis of the use of hydrogen as fuel within the framework of the MaHREs I and II projects is being conducted.

As regards the area of Natural Resources and Environment, the activity is concentrated in the Department of Inorganic Chemistry of the University of Granada, where new catalysts for hydrogenation reactions and electrolyzers for fuel cells are being analyzed and developed.

Lastly, the Department of Plant Biochemistry at the University of Seville is working on hydrogen production from algae in the Life Sciences area.

Graph 1 / Distribution of research centers belonging or attached to universities in Andalusia by area of activity.

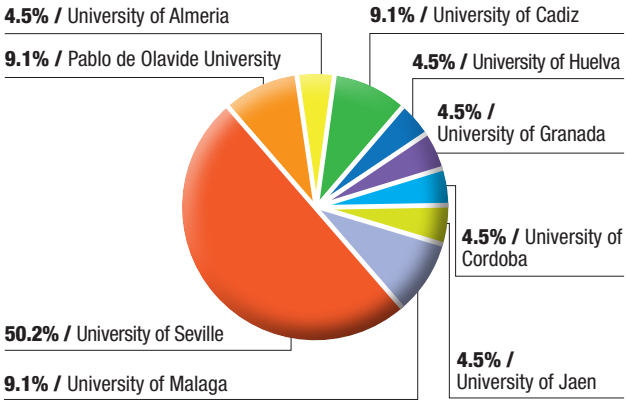
Total: 22 research centers.



Of note from the distribution by university is the concentration of groups in the University of Seville, due mainly to the existence of local companies and other Public Research Bodies that have acted traditionally as facilitators of the same.

Graph 2 / Distribution of research centers by university to which they belong or are attached to.

Total: 22 research centers.



With respect to Public Research Bodies (OPI), the activities carried out by the INTA's Test Centre of El Arenosillo, Mazagon (Huelva), and by the Almeria Solar Platform (PSA) of the Research Center for Energy, Environment and Technology (CIEMAT), in Tabernas (Almeria), are noteworthy.

The INTA, in addition to the activities indicated in section 4, "Past and Present of Hydrogen in Andalusia", has complete polymer fuel cell test benches and has actually commenced activities in the area of hydrogen production from fossil fuels (diesel) and biofuels (bioethanol). The group has participated in numerous European and national projects.

Furthermore, in recent years, the Solar Fuels Group of the Solar Concentration Systems Unit of the PSA has undertaken several projects aimed at developing technologies for hydrogen production via thermochemical processes from concentrated solar radiation (INNOHYP and SOLTER-H). Through the CIEMAT, the Platform is also promoting, together with its homologous centers, the CEA in France and ENEA in Italy, the creation of the Sushypro Experimental Platform – the site for which has not yet been chosen – and an action plan for testing hydrogen massive and clean production systems by means of CO_2 emission-free high temperature thermal processes.

Lastly, of note is the fact that participation in European projects by Andalusian research groups in this field has mostly been by the INTA, PSA, the Materials Science Institute of Seville (ICMSE)[3], and the Universities of Seville and Huelva.

A list of each of the Groups and Public Research Bodies is included in the annexes herein.

3 The ICMSE is a Joint Center established by the Spanish National Research Council and the University of Seville.

Companies /

/ At present, seven Andalusian companies directly involved in this sector and with demonstration projects backed by regional, national or European funding are worthy of mention: five in Seville (Carburos Metálicos S.A., Greenpower Technologies, S.L., Hynergreen Technologies, S.A., Inerco, S.A. and Endesa, S.A.), one in Almeria (Sistemas de Calor, S.L.) and one in Jaen (Santana Motor, S.A.).

The projects being developed by these companies involve the following lines of work: production, storage and use of clean hydrogen; design, development and manufacture of fuel cells; development of BoP (Balance of Plant) for fuel cell based systems, inclusion of these technologies in the transportation sector and their integration with renewable sources such as wind power.

The high concentration of these projects in Abengoa subsidiaries in noteworthy. The company commenced activities in the hydrogen and fuel cell sector in 1998 through its subsidiaries Inabensa and Greencell, which gave way, in 2003, to Hynergreen Technologies. These companies are also major participants in European projects.

Another 46 Andalusian entities with interest in and the technological capacity to undertake projects in the hydrogen and fuel cell sector in the near future must be added to the afore-mentioned companies.

The business sectors these companies are involved in are:

Plastics industry (9%), with potential to manufacture frames and seals for fuel cells and electrolyzers.

Components industry (19%), to utilize the developments derived from integration and use of fuel cells in sectors such as that of transportation, etc.

Renewable energy related industries (9%), interested in the contribution of hydrogen as a storage system that will help to resolve the problems deriving from the randomness of said sources.

Special alloys industry (8%), capable of meeting the demand for materials for the manufacturing of hydrogen storage systems.

Engineering companies (8%), with potential to develop energy integration projects.

Electronic companies (13%), to respond to the need to condition the voltage levels between the renewable sources and the loads (electrolyzers), and between the producers (fuel cells) and the grid.

Composite materials industry (6%), will have a clear application in the development of hydrogen storage systems thanks to the manufacturing of lightweight and resistant elements.

Transportation sector (9%), which is an obvious niche market for use of fuel cells in the automotive sector.

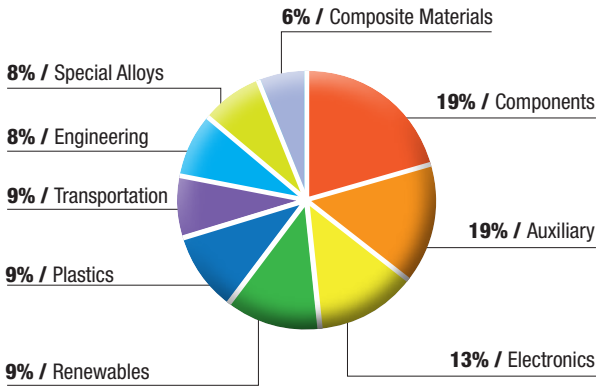
Auxiliary industry (19%) will contribute with machining systems for parts and pieces and integration of components.

The conclusion from the previous analysis is that there is sufficient potential in Andalusia to cover the entire hydrogen and fuel cell value chain (production, storage and final use of hydrogen, and design, manufacturing and integration of fuel cells).

Another conclusion from the study of these companies is that they are distributed throughout all the provinces of Andalusia (Graph 4). The province of Seville, with 38% of the same (20 entities) and participation in all the afore-mentioned areas, is of note.

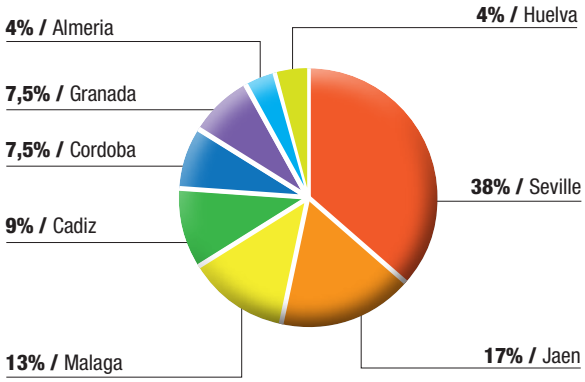
Graph 3 / Distribution of Andalusian companies with direct involvement or interest in hydrogen and fuel cells, by business activity.

Total: 53 companies.



Graph 4 / Distribution of Andalusian companies with direct involvement or interest in hydrogen and fuel cells, by province.

Total: 53 companies.



→ FROM THE RESULT OF BOTH DISTRIBUTIONS (GEOGRAPHIC AND BUSINESS ACTIVITY) IT IS CLEAR TO SEE THAT ANDALUSIA IS IN A BALANCED POSITION AND POSSESSES MAJOR POTENTIAL FOR INDUSTRIAL GROWTH IN THE HYDROGEN AND FUEL CELL SECTOR, WHICH WILL, IN TURN, FAVOR ITS TRANSITION TOWARD A SUSTAINABLE DEVELOPMENT MODEL.

6 Emblematic projects in Andalusia

From 2001 to 2009, 58 projects of special relevance in the hydrogen and fuel cell sector, with an overall investment of almost 40 million euro, have been rolled out in Andalusia.

Most of the projects involve areas of R&D&I related with hydrogen technologies, its production, purification and storage.

The annual investment in Andalusia in this matter (public and private) has gone from 200,000 euro in 2001 to almost 8 million euro in 2009.

Emblematic projects in Andalusia /

/ 2001 to 2009 has been taken as the time span for the analysis, as it is considered to be representative of the deployment of these technologies at national and regional level.

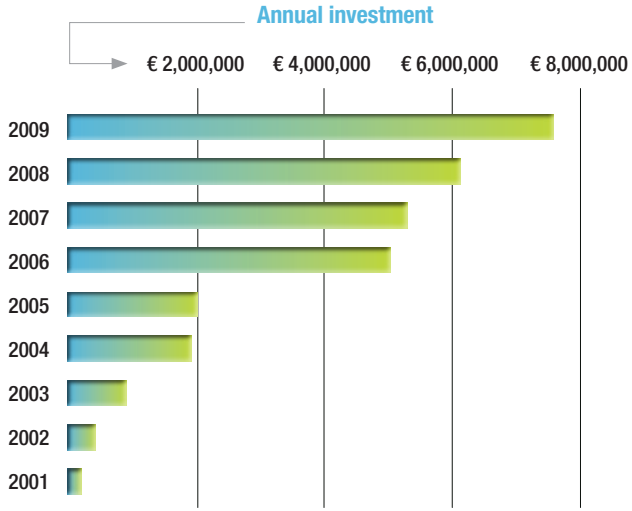
In this period, 58 projects aimed specifically at hydrogen and fuel cells, of special relevance in the sector and with significant involvement of our Autonomous community, were initiated.

The sum of the investments in said 58 projects, including public as well as private contributions, comes to almost 40 million euro (38.9 million euro). During the period in question, a constant increase in annual investment can be seen. The same went from approximately 200,000 euro in 2001 to almost 8 million euro in 2009 (Graph 5).

The jump in investment between 2005 and 2006, coinciding with the period in which most of the projects commenced, is of note.

Graph 5 / Evolution of investment associated with Andalusian projects.

Period: 2001-2009.



These annual investments highlight the growing interest in Andalusia in hydrogen and fuel cell technologies and are proof of how this Autonomous Community is playing an important role at national and international level in this field, attaining even the investment objectives established by the PTE-HPC (Spanish Hydrogen and Fuel Cell Technology Platform) and matching those foreseen by the JTI in the field of hydrogen and fuel cells.

As benchmarks for comparing the expenditure in Andalusia with that of other regions, it is worth noting that, through the 6th and 7th Framework Programmes[4], the annual investment of the European Community in these technologies is about 140 million euro for all its member states; in addition, Germany employs approximately 50 million euro a year in developing its own projects.

From the point of view of the recommendations of the different platforms and strategic studies, the PTE-HPC recommends some 75 million euro a year be invested in Spain (between the 17 autonomous communities) and the HY-CO ERA-Net[5] study suggests some 200 million euro for each of the European Union member states.

The evolution of the number of projects added in the 2001 to 2009 time span is shown in graph 6.

The years 2004, 2006 and 2009 stand out as specifically prolific for start-up of new projects related with hydrogen and fuel cells, such as the development of reformers by the INTA, those derived from the integration of renewable sources and hydrogen, the Hidrolica and Hercules-Las Columnas projects, or those for the integration of fuel cells in the automotive sector, the Delfin and Hercules-El Leon projects.

These periods coincide with those in which the sector received major support from public administrations, with milestones such as the publication of the successive calls for proposals by the Agency for Innovation and Development of Andalusia (IDEA) or the significant action taken by the Technological Corporation of Andalusia[6], ratifying the success of these types of programs.

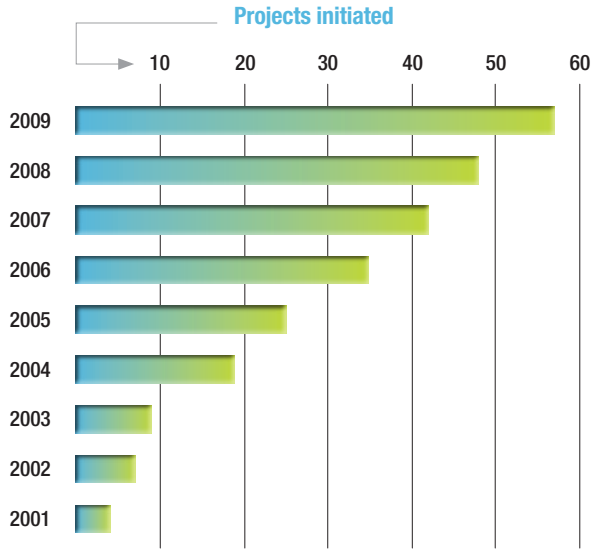
4 The Framework Programme for Research and Technological Development is the main instrument of the European Commission for promoting and financing research projects at European Union level.

5 Co-ordination Action to Establish a Hydrogen and Fuel Cell ERA-NET, the objective of which is to create a network that integrates national and regional R&D activities related to hydrogen and fuel cells.

6 The Technological Corporation of Andalusia (CTA) is a public-private foundation promoted by the Ministry of Economy, Innovation and Science of the Regional Government of Andalusia.

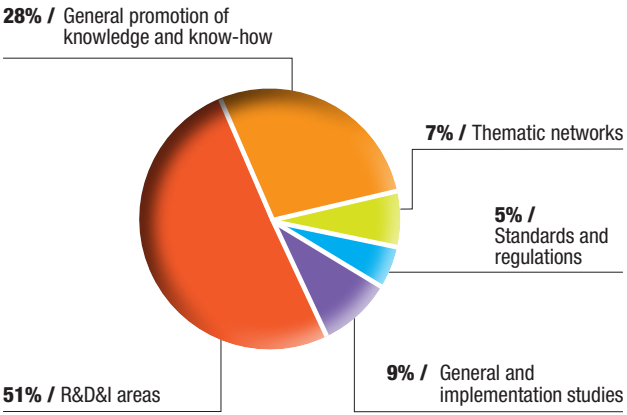
Graph 6 / Cumulative total of projects initiated each year in Andalusia.

Period: 2001-2009.



Graph 7 / Distribution of the Andalusian projects by their nature.

Total: 58 projects.



From the standpoint of their nature, 28% of the projects has focused on the general promotion of knowledge and know-how (basic research) in the hydrogen and fuel cells area, while 51% of the same has focused on R&D&I areas (including applied research, technological development and demonstration of the technologies developed).

9% of the projects focused on general and implementation studies, feasibility studies and strategic plans; 5% on development of standards and regulations for these new technologies; and the remaining 7% to participation or cooperation in thematic networks.

→ THE FACT THAT MOST OF THE PROJECTS ARE IN THE AREA OF APPLIED RESEARCH, EXCEEDING THOSE OF BASIC RESEARCH, INDICATES THAT THE ANDALUSIAN COMPANIES AND RESEARCH GROUPS ARE GEARING THEIR LINES OF WORK, TO A GREATER EXTENT, TO INTEGRATING AND APPLYING TECHNOLOGIES AND KNOW-HOW THAT HAVE BEEN DEVELOPED IN ADVANCE.

Among the general knowledge and know-how promotion projects, those focused on development of catalysts to obtain hydrogen (Universities of Cadiz and Seville), hydrogen generation by photochemical processes (University of Cadiz) and development of materials (Universities of Malaga and Seville) are noteworthy.

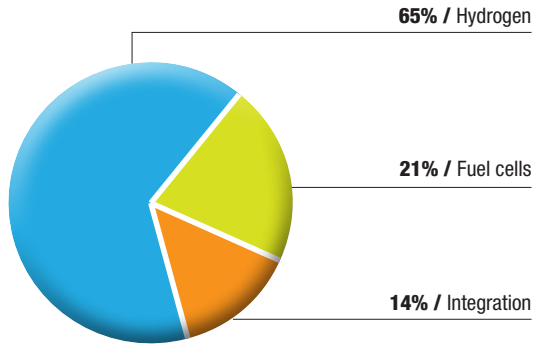
Among the innovation and development projects, those related with hydrogen production from renewable sources (FIRST, RES2H2, Hercules-Las Columnas, Sol-Ter-H or Hidrolica), those focused on hydrogen production from fossil fuels (REFORDI or SOLHYCARB), those that delve deep into the integration of systems (Hercules-El Leon, Delfin or Aquila), or those on development of elements for their integration into systems (Gencell, Homecell or Microcell), stand out.

As regards projects included in the general studies and implementation, and thematic networks categories, the MaHReA, EIHP and FCTESTNET Projects are worthy of mention as examples.

As regards distribution of the projects by technology, graph 8 shows that the majority of the same (65%) are related to hydrogen technologies, its production, purification and storage; 21% focus on development and use of fuel cells and their related systems; and the remaining 14% on systems that combine hydrogen production and its use in fuel cells.

Graph 8 / Distribution of Andalusian projects by technology.

Total: 58 projects.



The analysis by technology shows a balanced and logical result, if one considers Andalusia's commitment to renewable hydrogen and integration of renewable energy sources into the electric generation mix and that the projects on the use of fuel cells are focused on key sectors for the Andalusian economy, such as the transportation sector.

This greater focus toward key activities for the economy (energy and transport) is very consistent with the objectives and strategic lines defined by both the Spanish Hydrogen and Fuel Cell Technology Platform, and its European counterpart (materialized in the establishment of the JTI), as these are sectors where there has been increasing effort to establish the development of these new energy technologies.

A description of the projects carried out and underway in Andalusia is given on the following pages. They are distributed as per technology, with an indication of the Andalusian partners involved, the overall project budget, financing sources and synoptic description of the same. The cooperation that exists among research groups and companies is noteworthy, and indicates the degree of complementarity that has been achieved in development of this technology.

The number of projects carried out in a community context (26%) as against those that have received national and regional funding (34% each) and those with there own funding, which was 6% of the total, is also worthy of mention.

Likewise, the interdisciplinarity of the activities undertaken in the projects with the higher budgets as reflected in the number and field of activity of participants is also noteworthy.

Projects related with hydrogen production, purification and storage technologies /

→ REFORDI: Development of a 25 kW reformer for hydrogen production from diesel.

Total Budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 3,000,000	INTA	2004-2010	INTA, AICIA	€ 1,000,000

Objective: development, construction, operation and assessment of a diesel-fueled reformer that produces a stream of hydrogen capable of being used by a PEM type fuel cell (CO < 20 ppm).

→ THE PROJECT HAS BEEN EXECUTED IN TWO STAGES: IN THE FIRST, DESIGN OF THE CATALYTIC SYSTEM AND DEVELOPMENT OF THE CONTROL STRATEGIES WAS UNDERTAKEN, LEADING TO THE CONSTRUCTION OF A 5 KW PROTOTYPE. IN THE SECOND STAGE, ASPECTS RELATING TO ENERGY INTEGRATION AND ENHANCEMENT OF TRANSIENT BEHAVIOR DURING START-UPS AND SHUTDOWNS WERE ADDRESSED.

→ EIHP I and II: Development of legislation for hydrogen use in the automotive sector.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 2,000,000	Participants and EU's 5th Framework Programme	2001-2004	INTA	€ 300,000

→ HYAPPROVAL: Continuation of EIHP II.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 1,500,000	Participants and EU's 5th Framework Programme	2005-2007	INTA	€ 200,000

→ STORHY: Development of hydrogen storage systems.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 2,000,000	Participants and EU's 5th Framework Programme	2005-2008	INTA	€ 100,000

→ Design and Synthesis of multiporous coordination polymers (FQM-4228).

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 351,000	Regional Government of Andalusia. Ministry of Economy, Innovation and Science	2009-2013	University of Granada	€ 351,000

→ Cerium dioxide catalysts for hydrogen production from methane.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 202,500	Ministry of Science and Technology	2002-2005	University of Cadiz	€ 202,500

→ **Water as a source of atomic and molecular hydrogen. Implications in chemistry, biology and alternative energies** (FQM-3213)**.**

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 320,000	Regional Government of Andalusia. Ministry of Economy, Innovation and Science	2008-2012	University of Granada	€ 320,000

→ **Hydrogen production in microchannel reactors** (TEP-1961)**.**

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 444,000	Regional Government of Andalusia. Ministry of Economy, Innovation and Science	2007-2010	University of Seville	€ 444,000

→ **Application of plasma technology with catalysis to the production of hydrogen and to the construction of nanotubes for reforming of alcohols and plastic materials** (FQM-1741)**.**

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 354,000	Regional Government of Andalusia. Ministry of Economy, Innovation and Science	2007-2010	ICMS-CSIC and University of Seville	€ 354,000

→ **Design of advanced noble metals/Ceria-based fuel processing catalysts for hydrogen production.**

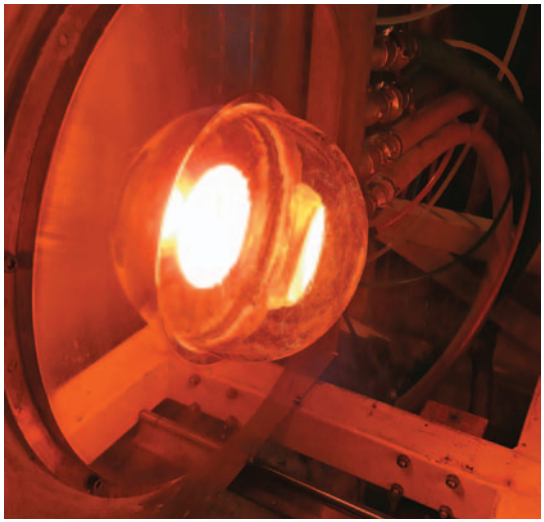
Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 250,000	Ministry of Education and Science	2004-2005	University of Cadiz	€ 250,000

→ SOLHYCARB: High Temperature Solar Chemical Reactor for Co-production of hydrogen and carbon black from natural gas cracking.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 2,000,000	Participants and EU's 5th Framework Programme	2006-2010	Abengoa Solar NT	€ 300,000

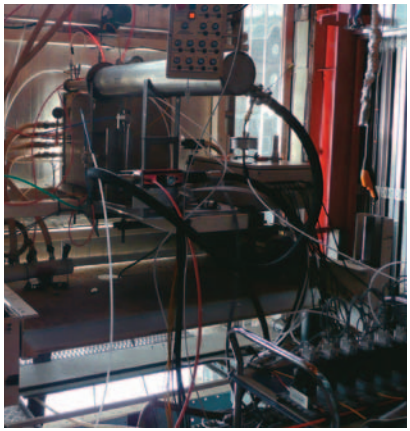
Its objective is the development of a new route for economic production of hydrogen and synthesis of nanostructured carbon materials from natural gas utilizing concentrated solar energy.

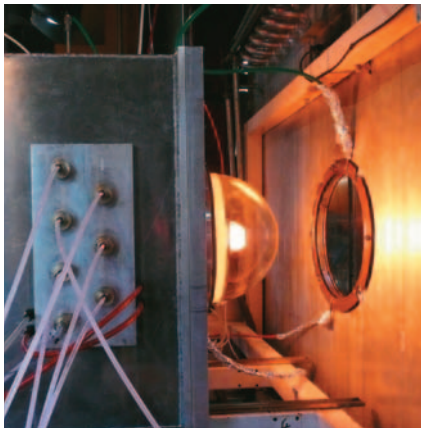
In the developed system, natural gas is broken down thermally in a high temperature solar reactor, producing a stream with high hydrogen content and a carbon-based nanostructured composite, of high commercial value. The solar thermal energy is stored in the hydrogen and the process is free of CO_2 emissions in a manner different to that of sequestration techniques.



Source: CNRS-PROMES

→ THE PROJECT AIMS AT THE DESIGN, CONSTRUCTION AND TESTING OF AN INNOVATIVE SOLAR REACTOR WITH OUTPUTS RANGING FROM 5 TO 50 KW THERMAL FOR OPERATING TEMPERATURES BETWEEN 1,500 AND 2,300 K AND 1 BAR PRESSURES.





→ **Photochemical generation of protons and hydrogen activation** (FQM-2734).

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 668,000	Regional Government of Andalusia. Ministry of Economy, Innovation and Science	2008-2012	University of Cadiz	€ 668,000

→ **New catalytic materials for production of hydrogen with very low CO content.**

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 350,000	Ministry of Education and Science	2005-2008	University of Cadiz	€ 350,000

→ **Lanthanide oxide-based nanostructured catalysts for hydrogen and biodiesel production.**

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 1,159,000	Ministry of Science and Innovation	2009-2013	University of Cadiz	€1,159,000

→ **Production and valorization of bio-hydrogen from urban solid wastes** (TEP-2472).

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 642,000	Regional Government of Andalusia. Ministry of Economy, Innovation and Science	2008-2012	University of Cadiz	€ 642,000

→ MAHRES: Preparation of the hydrogen supply and demand map in Spain.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 180,000	Hynergreen and the Ministry of Education and Science	2004	Hynergreen and Pablo de Olavide University	€ 180,000

→ MAHRES II: Analysis of multi-criterion decision that enables the drafting of a hydrogen map for the home market.

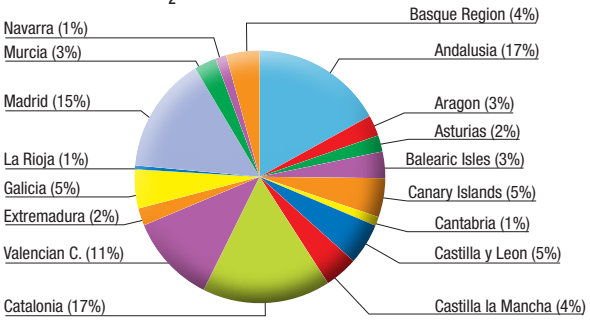
Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 140,000	Hynergreen	2006-2007	Hynergreen and Pablo de Olavide University	€ 140,000

The objective of this project was to analyze the feasibility of implementing the Hydrogen Economy in Spain and plan said process, with a first stage comprising coverage in 2010 of 10% of transportation energy demand with hydrogen from renewable sources.

To this end, a multi-objective programming model was developed. This would enable, for the period taken into account, planning of investments in renewable energies in Spain, as well as the production and distribution of the hydrogen generated throughout the different Spanish regions.

In the case of Andalusia, the results showed that this region is self-sufficient in renewable energy resources to cover 10% of its energy demand for transportation, utilizing, basically, wind power and thermosolar energy.

→ Demand for H_2 for transport in 2010



Total: $5x10^9$ t.

→ PROJECT **MAHREA** (MAP OF RENEWABLE HYDROGEN IN ANDALUSIA) IS THE CONTINUATION OF THESE PROJECTS. IT CONTEMPLATES, FROM SEVERAL TECHNICAL AND ECONOMIC STANDPOINTS, AND UNDER THE PERSPECTIVE OF DIFFERENT FUTURE ENERGY GENERATION AND DEMAND SCENARIOS, THE DIFFERENT POSSIBILITIES FOR RENEWABLE HYDROGEN PRODUCTION IN THIS AUTONOMOUS COMMUNITY, WITH THE FINAL OBJECTIVE OF SUSTAINABLE ENERGY SELF-SUFFICIENCY.

→ **HIDRYCAT: Study of dry reforming (catalytic) to obtain hydrogen and synthesis gas for Fischer-Tropsch.**

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 63,900	Ministry of Education and Science	2004-2007	RNM111 Research Group – Regional Government of Andalusia	€ 63,900

→ **SYNANOCAT: Obtaining synthesis gas and hydrogen by reforming hydrocarbons on Ni nanostructured catalysts.**

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 119,790	Ministry of Education and Science	2007-2010	University of Malaga and University of Seville	€ 55,000

→ **H2 – PLASMA: Hydrogen production by organic compound decomposition utilizing microwave plasma at atmospheric pressure.**

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 145,200	Ministry of Science and Innovation	2009-2011	University of Cordoba	€ 145,200

→ **Steam co-gasification of biomass/poor coal blends. Attainment of syngas capable of powering gas engines/fuel cells.**

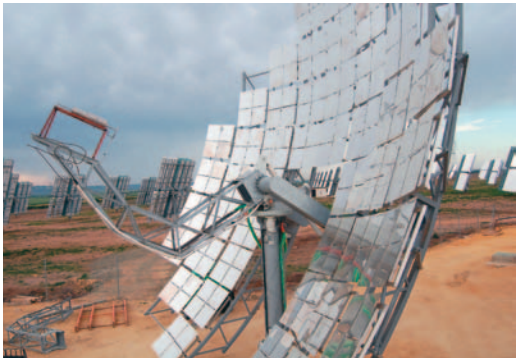
Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 101,075	University of Seville and Ministry of Education and Science	2004	University of Seville	€ 101,075

→ SOLTER-H: Development and construction of a prototype for hydrogen production from high temperature thermosolar energy.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 903,677	Participants and Ministry of Education and Science	2004-2008	Hynergreen, Abengoa Solar NT, PSA-CIEMAT	€ 903,677

The fundamental objective of the project was to demonstrate the feasibility of the hydrogen and concentrated solar thermal energy binomial though the use of ferrite-based thermochemical cycles.

Through these thermochemical cycles, that use an intermediate substance, it is possible to produce oxygen and hydrogen from water without having to resort to temperatures as high as in the case of "direct water splitting" by thermolysis, and simplifying the separation process for the gases produced. As part of the project, a 5 kW system was designed, developed and evaluated in the solar furnace of the Almeria Solar Platform.



→ Project for integration of wind power with the new hydrogen technologies.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 218,700	Participants and CTA	2007	Gamesa and University of Seville School of Engineering	€ 218,700

→ Development of a gas generation from biomass system, suitable for use in fuel cells.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 200,000	Ministry of Education and Science	2001-2004	University of Seville School of Engineering	€ 200,000

→ Clean hydrogen production: CO_2 emission-free alternatives.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 2,170,000	Madrid Community	2006-2009	INTA, CIEMAT	€ 130,200

→ Methane reforming for hydrogen production with plasmas and by catalytic and electrocatalytic processes.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 121,000	Ministry of Education and Science	2004-2007	ICMS- CSIC and University of Seville	€ 121,000

→ Microchannel catalytic reactors for hydrogen production from alcohols.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 365,420	Ministry of Education and Science	2006-2009	University of Seville School of Engineering	€ 365,420

→ HIDROLICA: Hydrogen production from wind power and integration of both technologies.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 1,955,580	Participants, IDEA and CTA	2006-2009	Endesa Generación, Greenpower and Inerco	€ 1,955,580

The main objective of project Hidrolica is to analyze the integration of renewable energies with the hydrogen energy vector, so that any possible technological and economical disadvantages for its implementation at commercial scale may be identified and resolved.

The results of this project contribute to fostering the integration of hydrogen in wind farms that are currently operating, as, in addition to enabling higher electrical energy production, they promote the penetration of hydrogen, either as an energy vector or as raw material, in potential markets, as of from which the formation of true hydrogen distribution networks would commence.

→ THIS PROJECT, CARRIED OUT AT TAHIVILLA WIND FARM IN TARIFA (CADIZ), UTILIZES WIND POWER AS THE PRIMARY SOURCE TO PRODUCE HYDROGEN BY ELECTROLYSIS.

→ Participation in the International Energy Agency Hydrogen Program: hydrogen production from wind power.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 25,860	Andalusian Energy Agency and the University of Seville School of Engineering	2007-2009	Andalusian Energy Agency and the University of Seville School of Engineering	€ 25,860

→ HYDROSOL II: Solar hydrogen via water splitting in advanced monolithic reactors for future solar power plants.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 2,100,000	European Commission, Directorate-General for Research	2005-2009	PSA-CIEMAT	€ 357,000

→ HYDROSOL III: Solar hydrogen via water splitting in advanced monolithic reactors for future solar power plants.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 2,100,000	Fuel Cells and Hydrogen JTI	2009-2012	PSA-CIEMAT	€ 378,000

→ Solar thermochemical application for production of syngas + H2 from heavy crude oil.

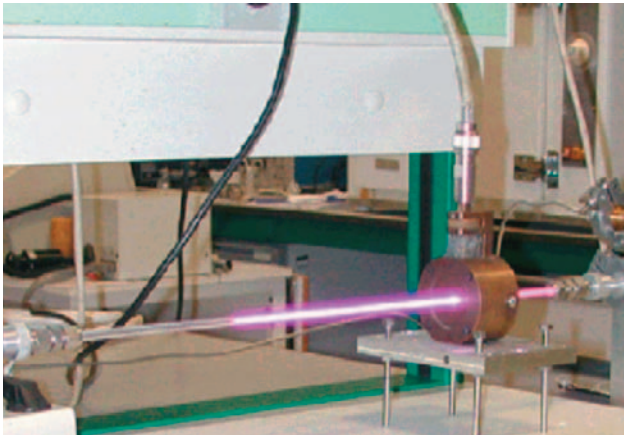
Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
$ 6,800,000	Venezuelan State Oil Company (PDVSA)	2004-2009	PSA-CIEMAT	€ 1,891,000

→ PLASMAGEN: Development of plasma reforming process for methane and other fuels.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 200,000	Hynergreen and IDEA	2005-2007	Hynergreen and ICMSE-CSIC	€ 200,000

This project aims at the development of a process to reform methane and/or other hydrocarbons utilizing plasma as a means to produce the breakdown of fuel molecules.

In a traditional reforming system, the fuel (be it hydrocarbon or alcohol) is combined with water (and/or pure oxygen) to produce hydrogen, but always with an emission of carbon dioxide (the carbon existing in the hydrocarbon or alcohol molecule becomes part of the CO_2 molecule when it combines with the oxygen).



In this novel system, which has already yielded promising results on its behavior in early trials, presents an alternative to conventional catalytic reforming, that enables plasma reforming of the hydrocarbon or alcohol without the need for oxygen. If natural gas were used as fuel it would give rise to hydrogen and carbon products in solid state.

→ INOHYP: Innovative medium-long term for hydrogen production – Coordinated Action.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 770,000	Participants and EU's 6th Framework Programme	2004-2007	PSA-CIEMAT	€ 15,400

→ HYRREG: Platform for generating projects for cooperation, to drive the Hydrogen Economy in southeast Europe.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 1,324,429	Interreg IVB SUDOE Program	2009-2011	Andalusian Institute of Technology-IAT and INTA	€ 212,000

→ Application of novel techniques for renewable electrical energy storage control utilizing hydrogen.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 320,000	University of Seville School of Engineering and the Ministry of Science and Innovation	2007-2010	University of Seville School of Engineering	€ 320,000

→ Feasibility study on hydrogen production from Wind Power.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 10,345	Andalusian Energy Agency	2005	Andalusian Energy Agency and University of Seville School of Engineering	€ 10,345

→ CONSOLI+DA: Solar R&D Consortium. Work package for solar hydrogen production.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 2,000,000	Hynergreen and IDEA	2008-2011	Hynergreen, Abengoa Solar NT, mc2	€ 2,000,000

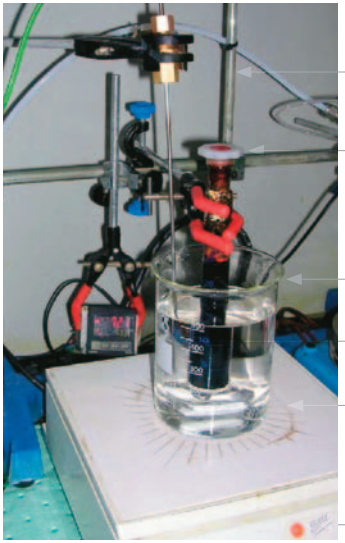
The ConSOLI+Da project is an undertaking at different levels for development of R&D in the solar energy sector, funded under the Cenit framework.

One of the activities included in the project focuses on the study of hydrogen as a means for storage of thermosolar energy, producing the gas at times when there is excess supply of solar energy and using it to generate electricity at peak demand times.

Different hydrogen production processes (thermolysis, thermochemical cycles, high and low temperature electrolysis, etc.) are being analyzed in project ConSOLI+Da, as are different systems for transforming this gas into electrical or thermal energy (fuel cells, turbines, etc).

→ Detail of the upper part of the column and the condensate collection ball.

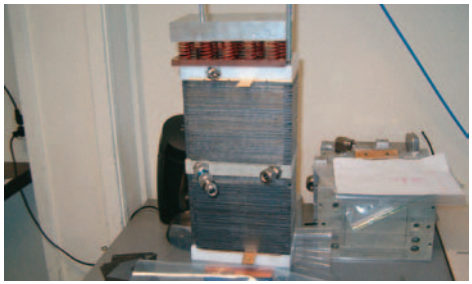
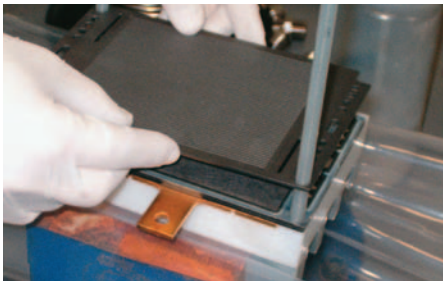
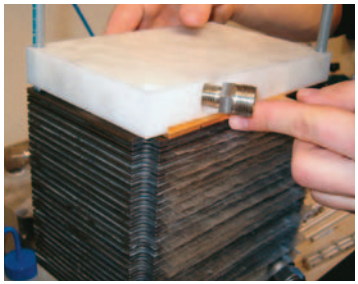
→ Detail of assembly for study at the laboratory of the Bunsen reaction.



Projects focused on development and use of fuel cells and related systems /

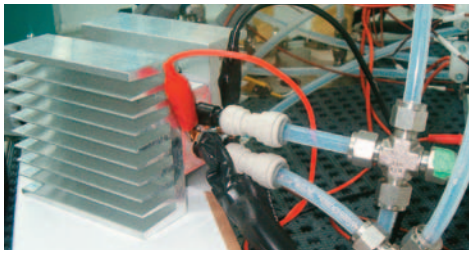
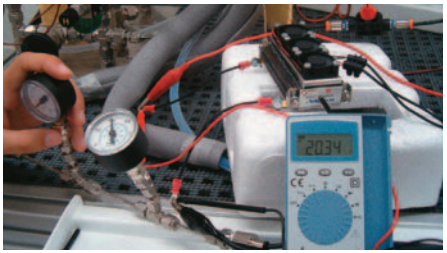
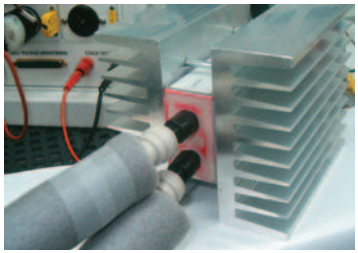
→ HOMECELL: Design and development of a 2 kW electric energy generation system, based on fuel cells, for the domestic market.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 690,000	Hynergreen, Ministry of Education and Science, and Regional Government of Andalusia	2003-2005	Hynergreen	€ 690,000

→ MICROCELL: Design and development of a polymer fuel cell for low consumption portable applications.

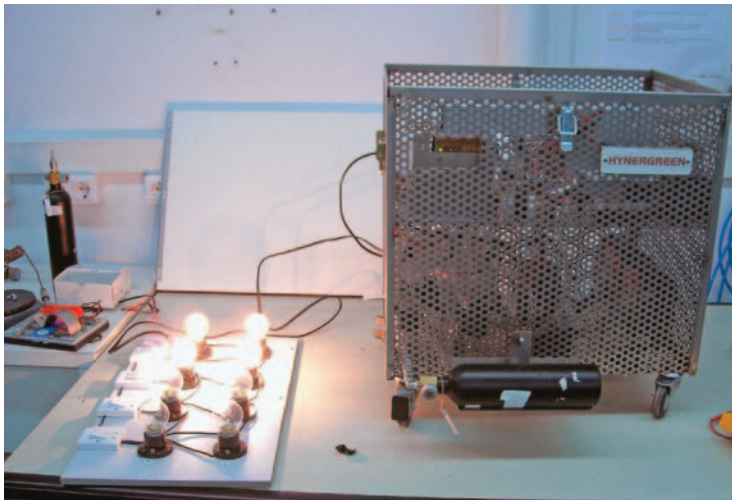
Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 670,000	Hynergreen, Ministry of Education and Science, and Regional Government of Andalusia	2003-2005	Hynergreen	€ 670,000

→ EPICO: Development of national fuel cells.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 3,500,000	Ministry of Education and Science	2005-2008	Hynergreen and INTA	€ 800,000

The objective of project EPiCo was the development in Spain of polymeric fuel cells (PEMFC). In the same, the members of the consortium designed, manufactured, evaluated and integrated these devices, with powers ranging from 4 W to 1,000 W; technologies were developed at all levels, not only membrane or polymer, but also in the field of control, and BoP (Balance of Plant). Some of the applications into which fuel cells were integrated were battery chargers, autonomous generators, monitoring equipment, electric bicycles, uninterrupted power supply systems, electric fences, etc.



→ GENCELL: DC distributed generation for systems based on fuel cells and biogas microturbines.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 120.000	IDEA	2006	Greenpower and University of Seville	€ 120.000

→ **Experimental validation of a methodology for development of bipolar plates for solid polymer fuel cells** (P08-TEP-04309)**.**

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 244,000	Regional Government of Andalusia. Ministry of Economy, Innovation and Science	2009-2011	University of Seville	€ 244,000

→ **Development of nanostructured nickel catalysts and attainment of hydrogen from methane and solid oxide fuel cell anodes** (FQM-2520)**.**

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 483.000	Regional Government of Andalusia. Ministry of Economy, Innovation and Science	2008-2012	Scientific Research Centre Isla de la Cartuja	€ 483.000

→ **Analysis of relevant conductor materials for use in fuel cells and other electrical devices**

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 242,000	Ministry of Education and Science	2007-2010	University of Malaga and CSIC	€ 242,000

→ **FCTESTNET: Development of test protocols for fuel cells.**

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 900,000	Participants and EU's 5th Framework Programme	2001-2004	INTA	€ 50,000

→ **FCTESTQA: Comparison of test protocols for fuel cells.**

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 1,500,000	Participants and EU's 5th Framework Programme	2006-2009	INTA	€ 100,000

→ REVCELL: Development of a reversible fuel cell system for stand alone applications.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 3,900,000	Participants and EU's 5th Framework Programme	2002-2006	Hynergreen and Inabensa	€ 400,000

The objective of this project was the development of a reversible fuel cell, i.e., that supports the normal functioning of a fuel cell, to produce electric energy by combining hydrogen and oxygen, producing water as a waste product, and also the contrary, typical of an electrolyzer device, by which water is dissociated into its aforesaid elementary components.

On this project, the reversible fuel cell was integrated with photovoltaic panels, thereby enabling the production of clean and renewable hydrogen in inaccessible and remote areas, in a decentralized manner. Thus, by means of a Revcell system and a solar installation, a user could avail of hydrogen (for example, to fuel a vehicle) and electric energy (suitably stored in the form of hydrogen, to be used even when the solar resource is not available, at night, for example).

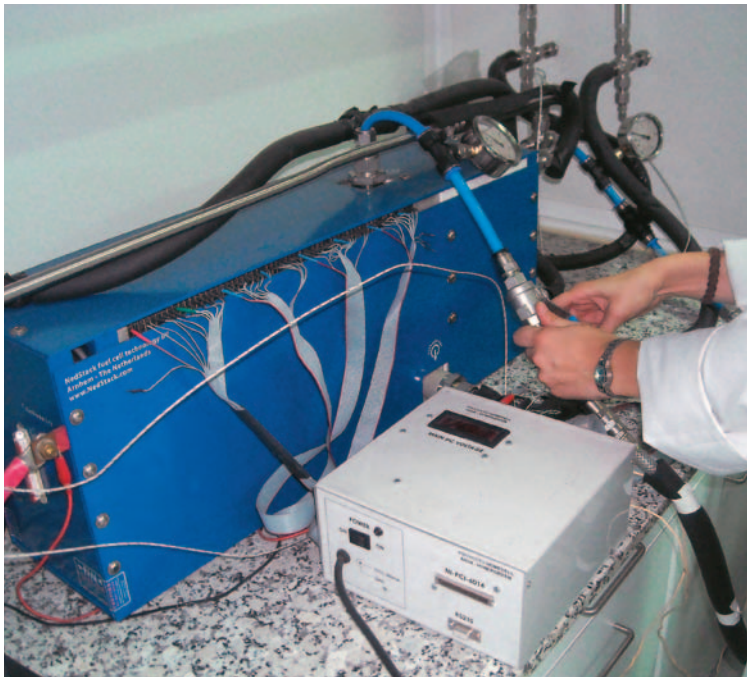
→ AQUILA: Development of fuel cell-based electric energy generators for the aeronautical sector.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 1,380,240	Hynergreen, IDEA, and CTA	2006-2008	Hynergreen and AICIA	€ 1,380,240

The objective of this project was to advance in the introduction of hydrogen and fuel cell technology in the aeronautical sector.

To this end, different possibilities for distributed electric energy generation on board planes utilizing different technologies, high, medium and low temperature fuel cells were analyzed.

On the other hand, in the field of hydrogen transportation, new materials and storage methods were studied, while for on-board production, electrolytic and fuel reforming processes were considered.



→ SANTA FE: Analysis of the technical feasibility of fuel cells applied to the railway sector.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 90,000	Hynergreen and IDEA	2009	Hynergreen and AICIA	€ 90,000

Projects that integrate hydrogen production systems and their use in fuel cells, for final applications /

→ **FIRST: Development of a supply system based on hydrogen and fuel cells for telecommunications.**

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 1,200,000	Participants and EU's 5th Framework Programme	2001-2004	INTA	€ 250.000

→ **RES2H2: Development, installation and operation of a storage system for surplus wind power, in hydrogen form.**

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 5,000,000	Participants and EU's 5th Framework Programme	2002-2006	INTA and Inabensa	€ 600,000

→ The storage system for surplus wind power, in hydrogen form, situated on the island of Gran Canaria.

→ H2-TODAY: Creation of a knowledge center based on web technology for the technical, commercial and environmental aspects of hydrogen technology.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 100,000	University of Malaga	2009	University of Malaga, ISCEER and INFOCODEX	€ 100,000

→ ECOTRANS: Ecological technologies for urban transportation. Work package for application of hydrogen and fuel cells.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 1,500,000	Hynergreen and CDTI	2008-2011	Hynergreen, University of Jaen and Cidaut	€ 1,500,000

→ H2-SUR: Commencement of infrastructure associated with the hydrogen economy in Andalusia.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 5,100,000	Participants and CDTI	2009-2011	Hynergreen, Alshark & Marine, Altum, Bicieléctrica	€ 5,100,000

→ SMARTCITY: Infrastructures and advanced smart energy distribution services. Energy generation and storage tasks, including hydrogen.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 320,000 *	European Regional Development Fund (ERDF) through CDTI, and participants	2009-2012	Endesa Servicios, Isotrol, Greenpower, Telvent, Ingeteam	€ 320,000

* The total budget for the project is 31 million euro. However, only the figure foreseen for hydrogen and fuel cells is reflected in the table.

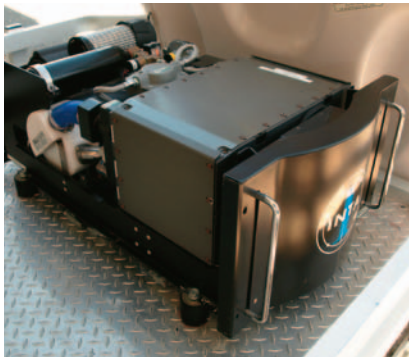
→ DELFIN: Development of a fuel cell powered electric vehicle.

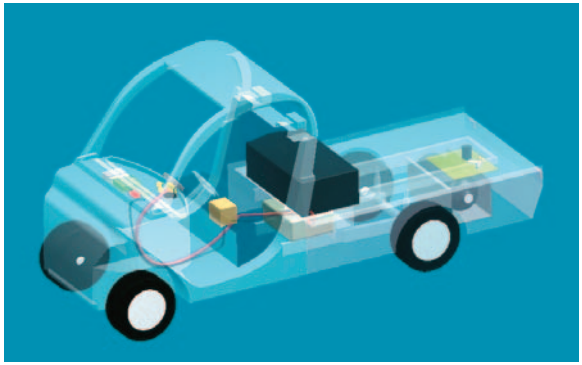
Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 230,000	INTA	2006-2008	INTA and AICIA	€ 230.000

The aim of this project is to analyze and validate different control strategies for operation of electric vehicles that incorporate fuel cells.

The prototype is a hybrid vehicle whose electric engine can be powered either by a fuel cell or by an additional system of electric batteries. In this regard, the incorporation of the fuel cell together with proper management of power can increase the autonomy of the vehicle by up to 2.5 times that of the commercial vehicle it is based on.

→ WORK IS CURRENTLY BEING CARRIED OUT ON OPTIMIZING THE CONFIGURATION OF THE VEHICLE AND ITS SUPPLY SYSTEM, IN ORDER TO INCREASE ITS EFFICIENCY AND AUTONOMY.





→ HERCULES: Development of a hydrogen production system using solar photovoltaic energy. Construction of a hydrogen filling station and integration of fuel cells in a commercial vehicle.

Total budget:	Funding:	Execution period:	Andalusian participants:	Budget Andalusian participants:
€ 9,000,000	European Regional Development Fund (ERDF) through the Ministry of Innovation and Science, IDEA and CTA	2006-2009	Hynergreen, INTA, AICIA, Greenpower, Andalusian Energy Agency, Carburos Metálicos, Abengoa Solar NT and Santana Motor	€ 9,000,000

→ AN ALL-TERRAIN VEHICLE HAS BEEN ADAPTED TO SUIT IT TO ELECTRIC PROPULSION, USING A FUEL CELL AND A HYDROGEN TANK FOR ENERGY STORAGE.

Hercules Project is a pioneering singular and strategic technology demonstration initiative in Spain that encompasses the entire hydrogen chain as an energy vector. The main objectives of the project are:

- **Development of the Hydrogen Economy in Spain by establishing a further point in the country's future "virtual hydrogen network".**
- **To validate the hydrogen and fuel cells binomial as a clean and efficient method for electricity storage and its use in the transportation sector.**

The project comprises two distinct parts:

1. **On the one hand, a solar energy renewable hydrogen filling station has been designed, developed and commissioned in Sanlucar la Mayor (Seville), next to the PS-20 thermosolar power plant.**
2. **On the other, an all-terrain vehicle has been adapted to suit it to electric propulsion, using a fuel cell and a hydrogen tank for energy storage.**

→ Solar energy renewable hydrogen filling station in Sanlucar la Mayor, next to the PS-20 thermosolar power plant.

7 Annexes

/ University research groups

/ Public research bodies (OPI)

/ Companies with projects underway

/ Companies with short-term interest in these technologies

University research groups /

Group / Dept.	Code	Contact	Observations
University of Almeria			
Department of Geometry, Topology and Organic Chemistry// Organic Chemistry Area	FQM 267	Maria Jose Iglesias Valdes-Solis Ctra. Sacramento s/n La Cañada de San Urbano 04120 Almeria	Coal pyrolysis.
University of Cadiz			
Department of Materials Science and Metallurgical Engineering and Inorganic Chemistry//Solid State Chemistry and Catalysis Group	FQM 110	Serafin Bernal Marquez Facultad de Ciencias Apdo.40 11510 Puerto Real (Cádiz)	Catalysts for hydrogen production from methane reforming.
Department of Electric Engineering	TEP 208	Jose Ramon Saenz Ruiz ESI I – E. Superior de Ingeniería C/ Chile, 1 11002 Cádiz	Control of fuel cells, especially SOFC. Works in collaboration with the University of Jaen.
University of Cordoba			
Department of Inorganic Chemistry and Chemical Engineering	FQM 175	Lourdes Hernan Paadin Campus de Rabanales, C-3, Planta Baja. 14071-Córdoba	Catalysts for reformers. Works in collaboration with the University of Malaga.
University of Granada			
Department of Inorganic Chemistry	RNM 172	Francisco Carrasco Marin Facultad de Ciencias Campus Universitario de Fuentenueva Avenida Severo Ochoa s/n 18071 Granada	Catalysts for reforming and coal gasification.
University of Huelva			
Department of Electronic Engineering, Computerized and Automatic Systems. "Control and Robotics" Research Group	TEP 192	Jose Manuel Andujar Marquez Esc. Politecnica Superior Campus de «La Rabida» Ctra de Palos de la Frontera s/n 21071 La Rabida, Palos de la Frontera (Huelva)	Modeling and control of renewable energy systems, including fuel cells.

University research groups /

Group / Dept.	Code	Contact	Observations
University of Jaen			
Department of Electric Engineering. Electric Research and Technology Group	TEP 152	Francisco Jurado Melguizo Director de Departamento Esc. Politecnica Superior de Linares C/ Alfonso X El Sabio, nº 28 23700 Linares-Jaen	Control of fuel cells, especially SOFC. Works in collaboration with the University of Cadiz.
University of Malaga			
Department of Inorganic Chemistry, Crystallography and Mineralogy. Area: Structural design of inorganic materials	FQM 113	Miguel A. García Aranda Facultad de Ciencias Campus de Teatinos 29071 Malaga	Solid electrolytes for SOFC.
Department of Inorganic Chemistry, Crystallography and Mineralogy. Area: porous inorganic solids: synthesis, characterization and catalytic applications.	FQM 155	Enrique Rodriguez Castellon Facultad de Ciencias Campus de Teatinos 29071 Malaga	Catalysts for reformers. Works in collaboration with the University of Cordoba.
University of Seville			
Department of Plant Biochemistry	CVI 198	Francisco Fernando de la Rosa Acosta Facultad de Biologia C/ Profesor García Gonzalez, s/n 41012 Sevilla	Hydrogen production from algae.
Department of Inorganic Chemistry	FQM-179	Guillermo Munuera Contreras Facultad de Quimica C/ Profesor Garcia Gonzalez, s/n 41012 Sevilla	Structures and reactivity of surfaces.
Research Group: Surfaces, Interfaces and Thin Films	FQM-196	Agustín Rodriguez Gonzalez-Elipe, Instituto de Ciencia de Materiales de Sevilla- CSIC C/ Americo Vespucio, nº 49 41092 Sevilla	Development of materials for reformers and SOFC.
Department of Aerospace Engineering and Fluid Mechanics	TEP-103	Escuela Superior de Ingenieros Camino de los Descubrimientos, s/n 41092 Sevilla	Application of nanomaterials to fuel cells.

University research groups /

Group / Dept.	Code	Contact	Observations
University of Seville			
Research Group on Structure and Surface Reactivity	TEP-106	Instituto de Ciencia de Materiales de Sevilla- CSIC C/ Americo Vespucio, nº 49 41092 Sevilla	Materials for SOFC
Department of Robotics and Systems Engineering	TEP 116	Carlos Bordons Alba Escuela Superior de Ingenieros Camino de los Descubrimientos, s/n 41092 Sevilla	Modeling of PEM fuel cells. Control systems of fuel cell systems.
Department of Electronic Engineering Electronic Technology Group	TEP 126	Juan Manuel Carrasco Solis Escuela Superior de Ingenieros Camino de los Descubrimientos, s/n 41092 Sevilla	Power conversion and conditioning systems for fuel cells.
Department of Chemical and Environmental Engineering	TEP-135	Pedro Ollero de Castro Escuela Superior de Ingenieros Camino de los Descubrimientos, s/n 41092 Sevilla	Gasification technology for hydrogen production.
Department of Energy Engineering. Machines and Thermal Engines Area	TEP 137	David Sanchez Martinez Escuela Superior de Ingenieros Camino de los Descubrimientos, s/n 41092 Sevilla	Modeling of SOFC installations. Integration of high temperature fuel cells and power systems.
Department of Energy Engineering. Thermotechnics Area	TEP 143	Felipe Rosa Iglesias Escuela Superior de Ingenieros Camino de los Descubrimientos, s/n 41092 Sevilla	Modeling of PEM fuel cells, installations for hydrogen production, storage and utilization in PEM fuel cells.
Research Group: Nanostructured and Microstructured Materials	TEP 217	Asuncion Fernandez Camacho Instituto de Ciencia de Materiales de Sevilla- CSIC C/ Americo Vespucio, nº 49 41092 Sevilla	Development of nanostructured materials for hydrogen storage.
Pablo de Olavide University			
Department of Physical, Chemical and Natural Systems. Applied Physics Area	FQM 205	M. Carmen Gordillo Bargueño Edificio 2, Carretera de Utrera, km.1 41013 Sevilla	Theoretical studies of hydrogen storage in nanotubes.
Department of Economy, Quantitative Methods and Economic History. Quantitative Methods Area	SEJ 332	Raul Brey Sanchez Edificio Nº 3, Jose Moñino - 3ª planta Ctra. de Utrera, Km. 1 41013 Sevilla	Economic analyses on use of hydrogen as fuel.

Public Research Bodies (OPI) /

OPI	Group / Dept.	Contact	Observations
Almeria Solar Platform (PSA) - CIEMAT	Solar Concentration Systems Unit. Solar Hydrogen and Industrial Processes Area	Eduardo Zarza Moya Apdo. de Correos, 22 Carretera Senes s/n 04200 Tabernas (Almería)	This installation is a fundamental instrument for the development of solar hydrogen production processes, specialized in solar concentration technologies applicable to reactors that operate at temperatures exceeding 1,000ºC.
National Institute for Aerospace Technology (INTA)	Laboratorio de Sistemas de Energía Terrestre (LSET)	Fernando Isorna LLerena Ctra. S. Juan del Puerto-Matalascañas, km.34 21130 Mazagon (Huelva)	It covers practically all the links in the chain: hydrogen production by reforming diesel, ethanol or with electrolyzers; characterization, testing and integration of PEMFC in power systems and plants; storage systems for hydrogen at high pressure or in metal hydrides; and development of regulations and standards for hydrogen technology and its applications.

Companies with projects underway /

Company	Contact	Observations
GreenPower Technologies, S.L.	Poligono PIBO Av. de Camas, 28. Parcela 100 41110 Bollullos de la Mitacion (Seville) www.greenpower.es	Design, development and manufacturing of power conditioners for fuel cells.
Hynergreen Technologies, S.A. [includes the previous activities of Inabensa and Greencell]	Avda. de la Buhaira, 2 41018 Seville www.hynergreen.com	Organization and exploitation of activities related with electricity production using different fuel cell technologies, as well as the production, storage and use of clean hydrogen, and its integration with renewable energies.
Inerco, S.A.	Parque Tecnologico de la Cartuja C/ Tomas Alba Edison, 2. Edificio INERCO, 41092 Seville www.inerco.com	Integral engineering services for design, project, construction and commissioning of industrial installations and new industrial developments, such as the new fuels production and storage innovation projects: hydrogen, biofuels, etc.
Sistemas de Calor, S.L.	Pol. Industrial La Algaida C/ Marmolistas 13 04740 Roquetas de Mar (Almeria) www.sistemasdecalor.com	Installation company specialized in the execution of solar energy, wind power and industrial heating projects. PEMFC residential applications.
Santana Motor	Avenida Primero de Mayo 23700 Linares (Jaen)	Integration of PEM fuel cells in vehicles.
Carburos Metálicos	Carburos Metálicos Poligono Industrial La Red S/N 41500 Alcala de Guadaira (Seville)	Integration of hydrogen storage systems in vehicles and development of hydrogen filling stations.
Endesa	Avenida de la Borbolla, 5 41004 Seville	Integration of wind power and hydrogen production systems.

Companies with short-term interest in these technologies /

Company	Contact	Observations
Almeria		
EJIDOFIL SL	Poligono Industrial La Redonda C/ IV Parcela 102 04700 El Ejido (Almeria) www.ejidofil.com	Treatment and manufacture of plastics. Possibility of use in components for fuel cells.
Cadiz		
Easy Industrial Solutions	Tecnoparque Bahia de Cadiz C/ Ingenieria, 4 11500 El Puerto de Santa Maria (Cadiz) www.easy-is.com	In-house technologies for developm ent of products with composite materials, especially carbon fiber. Possibility of applying these technologies in the development of compressed hydrogen storage tanks types III and IV.
Utilbox S.L.	Pol. Ind. Pelagatos, C/ de las Libertades, 28 11130 Chiclana de la Frontera (Cadiz) www.utilbox.es	Molding of EPS (expanded polystyrene) for packages and construction material. Possibility of use in components for fuel cells and electrolyzers.
SK10 Andalucía S.A.	Parque Industrial Bahia de Cadiz Avda. Parque Industrial 23-25 11500 Puerto de Santa Maria (Cadiz) www.sk10andalucia.com	Supplier of aeronautical structures in special alloys and composite materials. Potential supplier of materials and components for hydrogen production and storage systems, and fuel cells.
Mecanizaciones del Sur, S.A. (MECASUR)	Parque Ind. Bahia Sanlucar Pol. Ind. Bahia 11500 El Puerto de Santa Maria (Cadiz)	Manufacture and assembly of electronic and electric components for automobiles. Potential supplier of these components for fuel cell vehicles.
Infasur Aeronáutica S.L.	Pol. Ind. “El Trocadero” C/ Francia s/n, Parc. C1 y C2 11519 Puerto Real (Cadiz) www.infasur.com	Design, manufacture, assembly of duty tools, machining of aeronautical parts and assembly of sets. Possibility of manufacturing of electrolyzer and fuel cell components.

Companies with short-term interest in these technologies /

Company	Contact	Observations
Cordoba		
Proquisur S.L.	Pol. Ind. La Salina, parc 26,27 14960 Rute (Cordoba) www.proquisur.com	Manufacture and distribution of chemical products for automotive sector. Possible use in cooling circuits of fuel cells and electrolyzers.
Quimies de Rute S.L.	Blas Infante, s/n 14960 Rute (Cordoba) www.quimies.com	Manufacture and distribution of chemical products for automotive sector. Possible use in cooling circuits of fuel cells and electrolyzers.
Veblinter Andalucía S.A.	Pol. Las Quemadas C/Imprenta Alborada nº 225 14014 Cordoba www.veblinter.es	Manufacture and adaptation of special vehicles. Fuel cell applications for the propulsion of these vehicles.
Avia Composites S.L.	Prolongacion Ingeniero Torres Quevedo, Grupo Alarife, Nave 6 14013 Cordoba www.aviacomposite.com	Manufacture of all kinds of parts in glass and carbon fiber, especially components for commercial aviation and sports sectors. Potential supplier of materials and components for hydrogen production and storage systems, and fuel cells.
Granada		
Atarfil S.L.	Ctra. Cordoba km 429 Complejo El Rey - 18230 Atarfe (Granada) www.atarfil.com	Development, manufacture and commercialization of thermoplastic membranes and supplementary products. Possibility of use in components for fuel cells.
Transformados Plásticos Europa S.A.	Ctra. de Malaga. km. 446,2 18320 Santa Fe (Granada) www.plasticoseuropa.com	Manufacture and transformation of plastic films. Possibility of use in components for fuel cells.
Mhurtam European Group	Pol. Ind La Paz C/ Antonio Huertas Remigio 18200 Maracena (Granada) www.mhurtam.com	Manufacture of limited series automobiles. Fuel cell applications in these vehicles for propulsion.
Nederlandse Radiateuren Fabriek España S. A. (NRF España S.A.)	Apdo. correos nº 46 18210 Peligros (Granada) www.nrf.es	Manufacture of radiators and heaters for vehicles. Potential supplier of these components for fuel cell powered vehicles.
Huelva		
Polisur 2000 S.A.	Pol. Ind. El Chorrillo, Nave 45 21440 Lepe (Huelva) www.polisur.es	Transformation of plastics into packages, consumable products and construction materials. Possibility of use in components for fuel cells and electrolyzers.
Astilleros de Huelva S.A.	Glorieta Norte s/n 21001 Huelva www.astihuelva.es	Ship building. Fuel cell applications for propulsion and electricity generation.

Companies with short-term interest in these technologies /

Company	Contact	Observations
Jaen		
Procesos Industriales del Sur (PROINSUR)	Pol. Ind. C/ Mancha Real s/n 23600 Martos (Jaen) www.proinsur.com	Design and manufacture of plastic parts and components for the transportation sector. Possibility of applying know-how to the manufacture of polymer components of electrolyzers and fuel cells.
Reciclados Tuccitanos, S.L.	Pol. Ind. C/ Alcaudete, s/n 23600 Martos (Jaen) www.retuc.com	Recycling of plastic materials. Possibility of applying know-how to the manufacture of polymer components of electrolyzers and fuel cells.
Teknia Plasticos Martos S.A.	C/ Bailen, 53 Pol. Ind. de Martos - 23600 Martos (Jaen) www.teknia.es	Injection of thermoplastics and components for automotive sector. Potential supplier of components for fuel cell powered vehicles.
Termoplasticos Andaluces, S.L	P.I. Cañada de la Fuente, s/n 23600 Martos (Jaen)	Injection of thermoplastics. Parts and pieces for automobiles, communications, appliances. Possibility of use in components for fuel cells.
Alucoat Conversion S.A.	Camino de San Luis s/n 23700 Linares (Jaen) www.alucoat-conversion.com	Aluminum foil coatings, 20 to 200 microns, and products with layer and/or bilayer coatings, counter casting with film and prints. Possible use in components for fuel cells and electrolyzers.
Construcciones Industriales Andaluzas S.A. (CIANSA)	Camino de Ubeda, s/n Pol. Ind. Santa Rosa 23700 Linares (Jaen)	Manufacturer of parts in series, specially for the automotive sector, and of bodies for special vehicles. Potential supplier of components for fuel cell powered vehicles.
Gestamp Linares S. A.	Pol. Ind. Los Rubiales s/n. 23700 Linares (Jaén) www.corporaciongestamp.com	Production of components for automotive sector. Potential supplier of components for fuel cell powered vehicles.
Fabricados para la Automoción del Sur S. A. (FASUR)	Parque de Proveedores de Santana Motor Pol. Ind. Los Rubiales Parcelas 78-79 23700 Linares (Jaen) www.fasur.com	Manufacture parts, components and mechanical assemblies for the transportation sector. Potential supplier of components for fuel cell powered vehicles.
Malaga		
Naga Technologies, S.L.	Parque Tecnologico de Andalucia C/ Maria Curie 8, Edif. B 29590 Campanillas (Malaga) www.nagatech.es	Design and development of great depth submarine robotics projects. Applications of fuel cells in these vehicles for propulsion and autonomous electricity generation.
Isofotón	Parque Tecnologico de Andalucia Severo Ochoa, 50 29590 Campanillas (Malaga)	Manufacturer of photovoltaic modules. Use for hydrogen generation by electrolysis.
Predan, S.A	Parque Tecnologico de Andalucia Severo Ochoa, 37 29590 Campanillas (Malaga) www.predan.com	SMT Electromagnetic Components. Potential use of these components in power conditioning and control of fuel cell systems.

Companies with short-term interest in these technologies /

Company	Contact	Observations
Malaga		
Dogor Electronics, S.L.	Parque Tecnologico de Andalucia Avda. Juan Lopez Peñalver, 8 29590 Campanillas (Malaga) www.dogor.com	Design and manufacture of electronic and electromechanical plates, subsets and complete units. Potential use in power conditioning and control of fuel cell systems.
Raytheon Microelectronics España, S.A.	Parque Tecnologico de Andalucia Avda. Juan Lopez Peñalver, 12 29590 Campanillas (Malaga) www.rme.es	Microelectronics. Potential use of these components in power conditioning and control of fuel cell systems.
Randal Systems	Parque Tecnologico de Andalucia Avda. Juan Lopez Peñalver, 17 29590 Campanillas (Malaga) www.randalsystems.com	Development and implementation of systems for remote monitoring and/or control of installations. Potential use of these systems in control and monitoring of hydrogen production systems and use in fuel cells.
ION, S.A.	Parque Empresarial Santa Barbara C/ Tucidides, 50. 29004 Malaga www.ionsa.com	Manufacture of chemical products (degreasers, polishers, lubricants, coating agents, water treatment, etc.). Possibility of development of products for fuel cell systems.
Seville		
HISPACOLD, S.A.	Autovia Sevilla - Malaga, Km 1,8 41016 Seville www.hispacold.es	Manufacture of compressors and ventilators for air-conditioning in automotive sector. Possibility of development of hydrogen compressors and recirculation pumps for BoP of fuel cell systems in automotive sector.
Sociedad Andaluza de Componentes Especiales, S.A. - SACESA	Ctra. Nacional IV, Km. 531 41080 Seville	Carbon fiber structural components manufacturing technologies. Possibility of applying them in compressed hydrogen storage tanks.
Industria Siderometalurgica Gienense , S.L.-SIMGI S.L.	Polg. Ind Servialsa C/ C. Naves 6 y 14 a 22 41960 Gines (Seville) www.simgisl.com	Dressing, drilling and milling of mechanized aeronautical parts and manufacture of aeronautical pieces and duty tools. Possibility of applying know-how for metallic components of electrolyzers and fuel cells.
Galvatec, S.L.	P.E. Aeronáutico, Autovia A-4 Km.528 C/ Juan Olivert, nº22 41309 La Rinconada (Seville) www.galvatec.es	Specialized in: non-destructive tests, application of Surface Treatments and equipping of aeronautical parts and sets. Possibility of applying to coating of catalysts in electrodes for fuel cells and electrolyzers.
Industria Especializada en Aeronáutica, S.A. (INESPASA)	P. E. Aeronáutico Aeropolis C/ Ingeniero Rafael Rubio Elosa nº 10, 41300 Seville www.inespasa.com	Design, manufacture, assembly of duty tools, aeronautical machining of parts, and assembly of sets, focused on the aerospace industry and the transportation sector. Possibility of applying know-how to manufacture of metallic components of electrolyzers and fuel cells.

Empresas con interés a corto plazo en estas tecnologías /

Company	Contact	Observations
MP Mecánica de Precisión, S.L.	P. E. Aeronautico Aeropolis C/ Juan Olivert nº 32 41309 La Rinconada (Seville) www.mecapres.com	Development and execution of parts and components manufacturing processes, and design and manufacture of plate elements (cutting, bending, stamping, punching, etc). Possibility of applying know-how to manufacturing of metal components of electrolyzers and fuel cells.
Grupo Iturri	Avda. de Roberto Osborne, 5 41007 Seville www.iturrionline.com	Among other fields, manufacture of special vehicles: fire-prevention, ambulances, mobile hospitals, etc. Fuel cell applications in these vehicles for propulsion and autonomous electricity generation.
Técnicas Aeronáuticas, Defensa y Automoción, S.A (TADA)	Pol. Industrial Carretera Amarilla Avda de la Prensa nº 8 41007 Seville www.tada.es	Machining of parts and surface treatment processes for the aerospace industry. Possibility of applying know-how to manufacturing of polymer components of electrolyzers and fuel cells.
Mecatecnic Marques S.L.	P. E. Aeronautico Aeropolis C/ Juan Olivert, 34 41309 La Rinconada (Seville) www.mecatecnic.es	Machining, ultrasound inspection of composite materials, design and manufacture of duty tools. Possibility of applying know-how to manufacturing of polymer components of electrolyzers and fuel cells.
Ingeniatrics Tecnologías, S.L.	Avd. Americo Vespucio 5-4, 1ª p. mod. 12. 41092 Seville www.ingeniatrics.com	Development of new technologies related with the manipulation of fluids at micro and nano scale. Potential use of these techniques in design of bipolar plates and electrodes of fuel cells.
Cyclus ID	Apartado 316 41530 Moron de la Frontera (Seville) www.cyclusid.com	Purification of wastes. Possibility of using wastes for hydrogen production and electricity generation.
ELIMCO, S.A.	P. E. Aeronáutico Aeropolis C/ Hispano Aviación, Nº 7-9 41309 La Rinconada (Sevilla) www.elimco.com	Microelectronics, advanced control and integration of systems. Application to the control of hydrogen production and fuel cell systems.
Plasgen Materias Plasticas S.L.	Pol. Ind. El mirador, 11 Apartado correos 337 41400 Ecija (Seville) www.plasgen.es	Company dedicated to manufacture and transformation of plastic films. Possibility of use in components for fuel cells.
Talleres Bosado S.A.	Pol. Ind. Store C/B, Parc. 12-3 41008 Seville www.bosado.com	Manufacture of flexible connections and pipes. Potential supplier for hydrogen production and storage systems, and fuel cells.
Testing and Engineering of aeronautical materials anda atructures, S.L. (teams)	P. E. Aeronautico Aeropolis Wilburg y Orville Wright Nº 1 41309 La Rinconada (Seville) www.teams.es	Metallic and composite materials, and structural elements, characterization tests. Possibility of applying its know-how in the characterization and control of composite materials in the field of alternative energies and fuel cells.

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