HYDROGEN MASTER PLAN IN ARAGON

[2016 - 2020]

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FOUNDATION FOR THE
DEVELOPMENT OF NEW
HYDROGEN TECHNOLOGIES
IN ARAGON

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[2016-2020]

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PREFACE

The composition of the Foundation for Hydrogen in Aragon reflects, in some way, an important part of the Aragonese industrial sector, its strengths and characteristics, as well as those of the scientific and technological centres involved in its drive and development.

Although it would be possible to consider a good number of statistics and variables, discussion about the Foundation is referring to an industrial and entrepreneurial development tool, due to the fact that alternative and new technologies related to energy as an opportunity for development are not only aimed to the industrial sector, but they also mean great opportunities for the tertiary sector.

The work that the Foundation carries out allows us to see how the world - and in particular the part of the world that is Aragon- fights against one of the challenges of civilisation and of global sustainability, by investigating technologically and economically feasible formulas for the "decarbonisation" of the planet, along with an element of diversification and specialisation of the productive fabric and, ultimately, of society as a whole.

In this environment of knowledge and scientific research, but above all applied research, development, demonstration and innovation, together we look for real technological and tangible solutions. In short, solutions to serve as an engine to the Aragonese companies, for a genuine change in the productive model through a viable technological disruption, well-managed in time, that will give them the skills to allow them to create employment in the coming years, with capacities of global competition.

The project launched by the Foundation does not only take into account employability, which has been its main concern (it has been leading European projects and forming qualified professionals for several years), or internationalization (in 2005 Zaragoza hosted the second European Congress of Hydrogen and will host the World Congress of Hydrogen in June 2016).

The work and the objectives of the Foundation affect and are affected by the main productive sub-sectors which already exist in Aragon: energy, automotive, chemical, metal mechanical, logistics, electrical and electronics. All of these share an attitude of observation of the technological and market development and are committed to expanding this knowledge, applying it in a real way, involving the technological and research centres, training centres and subsectors such as tourism, the real estate sector, civil work and financial institutions, so that all may know in advance these new development paths.

The work the Foundation develops comes from a network that allows, through the collaboration of all members, a process of enrichment that cedes to society part of its experience and its approach, orienting and encouraging the Aragonese SMES and professionals and workers on areas of a more likely future with more opportunities.

Since 2003, the Government of Aragon has acted as a catalyst and has given financial support to a Foundation which has been fulfilling its objectives and has been benefiting from the loyalty, knowledge, information and experience of its members. All of this places it in a well-positioned launch padbut surrounded by other agents with technological and economic possibilities more powerful than those of the Foundation itself. However, there is no doubt about its capacity and the place that it can occupy on the national, European and international scale because it is prepared for the challenges that can appear imminently.

All of this work is carried out in a strategical approach framework which is reflected in the third Hydrogen Master Plan in Aragon, a document that arises as a result of a deep reflection, mainly by the experts of the companies that make up this board and that aligns with the predictions of the 2020 Strategy, the Directive on Alternative Fuels. This new Master Plan 2016 - 2020 is structured mainly around five major courses of action: production; storage, transport and distribution; applications; transfer of technology protection and economic impact; and training and awareness.

Far from being a theoretical document and mere compilation, this Plan is a valuable tool to identify new opportunities in hydrogen technologies that enable decisions to be made at institutional, business and academic levels. It should also serve to determine strategic lines in this regard in the Autonomous Community and for the establishment of accurate roadmaps and time horizons with which to implement them.

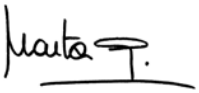
Things have changed a lot in recent years and the Master Plan sees the light of day in a period of time when the hydrogen sector is facing new technological challenges, as well as considerable support and policy development. In this new phase, the technologies for hydrogen and fuel cells are called upon to be introduced in the market applications. This is the case, for example, of an infrastructure of hydrogen refuelling station as fuel for vehicles, which the European Commission itself has supported by adopting a Directive on alternative fuels.

On the other hand, nobody can deny that hydrogen development has to evolve in parallel with that of the requirements of the market, especially with regard to the production systems and solutions for transportation, storage and distribution, and that is precisely why the approach and the promotion of the technologies in the target market and, by extension, to all citizens is one of the priority items for the next few years.

This is the context in which the Foundation for the Development of New Hydrogen Technologies in Aragon and the companies and research centres that comprise its Board, carry out their work, each one at its level and according to their size and characteristics, but creating a dynamic whole, vigorous and effective supported by valuable external collaborations.

To involve all sectors of society - and not only the production, economic or scientific - in the benefits of this revolution that has only just begun is the main responsibility of the Foundation, an exciting challenge that requires the cooperation of all.

The Foundation's Board, in its meeting held on 9 December 2015, unanimously agreed to approve the Hydrogen Master Plan in Aragon 2016 - 2020, developed by the Foundation, as well as the commitments to adopt it as the basic document for the work done in this period, to disseminate it in society and to raise it to the public administrations and relevant organizations to achieve the maximum support.



Her Excell Marta Gastón Menal

President of the Hydrogen Foundation in Aragon. Regional Minister of Economy, Industry and Employment. Government of Aragón.

01.

INTRODUCTION

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INTRODUCTION

The current Hydrogen Master Plan 2016 - 2020 constitutes the third revision of a challenge initiated in 2007 with hydrogen as a key technology for industrial development, which affects and is affected by the most important industrial subsectors in Aragon, and on the other hand, working towards the reduction of the energy dependence.

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The current Hydrogen Master Plan 2016 - 2020 constitutes the third revision of a challenge initiated in 2007 with hydrogen as a key technology for industrial development, which affects and is affected by the most important industrial subsectors in Aragon, and on the other hand, working towards the reduction of the energy dependence. On that date, the Plan constituted a first guide of performances for all companies and agencies that were part of it. It also marked, to some extent, the evolution of the Foundation for the Development of New Hydrogen Technologies in Aragon (FHa) in its first years, although it was set up with the purpose of offering unequivocal experience to the entire Aragonese business fabric, especially SMEs and in strategic sectors. The Plan was not a rigid list of projects but rather a guide being continuously reviewed and revised, as exemplified by the publication in 2011 of the subsequent Plan 2011-2015.

An important milestone was the adoption by the Government of Aragon of the strategy emanating from the Master Plans carried out by the Foundation itself. This Autonomous Community's strategy was included, after the corresponding dialogue with economic and social agents and with the Aragonese industrial and business sector, in the programmes and policies of the Government that supported the objectives of the Master Plan, thus showing how it has been supported from the beginning.

Eight years after the first one, the drafting of the new Master Plan comes about in a period in which the hydrogen sector is facing new technological challenges, with an important regulation impetus for its development.

In Europe, the European Framework Programme for Research and Innovation, Horizon 2020, offers an important support through the initiative Fuel Cells and Hydrogen Joint Undertaking (FCH 2 JU) heir of the previous FCH JU of the 7th European Framework Programme. This is accompanied by the national commitment to hydrogen technologies, where they are widely recognised not only in their national plans but also through the transposition of the Directive 2014/94/EU relating to the implementation of an infrastructure for alternative fuels through its Alternative Fuel Vehicle Strategy, which contemplates hydrogen as a fuel to be considered.

In this area, as explained above, since its inception Aragon has adopted a leadership position in the field, with a clear commitment from the different institutions of the region, especially its Government and Courts, endorsed by major economic and social actors through its Board.

For all these reasons, this new Plan represents a new step further, decided as a result of the confidence provided by the experience of the Autonomous Community in favour of the hydrogen technologies through the development of five work lines: production; storage, transport and distribution; applications; transfer of technology, protection and economic impact; and training and awareness. These lines include actions and activities with a clear orientation to results. Its development has been the product of an intensive participatory process in which discussion has become open not only to the members but also to new enterprises and agencies that might be interested.

01. INTRODUCTION

As a result of the work developed in the last few months, the Hydrogen Master Director Plan in Aragon 2016 - 2020 is structured in the following sections:

- **Framework for Action:** description of the development of hydrogen technologies in its three levels: European, national and regional. A brief analysis has been established in each one of them about the main plans and programmes through which to develop the new Plan, as well as the most significant regulatory aspects.
- **Achievements from the previous Master Plan:** main projects developed by the FHa and their members, as well as the most outstanding awards, agreements and partnerships during the period 2011 - 2015.
- **Aims and methodology:** presentation of the general and specific objectives born from the new Plan as well as the work methodology applied to the formulation of the new planning strategy.
- **Work Lines:** presentation of the five work lines selected. For each of them, a brief presentation of the state of the art in technology and regulations has been made, as well as opportunities identification for the new period 2016 - 2020. Finally, each line includes a description of the most significant actions and activities with quantification in 2018 and 2020 of results to be achieved.
- **Monitoring:** description of the proposed monitoring system to analyse the fulfilment of the objectives presented and classified in indicators of monitoring, outcome and management.
- Finally, a brief presentation of the **conclusions** of the Plan is set out.

In short, the present Hydrogen Master Plan in Aragon 2016 - 2020 has been drawn up with the objective of again being a useful tool of support to the service of Aragonese society and, in particular, the Aragonese business fabric to continue driving hydrogen technologies in the Autonomous Community, as well as important changes in other issues associated with them.

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SCOPE FOR ACTION

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The security of energy supply and the sustainability in the use of resources has become a clear challenge for the EU at the beginning of the21st century, and in particular during the last decade.

Foto: Xavier Häpe

2.1. EUROPEAN SCOPE

Today, the energy system of the European Union is still highly dependent on fossil fuels. In 2013, 53.2 % of the primary energy consumed in the EU was from imported energy resources[1] in addition to the environmental casuistry - in the same year, only 53 % of the primary energy generated was based on low carbon technologies from nuclear energy (28.7%) and renewable energy (24.3%, with hydro power being the main source of resources, accounting for almost 50 per cent of production of renewable energy[2]). The security of energy supply and the sustainability in the use of resources has become a clear challenge for the EU at the beginning of the 21st century, and in particular during the last decade.

Against this background, the EU is facing a substantial change in its energy system, from an electricity generation based on fossil fuels and nuclear power to a system which continuously seeks to increase the penetration of intermittent renewable energy, such as wind and solar photovoltaics, and intends to decarbonise other sectors such as transport and the production of heat. Given these new challenges, the EU has established a number of priorities in the development of energy infrastructures for 2020 and subsequent years in which it is desired to update and modernise the European energy networks, developing power transmission corridors to ensure the integration of renewable energy throughout Europe in the medium-term (2020). Gas and oil corridors are also included in the requirements of future infrastructures in the medium term, as well as the development of the technologies of smart grids and distributed generation, which will need energy storage systems such as hydrogen[3]. The final objective of these measures is to make progress on the goals in energy planned by the EU in 2020, within the well-known 2020 Energy Strategy, or 20-20-20 Programme, which aims to increase the percentage of renewable energy over the primary energy consumption up to 20%, to get a 20% reduction of the greenhouse gas emissions (GHG) with respect to the values of 1990 and to gain energy savings of 20% or higher[4].

In the long term, looking towards 2050, the European Union proposes a decarbonised electrical system based on renewable resources of the Member States with management of these intermittent renewable resources in its majority through long-distance and high-voltage power grids and **large-scale energy storage systems, including hydrogen technologies.** This framework for action is presented in the European Energy Roadmap 2050[5]. According to this plan, in the period of transition toward an energy model based on renewable energy in 2050, natural gas will have an important role to play by replacing the technologies of coal and oil in the short and medium term, until 2030 - 2035, hence the importance of technologies such as the **Power-to-gas**, one of the lines of action proposed in this Plan, which consists of the enrichment of natural gas networks with green hydrogen from renewable sources to take advantage of the existing natural gas infrastructure.

With regard to the transport sector, electric mobility with electrochemical batteries and hydrogen and fuel cells is presented as the main option for the future to replace the current fossil fuels, whilst those such as Compressed Natural Gas (CNG) and other synthetic fuels are presented as key during the period of transition. It is important to emphasise, as a short-term action, the European initiative for the promotion of alternative fuels, in particular Directive 2014/94/EU on the implementation of an infrastructure for alternative fuels, including electricity, biofuels, synthetic and paraffinic fuels,

[1] European Commission, Eurostat, Energy, "Energy dependence" http://ec.europa.eu/eurostat/web/energy/data/main-tables, 2015.
[2] European Commission, Eurostat, Energy, "Energy dependence" http://ec.europa.eu/eurostat/web/energy/data/main-tables, 2015.
[3] Energy infrastructure priorities for 2020 and beyond - A Blueprint for integrated European energy network (EIP). European Commission, COM(2010) 677 final, 2010.
[4] Energy 2020. A strategy for competitive, sustainable and secure energy. European Commission, COM(2010) 639 final, 2010.
[5] Energy Roadmap 2050 (ER2050). European Commission, COM(2011) 885/2, 2011.

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natural gas - including CNG and Liquefied Natural Gas (LNG), Liquefied Petroleum Gas (LPG) and hydrogen[6].

In short, it can be summarised that hydrogen is seen as one of the energy storage systems on a distribution-network scale and large-scale to manage energy systems with high penetration of intermittent renewable energy such as wind and photovoltaics, given that both of these are the renewable technologies with furthest expected growth in the EU in the coming years. The stored hydrogen will be then used in various applications such as industry, the residential sector, power grids management, systems such as the Power-to-gas previously mentioned and, mainly, as a transport fuel. In the latter case, the short and medium term deployment phase is expected until 2025 and it will be established on the transport fuel market, once the required infrastructure in Europe in line with the framework of Directive 2014/94/EU is developed.

In this scenario, the EU decided to establish the bases for the development of technologies for hydrogen and fuel cells. **In 2003, the European Hydrogen and Fuel Cell Technology Platform (HFP) is founded**, and in 2005, it published the Strategic Research Agenda and Deployment Strategy, from which in 2007, a Implementation Plan for the development and the market introduction of these technologies in the long term was established. This is how, in **2007, the European Commission (EC) proposed the creation of the Fuel Cells and Hydrogen Joint Undertaking (hereinafter called FCH JU) in connection with the 7th Framework Programme of the EC.** The FCH JU is defined as a public-private initiative formed by a consortium including the EU (which took part through the Commission itself), the European industry linked to the hydrogen sector through the European Industry Grouping and a Research Grouping formed by the academic sector and research centres. The main objective of the FCH JU was to accelerate the development and deployment of technologies for hydrogen and fuel cells through the implementation of an integrated programme of R&D activities. The objectives of the programme were defined in a Multi - Annual Implementation Plan (MAIP) for the period 2008 - 2013, which focused on four main areas of activity: transport and hydrogen refuelling infrastructure; hydrogen production and distribution;

[6] Directive 2014/94/EU on the implementation of an infrastructure for alternative fuels. European Commission. Official Journal of the European Union L307/1, October 2014.

stationary generation systems and cogeneration systems; and niche market applications, in addition to other cross-cutting activities. The clear aim of the FCH JU was to promote R&D to reach specific objectives of development for each one of the areas with a budget of €450 million.

Given the success of the previous programme, the EU decided to continue supporting the technologies for hydrogen and fuel cells in the new R&D&I programme for the period 2014 - 2020, the well-known Horizon 2020. This creates the **second phase of the Fuel Cells and Hydrogen Joint Undertaking (FCH 2 JU) established for the period 2014 - 2020 and with a budget of €1.33 billion, of which the Commission itself contributes €665 million.** The structure of the public- private consortium is currently maintained in the same way as in the FCH JU, with the presence of the EC, an industrial group Hydrogen Europe (initially named New Energy World Industrial Grouping (NEW-IG)) and the academic and research group named New European Research Grouping for Hydrogen and Fuel Cells (N.ERGHY). Despite being similar to its predecessor programme (FCH JU) - the implementation of an R&D&I programme the main difference in the objective of the FCH 2 JU lies in the challenge of developing technology available to penetrate the market at the end of its force and effect, in 2020, ensuring a European hydrogen and fuel cells industry that is competitive at a global level. The programme is structured in two main pillars devoted to transport and energy, together with cross-sectional research actions. In addition, its main novelty consists of the presence of the Overarching Project, in which these two pillars are joined by the development of large demonstration projects.

Another difference between the current European programme for promotion of hydrogen technologies, the FCH 2 JU (2014 - 2020) and the previous programme, FCH JU (2007 - 2013) is the bid at European level to enhance the investment in R&D during previous periods with the promotion of projects of demonstration and rapprochement of the technology to the market, directly emphasising cost reduction and increases in performance and efficiency of the systems and equipment. In this new period of the FCH 2 JU, the technologies to promote at European level have already been identified and the options for basic R&D are reduced to very specific applications that still might need this kind of support.

At the international level, concern for the environment and climate change has been a reality for the majority of the major world powers since the signing of the Kyoto Protocol. The actions and targets set in Kyoto have been monitored during subsequent years with events such as the COP15 or 2009 Copenhagen Summit and the COP 21 of Paris 2015. In both cases, hydrogen already occupies a prominent role including within the actions of the event, the inauguration of hydrogen refuelling stations in Paris and discussions about the benefits of hydrogen technologies for the protection of the environment.

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2.2. NATIONAL SCOPE

In Spain, hydrogen technologies are also widely recognized and accepted as a tool with great potential to achieve the objectives of sustainability in the energy and transport sectors. In 2007, as part of the **Spanish Strategy for Climate Change and Clean Energy 2007 - 2013 – 2020**[7], it was already indicated, as part of the action area in renewable energy, the generation of biohydrogen in the energy field, and the incentive of hydrogen technologies (such as fuel cells) to give solutions in the field of mobility using it as clean fuel generated from renewable energy. Thus, its importance in the different national strategies and action plans relating to renewable energy is being recognised due to its versatility and flexibility to be used in different applications.

Reference was also made on a preliminary basis to actions related to renewable energy and energy efficiency in the Renewable Energy Plan 2005 – 2010[8] and in the Energy Saving and Efficiency Strategy Action Plan 2008 - 2012 in Spain[9] respectively. Both documents have been updated and their second phase is being implemented, with hydrogen technologies still being widely described and characterised.

Recently, the National Renewable Energy Action Plan (NREAP) 2011 – 2020[10] is based on the mandates of the Directive 2009/28/EC of the European Parliament and of the Council of 23rd April, on the promotion of the use of energy from renewable sources which stipulated that each Member State should develop a National Action Plan in the field of Renewable energy, and updates to the Renewable Energy Plan 2005 - 2010. For the case of hydrogen, the role in the Plan is to support the renewable energy generation to store the surplus generated so that they can be used for different applications such as delivery to the gas network, sustainable mobility, uses in the chemical industry or re-electrification through fuel cells. There were therefore established goals for hydrogen generation through renewable energy that, despite some very low levels being established for the year 2020, make it clear that the clean hydrogen generated by renewable energy should begin to be considered in the short and medium term in Spain. In this scenario, the Secretary of State for Energy at the Ministry of Industry, Tourism and Trade, through the IDAE, decided to deepen in the NREAP 2011 - 2020. The objective of this analysis in 2011 was to consider the evolution of the world and Spanish economy and the analytical work of the Spanish energy strategy for the next 25 years. They recommended a participation in renewable energy of 20.8 % in 2020 in response to the Law No. 2/2011 of Sustainable Economy, which required the drafting of all the plans needed to meet the objectives of the Directive 2009/28/EC. In this way, the Renewable Energy Plan (REP) 2011 – 2020[11] was launched following NREAP 2011 – 2020, which gave added depth to its objectives and also conducted an in-depth sectoral analysis. The REP 2011 - 2020, in its entirety, recognizes the potential of hydrogen technologies in the following areas:

[7] Spanish Strategy for Climate Change and Clean Energy 2007 - 2013 – 2020. Ministry of Environment, Government of Spain 2007.
[8] Renewable Energy Plan 2005 – 2010. Ministry of Industry, Tourism and Environment. IDAE, 2005.
[9] Energy Saving and Efficiency Strategy Action Plan 2008 - 2012 in Spain. Ministry of Industry, Tourism and Trade, IDAE. 2007.
[10] National Renewable Energy Action Plan (NREAP) 2011 – 2020. Ministry of Industry, Tourism and Trade, IDAE. 2010.
[11] Renewable Energy Plan (REP) 2011 – 2020. IDAE, 2011.

- Clean biofuel generation as biodiesel.
- Clean biogas generation from biomass.
- Combustion engine propulsion.
- Gasification, fermentation and pyrolysis to get hydrogen from biomass.
- Electrochemical storage of hydrogen generated from electrolysis on a large scale to be used in the chemical industry, the gas network or in applications with fuel cells such as hydrogen-powered vehicles.

This Plan recognizes hydrogen as the best alternative to store energy in the long term and large quantities of wind energy surplus, with regard to systems such as the adiabatic storage of energy in compressed air or electrochemical batteries.

In addition, in the sectoral analysis, hydrogen is explicitly mentioned in the different lines of R&D&I of REP 2011 - 2020 highlighting:

- Biogas sector: following the communication by the European Commission "European Strategic Energy Technology Plan (towards a low carbon future)" recognizes the potential of the conversion of biogas in hydrogen.
- Wind Sector: for the work areas which REP 2011 - 2020 recognizes (Work Area 3, applications), the ability is provided to search for the development of energy storage projects for its application in off-peak periods, through the use of systems for the production of hydrogen and fuel cells.
- Horizontal sector: accumulation systems of energy from the power grid. Hydrogen storage is described as promising for the future, for which large-scale demonstrations, efficiency increase and the seeking out, adaptation or building of systems suitable for storing are fundamental.

On the other hand, the **Energy Savings and Efficiency Action Plan (ESEP)**[12] has been updated for the period 2011 - 2020 and again for the period 2014 - 2020 following the adoption of the Directive 2012/72/EC on energy efficiency by the European Parliament and by the Council, which aims for a reduction of 20% in the energy consumption for all Member States.

In the fundamental version, developed for the period 2011 - 2020 and which will be subject of adaptation according to the mandates and directives to fulfil the 2020 objectives, hydrogen technologies applied to the transport sector are mentioned. Specifically, it recognises the importance of starting to renew conventional vehicle fleets with hydrogen and fuel cell propelled vehicles. In particular, in order to achieve this objective, financial aid is proposed for the acquisition of vehicles that use hydrogen as fuel by compensating the extra cost involved in their purchase.

Accordingly, the Ministry of Industry, Energy and Tourism (MINETUR), as an official body responsible for transposing the European Directive 2014/94 relating to the implementation of an infrastructure for alternative fuels, has included hydrogen as one of fuels to consider within its Alternative Fuel Vehicle (AFV) Strategy. In this action, the commitment of MINETUR to these technologies is evident, since the transposition of the Directive to member countries with regard to hydrogen was optional and not compulsory.

[12] Energy Savings and Efficiency Action Plan (ESEP) 2011-2020. IDAE, 2011.

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F.01 Current and estimate Alternative Fuel Vehicle (AFV) Proposal 2020

	Fleet (No. Vehicles)		Infrastructure (No. public access supply / refuelling stations)	
	Current	**Estimated 2020**	**Current**	**Minimum in 2020 according to Directive criterion**
LPG	40.000	250.000	450	1.200
LNG	300	800	17 global	14 TEN-T
GNC	4.290	17.200	25 global	119 urban+17 in TEN-T
Electric Vehicle	10.000	150.000	Aprox. 1.000 in operation	1.190 urban
Hydrogen	Demonstration Projects	2.800	6	21

Source: MINETUR

On the other hand, the report **Assessment of the Potential for the Development of Energy Technologies in Spain,** developed by the Alliance for Energy Research and Innovation (ALINNE), describes hydrogen and fuel cells technologies as one of those which will contribute to an extraordinary development of new energy technologies in the next ten years.

In the end, as observed in the different existing plans previously described, it is clear that Spain recognizes the potential of hydrogen technologies to achieve the goals of the plans and strategies related to renewable energy, energy efficiency and sustainability. However, it is necessary to first achieve an increase in efficiency and a reduction of the cost of components and systems to achieve the competitiveness of hydrogen technologies with respect to those existing in the state of the art, for which support from national R&D&I plans is needed. It is undeniable that public authority, with honourable and notable exceptions, can do more for the deployment and development of these technologies. A possible reason for this may lie in the fact that knowledge of these technologies is not yet widespread in society.

In Spain, the **National R&D&I Plan** has been regularly updated since 1988. During the period 2005 - 2013, the percentage of financing allocated to projects related to hydrogen and fuel cells under the main calls for initiatives in collaboration (Singular Strategic Projects 2005 - 2011 and call INNPACTO 2010 – 2013), accounted for about 6.25% with respect to other thematic lines of the Plan as wind power and bioenergy[11].

Currently, the National Plan 2013 - 2016 recognises[13] a series of challenges including hydrogen technologies. In particular, the corresponding challenge to secure, efficient and clean energy is looking for a sustainable generation and an environmentally-friendly and socio-economically acceptable energy distribution. To do this, it promotes the transition towards an energy system that allows the reduction of fossil fuel dependence at a time when they are scarce and demand is growing, whilst at the same time their environmental impact is significant. Within this challenge, the fifth scientific-technical and business priority is hydrogen and fuel cells, including: (1) hydrogen production; (2) research and development of technologies for hydrogen and fuel cells; (3) hydrogen storage and distribution, and (4) portable and stationary hydrogen applications.

In Spain there are entities such as the Spanish Hydrogen Association (AeH2), the National Hydrogen Centre (CNH2), the Spanish Hydrogen and Fuel Cell Platform (PTEHPC) and the Spanish Fuel Cell Association (APPICE), which are very active in the promotion and development of projects related to hydrogen technologies.

In regard to the Spanish regions, practically all of them promote the use of technology and are active at national and European levels, especially Andalusia, Canary Islands, Catalonia, Autonomous Community of Madrid, Navarre, Galicia, the Basque Country, Valencia and Castilla La Mancha.

It should be noted that in 2016, as an important national milestone, the World Congress of Hydrogen (World Hydrogen Energy Conference WHEC 2016), will be held in Zaragoza, Spain, from 13 thto 16th of June. The congress represents a great opportunity to position the Spanish leading figures in hydrogen and fuel cell technologies in the international arena. The event's key achievement and possible success will be the collaboration between FHa, supported by their members, and the main entities active in the field of hydrogen and fuel cells at the national level, led by the AeH_2.

[13] National Plan for Scientific Research, Technology and Innovation 2013-2016. Ministry of Economy and Competitiveness, 2012.

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2.3 REGIONAL SCOPE

On a regional level, support for the development of hydrogen technologies in Aragon has been a reality since the 2007 - 2011 legislatureand was reflected in the strategic plans in force at the time. This reality continued being prominent in the Aragonese Strategy for Competitiveness and Growth, developed by the Government of Aragon in 2012, which considered the promotion and dynamisation of the proceedings of the FHa, and in particular of its previous Strategic Plan, the Hydrogen Master Plan in Aragon 2011 – 2015, amongst its projects.

Currently, the support is still evident and contained, in turn, within the main existing strategies, promotion of business and industry in the region as well as in the Energy Plan of Aragon 2013 - 2020.

Notable among these is the R**esearch and Innovation Strategy for a Smart Specialization in Aragon RIS3.** Smart specialization means identifying the characteristics and assets that are unique to each country and region, emphasising the competitive advantages of each one of them and gathering participants and regional resources around a vision of their future aiming towards excellence. It also means strengthening the regional innovation systems, maximising knowledge flows and disseminating the benefits of innovation for all the regional economy. These are the principles that have marked the development of RIS3 Aragon with the objective of that investment in research and innovation become truly effective. This strategy involves the implementation by the European Commission at the regional level of the design of a research and innovation strategy through a consensual vision of the transformation of the regional economy.

In this framework, RIS3 Aragon includes explicit support for hydrogen that is reflected in two of the three strategic priorities selected: connectivity and resources efficiency. In each of the strategic priorities, strategic lines are defined and they outline typologies of specific projects that can be supported with European funding programmes (ERDF, ESF, Horizon 2020) as well as charged to the regional budgets.

The strategic priority of connectivity includes activities relating to the sectors of logistics and transport material, highlighting the strategic line 4, "Development of more fuel efficient vehicles", that includes typologies of specific projects associated with hydrogen.

F.02 Strategic Line 4

Strategic Line	Typology of projects
L4.- Development of more fuel efficient vehicles	Special attention to the Development of Hydrogen Technologies
	Refuelling infrastructure: charging and hydrogen stations

In regards to the strategic priority of resource efficiency, it emphasises the strategic line 4, "Storage and Integration of Energy Systems", in which the development of actions applied to hydrogen is contemplated through the use of smart grids in their own space or through the utilization of the geographical conditions of the region.

F.03 Strategic Line 5

Strategic Line	Typology of projects
L5.- Storage and integration of energy systems	Development of energy storage systems (MWh), fuel cells, batteries
	Development of smart grids

As a main element of regional planning financed by ERDF funds for the new programming period of the European Union 2014-2020, the **ERDF Operational Programme for Aragon 2014-2020** stands out.

Among the selection of thematic objectives included in the Aragonese programme is the "Axis 4: Supporting the Shift toward a Low Carbon Economy in All Sectors". The central concept includes performances associated with the shift towards a low carbon economy within the framework of the programme, focused on the promotion of energy efficiency in different sectors (residential, businesses and public administration) and the promotion of the deployment, production, storage and use of renewable energy.

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SCOPE FOR ACTION

The Programme explicitly covers the impetus to hydrogen in the region highlighting initiatives with a clear vocation of public-private collaboration, supported and promoted by the Government of Aragon, as it is the case of the Foundation for the Development of New Hydrogen Technologies in Aragon. The programme emphasises from the FHa *"its character clearly aimed toward industrial development, as a factor for business cooperation of intersectoral nature in response to the whole energy-industry value chain in the scope of the use of renewable energy and technologies of hydrogen in buildings, fuel decarbonisation, sustainable mobility, deployment of infrastructure for alternative fuels, management and integration of renewable resources, carrying out research, development, innovation, training, dissemination and awareness actions"*.

In the planned budgetary allocation for the programming period 2014 - 2020 a general item dedicated to the support of *"Other renewable energy (including hydropower, geothermal and marine) and the integration of renewable energy (including storage, conversion of electricity in gas and renewable hydrogen infrastructures)"* is included.

On the other hand, the **Aragon Strategy,** approved by Royal Decree 202/2014, on 2nd December, of the Government of Aragon, sets as core ideas, amongst others, the increase of public effort in R&D&I and the promotion of innovation, among other areas, in technologies based on hydrogen and the development of research in the technologies of hydrogen as a fuel to apply to transport systems.

Finally, the Energy Plan of Aragon (PLEAR 2013 - 2020) is highlighted as sectoral programme that includes hydrogen technologies. Its support includes both applications in the field of transport and the development of its own heading within the section of R&D&I pointing to hydrogen as one of the priority lines of action in this field. The Plan assumes as its own the strategic lines described in the Hydrogen Master Plan of Aragon 2011 - 2015.

Resulting from the specific measures to promote hydrogen technologies, the FHa, which is the main instrument of the Government of Aragon to express that support, has continued increasing the number of companies and agencies that have been involved. Currently, the Board is composed of more than 70 members, key to the Aragonese economy: companies, entities of all sectors and research centres.

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To consult the list of the Board of the Foundation members: Annex I

Board of the Foundation for the Development of New Hydrogen Technologies in Aragon (2016)

03.

ACHIEVEMENTS OBTAINED IN THE PREVIOUS MASTER PLAN

03. ACHIEVEMENTS OBTAINED IN THE PREVIOUS MASTER PLAN

During this period 2011 to 2015, technologies for hydrogen and fuel cells have continued their development and settlement in the main business, industry and scientific sectors of Aragon.

The Autonomous Community has positioned itself actively in the main focus of the activity of Research, Development and Innovation (R&D&I) in Europe, as shown in the public-private initiative in support of research, technological development and demonstration activities of hydrogen and fuel cells, *Fuel Cell and Hydrogen Joint Undertaking*, FCH JU, promoted by the 7th Framework Programme for Research and Development and continued in Horizon 2020. This positioning has been facilitated mainly thanks to the participation of the FHa in its working groups relating to the pillars of energy, transport and cross-cutting activities. In this last area cross-cutting tasks such as training, awareness and market and regulatory analysis are included. Within this initiative, the FHa has participated, together with several Aragonese entities, in six projects of the programme in the period 2007 - 2014, acting as a coordinator in three of them, showing the leadership it has achieved in Europe.

In this regard, thanks to the support for the first part of the Plan from the Department of Industry and Innovation, and from the Department of Economy, Industry and Employment of the Government of Aragon for the second one, along with Aragonese entities and companies, the region has been present in the main forums of the sector in Europe and Spain. Additionally, at European level, it is worth highlighting the presence of what is currently known as the General Directorate of Industry and SMES, initially, and the General Director of Industry, SMES, Trade and Crafts of the Government of Aragon in the Association for Hydrogen and Fuel Cells and Electro-mobility in European Regions, (HyER), formerly called HyRaMP, occupying one of the vice-presidency during the lifetime of the Master Plan.

In Spain, the Government of Aragon and the FHa are active members of the Spanish Fuel Cell Association, (APPICE), the Spanish Hydrogen Association (AeH2) and the Spanish Hydrogen and Fuel Cell Platform (PTEHPC), participating in their government boards. Additionally, the FHa is present in one of the three government bodies that compose the FCH JU, the research group N.ERGHY.

With regards to technology development, along with the development of the previous Master Plan (2011 - 2015), Aragon has continued to be very active during the whole period in multiple lines, highlighting in a special way the production of hydrogen, the storage, transport and distribution of hydrogen and its applications with fuel cells.

03. ACHIEVEMENTS OBTAINED IN THE PREVIOUS MASTER PLAN

- In the field of **hydrogen production** with alkaline electrolysis technology, great strides have been made in terms of innovation, mainly through the ELYGRID Project. The tasks initiated continue through the ELYntegration Project, which began in September 2015.

- In the area of storage, better understanding was gained in the knowledge of the different systems, reaching important milestones such as registering patents or coordinating one of the most important European projects related to hydrogen storage in underground salt caverns, such as the HyUnder Project.

- The proceedings in fuel cells have focused not only on the R&D stage for the development of technology of PEMFC and SOFC at a regional level, but also on a series of technology innovation projects to bring solutions based on fuel cells to the market. This last action has been carried out through the development of prototypes and simulation by the FHa of affordable solutions to niche market applications, such as an uninterruptible power supply (UPS) fed with hydrogen, material handling vehicles for logistics and auxiliary power units (APUs). The Zero-Hytechpark project has to be specially mentioned in this area, which was awarded by the LIFE+ Programme as one of the best projects in its environmental category.

- Other actions carried out have included the development of innovative systems of hydrogen compression using metal hydrides, new designs for purification processes of hydrogen, energy storage systems with flow batteries or the study of techno-economic analysis of large-scale energy storage through hydrogen, amongst others.

Aragon also has been very active in the field of training and raising awareness. In the first area, FHa has coordinated and participated in several European projects of training to professionals in order to facilitate the accessibility of the new technologies of hydrogen to the market with the training of skilled technicians. Also in the field of academic education, the University of Zaragoza includes a subject on hydrogen and fuel cells in its Masters Programme in Renewable energy and Energy Efficiency that gives access to PhD studies in the field. As a result of these activities, several PhD thesis on hydrogen have been submitted in Aragon. In addition, the FHa participates together with Grupo San Valero, through SEAS Estudios Abiertos, in the implementation of online courses on hydrogen available in all Spanish-speaking countries, training over 1,000 pupils during this period.

In the field of awareness-raising, the FHa has continued bringing hydrogen technologies to students, companies and the general public by hosting different demonstrative events related to the framework of the projects in which it participates. Furthermore, to reinforce this, the FHa develops, from its own initiatives, specific activities aimed at raising the awareness of European citizens about the benefits of hydrogen technologies. In this spirit, the FHa participates in the European projects funded by the FCH JU, such as KnowHy and Hy4All, launched in 2014 and 2015 respectively, as well as collaborating with top-level European entities.

In addition to the projects identified in which the FHa has been directly involved, numerous Aragonese entities have participated in various regional, national and European cooperation programmes, making it possible to substantially progress in developments related to specific projects on hydrogen and fuel cells. The rate of return obtained from the region based on efforts and resources invested has been higher than 250% during the period 2011 to 2015, mainly due to the funding received from applications to European R&DI funding programmes.

03. ACHIEVEMENTS OBTAINED IN THE PREVIOUS MASTER PLAN

The following table lists the projects in which the Foundation and its members have participated in this period:

F.04 Projects in which the Foundation and its members have participated in this period

Project Name	Participants in Aragon	Financing Entity	Period	Project Budget
Improvements to Integrate High Pressure Alkaline Electrolysers for Electricity/H2 production from Renewable energy to Balance the Grid (ELYGRID Project)	FHa - Instrumentación y Componentes (INYCOM) - Lapesa Grupo Empresarial	FCH JU - Fuel Cell and Hydrogen Joint Undertaking	2011 - 2014	3.701.178 €
Assessment of the potential, the actors and relevant business cases for large scale and seasonal storage of renewable electricity by hydrogen underground storage in Europe (HYUNDER Project)	FHa	FCH JU - Fuel Cell and Hydrogen Joint Undertaking	2012 - 2014	1.766.516 €
Grid Integrated Multi Megawatt High Pressure Alkaline Electrolysers for Energy Applications (ELYntegration Project)	FHa - Instrumentación y Componentes (INYCOM)	FCH 2 JU - Fuel Cell and Hydrogen Joint Undertaking 2	2015 - 2018	3.301.391 €
Hydrogen for all of Europe (Hy4All Project)	FHa	FCH 2 JU - Fuel Cell and Hydrogen Joint Undertaking 2	2015 - 2018	1.998.339 €
Intelligent Systems for optimization and Self-management of micrigrids with renewable energy applied to industrial areas in SUDOE region (Optimagrid Project)	FHa - San Jorge University – CIRCE	SUDOE – Interreg IV	2011 - 2014	1.190.271 €
Zero emissions using renewable energy and hydrogen technologies in building and sustainable mobility in Technology Parks (Zero-Hytechpark Project)	FHa - Walqa Technology Park	FCH JU - Fuel Cell and Hydrogen Joint Undertaking	2010 - 2014	1.408.110 €
Fluid Management component improvement for Back up fuel cell systems (FluMaBackProject)	FHa	FCH JU - Fuel Cell and Hydrogen Joint Undertaking	2012 - 2015	3.747.213 €
Improving the Knowledge in Hydrogen and Fuel Cell Technology for Technicians and Workers (KnowHy Project)	FHa - Fundación San Valero	FCH JU - Fuel Cell and Hydrogen Joint Undertaking	2014 - 2017	1.080.417 €

(continued)

Network for Vocational Education and Training in Renewable Energy (NetVET-Re Project)	FHa - Integrated Public Centre of Vocational Training Pirámide	Lifelong Learning Programme, Leonardo Da Vinci	2013 - 2015	99.000 €
Development of Energy Storage Simulation Systems based on Flow Batteries associated with Wind parks	Grupo Jorge - FHa	Internal Project	2011 - 2013	Confidencial
Development of emergency system based on Fuel cell and hydrogen for IMOCA sailboat at Vendée Globe 2012	FHa	Customer Project (Acciona)	2011 - 2012	Confidencial
Hydrogen Fuel Cell for AUNAV.NEXT (Explosive Deactivate Robot)	Proytecsa – Fha	EEA Grants	2015	Confidencial
Power-to-gas technology in the Aragonese Pyrenees. Innovation and Energy Efficiency in mountain destinations	CIRCE –Mountain Tourism Cluster – FHa	AEI Programme– Ministry of Industry, Tourism and Trade	2014	56.379 €
Development of a new steam generation system for industrial application by means of solar power concentrators (Vacos)	SATEL- Vea Global- Tafyesa- FHa	AEI Programme– Ministry of Industry, Tourism and Trade	2014	80.094 €
Development of a model of solution blocks for electrical supply (Model-Block)	SATEL- Vea Global- Tafyesa- FHa	AEI Programme– Ministry of Industry, Tourism and Trade	2014	77.189 €
Optimization of the fluid dynamic and mechanical design of a high temperature PEM Fuel Cell system	LIFTEC (CSIC)	Ministry of Science and Innovation	2010-2012	449.164 €
Design and manufacture of an ultralight average power PEM fuel cell for an UAV unit of energy	LIFTEC (CSIC)	Ministry of Economy and Competitiveness	2013-2015	59.560 €
Profitable Small Scale Renewable Energy System in Agrifood Industry and Rural Areas: Demonstration in the Wine Sector (LIFE+REWIND)	LIFTEC (CSIC)- Viñas del Vero – University of Zaragoza – INTERGIA Sustainable Energy	LIFE Programme	2014-2017	1.562.994 €
PROQUIPOL: Chemical processes of complex polymer waste into resources	CIRCE	Ministry of Science and Innovation	2009-2011	629.753 €

03. ACHIEVEMENTS OBTAINED IN THE PREVIOUS MASTER PLAN

(continued)

Sustainable hydrogen production from biological waste by means of Steam-Iron process	University of Zaragoza I3A	Ministry of Science and Innovation	2011-2014	181.500 €
Biogas dry reforming: Intensification of the process with energetic aims	University of Zaragoza I3A	Ministry of Economy and Competitiveness	2014-2016	364.300 €
Professional Training for hydrogen use	CPIFP- Pirámide	Government of Aragon. Projects for Innovation in Vocational Training	2015	2.000 €

Meeting Elygrid project.

The evolution experienced by the increase of actions associated with hydrogen in Aragon is reflected in different indicators, all of them positive, which show the firm commitment of the Autonomous Community in this matter:

- In terms of the number of projects funded, there were 96 for the period 2011 - 2015, with an annual average of 20 projects related to hydrogen and fuel cells.
- In the field of human resources, the number of people trained has increased to 184 people, although a higher figure of 250 people in the case of professionals dedicated to these technologies.
- In the field of training, it is highlighted that a total of 8 PhDa thesis have been conducted in the field of hydrogen in the period.
- As a result, the figures of the economic activity in the period associated with hydrogen technologies amounted to almost €6 million.

F.05 Indicators for the follow-up of the Hydrogen Master Plan in Aragon (2011 - 2015)

	Year 2011	Year 2012	Year 2013	Year 2014	Year 2015	TOTAL
No. of funded projects related to hydrogen in Aragon	24	20	17	19	16	96
No. of PhD thesis in hydrogen field in Aragon	2	1	1	1	3	8
No. of people trained in hydrogen technologies in their entity in Aragon	45	31	30	39	39	184
No. of professionals dedicated to hydrogen technologies in their entity in Aragon	49	50	49	50	52	250
Economic activity in hydrogen technologies in Aragon	1.519.126 €	1.186.298 €	908.329 €	1.183.259 €	1.167.733 €	5.964.745 €

03. ACHIEVEMENTS OBTAINED IN THE PREVIOUS MASTER PLAN

During the five years of implementation of the Master Plan 2011 - 2015, the hard work and good deeds of the Aragonese entities of the hydrogen sector has been recognized with different awards.

The FHa received the following:

- Year 2013: Prize for Institutional Management by Revista Ejecutivos.
- Year 2014: Aragon Environment Award in the area of non-profit entities by the Department of Agriculture, Livestock and the Environment of the Government of Aragon.
- Year 2014: Diploma in recognition as a Success Story in the Business Eco-Innovation by CIRCE Foundation.
- Year 2015: Best Life Project for Zero-Hytechpark Project by the European Commission through its programme for environment LIFE+.

Also deserving of a special mention during this period 2011 - 2015 is an event to celebrate the tenth anniversary of the Foundation held in the Walqa technology Park, where the Foundation has its headquarters. This served to review the path taken to date and to set new challenges for the future. This event was attended by more than a hundred institutional representatives and companies, some of some of them international.

During the execution period of the Master Plan 2011 - 2015, Aragon, with the objective of promoting the deployment of hydrogen technologies, **has intensified its activity with other very active regions and municipalities.** The work being carried out by the Government of Aragon in HyER allows Aragonese entities and organizations to make way in new markets, as well as facilitating the establishment of solid partnerships and alliances, such as one established by the FHa with the Scottish Hydrogen and Fuel Cells Association (SHFCA), which will allow closer relations between the members of the Foundation and the members of the Association, with the goal of identifying opportunities and setting up new projects.

In the same way, Aragon, through the Foundation, has positioned itself actively to ensure the deployment of a refuelling station network so as to define the first hydrogen corridor in crossing the Pyrenees, thus connecting France and Central Europe with the Iberian Peninsula.

Last but not least, the Foundation has encouraged **partnership actions.** The Foundation continues to develop very active work in this area. In addition to its presence in the partnerships above mentioned, AeH2, APPICE, PTEPC and N.ERGHY, it is present at the national level, in the AEN/CTN 181 Committee: Hydrogen Technologies of Spanish Association for Standardisation and Certification (AENOR). At international level, it collaborates with the hydrogen working group in the Comité Européen de Normalisation Electrotechnique (CENELEC). In this period, the FHa in Aragon has continued its link with International Energy Agency (IEA) through its working groups on the Hydrogen Implementing Agreement (HIA).

As part of the activities of the Foundation, and with the object of increasing its visibility, and by extension that of Aragon, it is important to point out its participation in the main national, European and world forums, calls and congresses. As an example, one can mention the presence of the Foundation in the editions of the Ibero-American Conference on Hydrogen and Fuel Cells (IBERCONAPPICE), in the European Hydrogen Energy Conference (EHEC) or the World Hydrogen Energy Conference (WHEC). In the latter case, both the Foundation and the Government of Aragon have participated to ensure that, among other objectives, its twentieth edition (WHEC 2016) will take place in Zaragoza.

04.

AIMS AND METHODOLOGY

04.
AIMS AND METHODOLOGY

GENERAL AIMS OF THE PLAN

- To have a tool for the identification of opportunities of the new hydrogen technologies detected in Aragon, which will allow decisions to be taken on an institutional, business and academic level.
- To identify the strategic lines for the region and establish a time scale and actions plans for the deployment of these lines.
- To involve the Aragonese economy in the adoption of new technologies as a differentiating competitive positioning factor in the medium and long term

SPECIFIC AIMS OF THE PLAN

- To review the state of the art of technology, current development, projects, reference companies in the sector, potential of the region in the matter, incipient markets and to define opportunities.
- To identify strategic lines of work for the coming years and opportunities for specific development for the Aragonese business sector.
- To set cross-cutting and general support actions: training, awareness-raising, technology transfer, protection and impact needed to guarantee the success of the deployment of the rest of the work lines (production, storage, transportation, distribution and applications.)
- To define actions oriented to achieve specific results through the establishment of monitoring indicators that allow monitoring effectively the objectives proposed.
- To carry out a survey with longer temporary timeframes2020-2050, defining the continuity of the strategic lines drawn and setting the bases to reach these.

METHODOLOGY

The methodology applied for the development of the Hydrogen Master Plan 2016 - 2020 has been carried out through the definition of a dual approach: internal, through the review of the previous Plan, the state of the art and the experience provided from the FHa and its members, and external, through the development of an intensive participatory process that has included both the members and the new companies, as well as agencies that may be interested in these developments.

INTERNAL ANALYSIS

- Master Plan 2011 – 2015 Review. Evaluation of the results achieved in the Plan 2011 - 2015 through its monitoring indicators and analysis of the six thematic areas defined in the Plan. In each one of them an analysis of the causes of their evolution has been carried out with the goal of establishing those areas that have greater opportunities for development and those that it is necessary to promote from a strategic point of view in the new Plan.

- Hydrogen current state-of-the-art Review. Analysis of the evolution of the state of the art in hydrogen technologies as well as the evolution of plans, strategies and programmes at national and international level.

- Identification of lines of work for the new Plan 2016-2020. A first proposal has been established as a result of the previous review and industry trends, by setting the following lines in five areas:

  A. Production.

  B. Storage, transport and distribution.

  C. Applications.

  D. Transfer of technology, protection and economic impact.

  E. Training and awareness.

EXTERNAL ANALYSIS

- **Participatory process.** Following the internal analysis carried out, at the drafting stage of the Plan, it has moved on to an intensive participatory process, focused on the five lines of work identified. To do this, two rounds of working groups have been established where both the Foundation members and relevant companies and entities in the issue being addressed have provided feedback.

  The aim of the first round of working groups, held during in July 2015, was to show the degree of implementation of the Master Plan 2011 - 2015 and discuss the new strategic lines and new proposals for action. A first predefinition of performances was proposed by establishing a period of reception of suggestions on the topics analyzed.

  In the second round, celebrated during September 2015, action was taken to review the proposals received, in addition to firming up and adding to those presented in the first phase. This has allowed participants to share interests on new projects.

As a result of both work approaches, the new Master Plan 2016 - 2020 establishes a **results-oriented monitoring system**. For this purpose, a battery of monitoring, outcome and management indicators has been established that will monitor the actions proposed.

05.

LINES OF WORK

05. LINES OF WORK

The Master Plan 2016-2020 is structured into five lines of work:

A. Production.

B. Storage, transport and distribution.

C. Applications.

D. Transfer of technology, protection and economic impact.

E. Training and awareness.

In the description of each one of the lines of work the following sequence for their presentation has been established:

- **State-of-the-art:** in each one of the lines of work, there is a brief presentation of the degree of progress of technology, as well as the most relevant advances and projects in each of the cases. The aim is to obtain a comprehensive view on the trends in the related sectors.
- **Opportunities:** the main opportunities in each line of work have been identified so as to anticipate in many cases the actions to be carried out in the scope of the present Plan.
- **Actions planned:** for each line of work the actions and main proceedings planned have been identified by setting the priority level of the action (High, Medium, Low). In addition, for each action, the modification of the TRL projected have been identified.

The **TRL** (Technology Readiness Level) is a measurement system that estimates the maturity or preparation of a particular development on the basis of a classification in nine different levels, with the possibility of adaptation to specific cases. Such a system has a relevant role within Horizon 2020, and therefore it has been decided to include it within the monitoring system of the lines of work of the Plan.

TRL-0	Idea.
TRL-1	Basic Research.
TRL-2	Technology Concept Formulated.
TRL-3	Applied Research.
TRL-4	Small-scale Prototype.
TRL-5	Large-scale Prototype
TRL-6	Prototype System.
TRL-7	Demo System.
TRL-8	First Commercial-type System.
TRL-9	Complete Commercial Application.

With the objective of establishing a plan results-oriented, two milestones in 2018 and 2020have been established to assess the degree of progress of the Plan.

In the case of electrolysis (included in the work line of *"production"*), being a long term action, the level of detail of the actions and action lines is superior to the rest. This will identify changes in the TRL per action line and objectives with a greater level of detail.

On the other hand, in the case of *"transfer of technology, protection and economic impact"* and *"training and awareness"*, given the typology of actions, the TRL classification does not apply and indicators in relation to participation and the level of acceptance are the option chosen.

A.

HYDROGEN PRODUCTION

A.
HYDROGEN PRODUCTION

The main processes of hydrogen generation today can be differentiated in a general way from those which resort to hydrocarbons and those which generate it by splitting of the water molecule, in addition to other more innovative processes.

Electrolysis is one of the most promising hydrogen production methods, as it is done by the dissociation of the water molecule in H2 and O2 through the use of electrical energy in the form of direct current. Pollutant emissions during this reaction are null, and if in addition the energy used comes from renewable sources, it is considered that the overall process of hydrogen generation is clean ("Green H2"). The device used for these processes is called an electrolyser, for whose configuration there are several technologies in different degrees of industrial development. The alkaline technology electrolysers are the ones with a greater industrial presence currently, since they have a higher technology readiness level and a better economic profitability. On the other hand, polymer membrane (PEM) electrolysers have been developed over the past number of years, and although there is also a need to be more competitive in cost, they have started to compete with alkaline electrolysers in market niches where greater volume of hydrogen production is required. The solid oxide electrolysis, which can be performed at high temperatures (500°C - 800°C), is also in constant development and it promises improvements with regards to the overall performance of the process.

As an alternative to the traditional electrolysis, there are other processes such as the photoelectrolysis, where the electrode absorbs sunlight directly and generates the electric potential necessary to dissociate the water molecule by a direct current. The photoelectrolysis is a technology with a promising future in terms of cost and efficiency, whose most immediate objective is to find more suitable materials for its development.

Also, using water as a starting point, the thermochemical electrolysis gets its dissociation into hydrogen and oxygen through the application of large doses of heat in two thermal cycles (sulphur-iodine) which act as intermediate processes to get a complete transformation of water into hydrogen and oxygen. Operation simplicity is its main advantage; however it also has disadvantages, such as the need for very high temperatures to complete the entire process. The practical implementation of some of these production techniques is raised in combination with other processes that generate large quantities of residual heat, as it is the case for electricity generation from nuclear energy, whose exploitation for hydrogen production would increase the overall performance of both and result in a substantial reduction of transaction costs where it is produced.

In order to get clean hydrogen there are other methods in addition to the ones mentioned previously, although they are at a more

A. HYDROGEN PRODUCTION

experimental level. Especially interesting are those related to biological pathways of hydrogen production, such as **dark fermentation,** using algae or bacteria capable of producing hydrogen.

Fossil fuel **Reforming** constitutes the largest share of the world hydrogen production[14], primarily due to its very low operating costs and high operational performance (70-85%). The process involves the reaction that occurs when a particular hydrocarbon (usually Natural Gas) contacts steam in a reactor at very high temperatures resulting as a product of this reaction, hydrogen as well as carbon monoxide and carbon dioxide (CO and CO_2). The implementation of a second stage allows increasing the performance of the process since it increases hydrogen generation and at the same time consumes the CO produced in the first stage. However, the large amounts of CO_2 released (7 kg CO2 per kg of H2 produced) move it away from being a process which could be considered, in general terms, clean and sustainable. Similarly, there are other processes to generate hydrogen, such as the so-called **Partial Oxidation** where a hydrocarbon reaction is carried out with oxygen at a very high temperature (1,300 °C - 1,500 °C). They are also processes with a high performance, but with associated safety challenges that hinder its use in portable or compact applications. The previous production methods can be combined in the so-called **Autothermal Reforming,** which consists of adding a stream of steam to a process by partial oxidation, causing the reaction of steam reforming. The result is a simpler process with

[14] State of the Art on Alternative Fuels Transport Systems in the European Union, European Commission, DG MOVE - Expert group on future transport fuels.

regards to the needed reaction temperature control. It also has other advantages, such as low operating costs and high performance of operation, as well as the possibility of using compact size reactors. Along with these reforming processes, plasma reforming stands out, as it has been developed to allow the production of mixtures very rich in hydrogen which can be applied to a large variety of fuels, with high performance and without the need for catalysts, but with the disadvantages of having a high dependence on electricity and the high pressures of the process.

Another of the most important processes for the production of hydrogen from hydrocarbons is Gasification, which consists of a partial oxidation of the raw material, this being normally coal or biomass, similar to the processes described above. The result is a mixture of H_2, CH_4, hydrocarbons, CO and N_2. The most critical problems are derived from the large volume of biomass needed to be transported to the production plant and the moisture content of the raw material, as well as the resources that should be used to remove impurities from the resulting gas. Finally, a similar process still in the development phase is Liquid Phase Reforming, which uses oxygenated hydrocarbons or carbohydrates for hydrogen generation. It is characterized by its development at low temperatures and very high pressures (up to 30 MPa), and it has important advantages such as the fact that it is not necessary to vaporize or transform the raw material to gas phase.

The processes of the hydrogen generation from hydrocarbons are implanted on an industrial scale, because they have been closely linked with the development of the petrochemical industry. Nowadays, research and innovation are focused on applying and adapting satisfactorily these processes to the use of hydrocarbons that can be obtained from renewable sources or from valorization and/or reuse of waste. This is the case of biomass, biogas or biomethane obtained, for example, in the treatment of waste.

In Aragon, and from the FHa, the main developments to date have been made in the field of alkaline electrolysis. Electrolysis from renewable energy is seen in Europe as a priority pathway for clean hydrogen production, either by alkaline electrolysis or by PEM electrolysis. In this sense, the FHa has participated as coordinator in ELYGRID Project, whose main objective was the implementation of improvements to a traditional alkaline electrolysis system to be able to offer grid services or energy management systems in electricity grids with high penetration of renewable constitute energy. The tasks initiated with the ELYGRID Project, completed in 2014, have continued to the present with the ELYntegration Project, which will take place between 2015 and 2018. Below it is described the state of the art projects led by the FHa and the objectives in the short and medium term regarding European targets.

A. HYDROGEN PRODUCTION

F.06 State of the art and future objectives for hydrogen production from renewable energy as an energy storage system and electrical network management [15] [16] [17] [18]

		State of the art		2017 - 2018		2020	
		FCHJU2 (Objectives 2012)	ELYGRID – FHa Project coordinator (results 2014)	FCH2JU (Objectives 2017)	ELYntegration – FHa Project coordinator (Objectives 2018)	MAWP FCH2JU (published in 2014)	Electrolysis Study (published in 2014)
KPI1	H_2 electrolytic production, energy consumption (kWh/kg) @ nominal production	57-60 @100 kg/d	51,2@100 kg/d	55 @ 500kg/d	52 @500 kg/d	52 @500 kg/d	52 @500 kg/d
KPI2	H_2 electrolytic production, CAPEX @ nominal power including additional equipments and commissioning	8,0 M€/(t/d)	1,58 M€/(t/d)	3,7 M€/(t/d)	<1,30 M€/(t/d)	2 M€/(t/d)	-
KPI3	H_2 electrolytic production, loss of efficiency for degradation @ nominal power and considering 8000 hours of operation a year	2% - 4% / year	Not included as an aim in the project	2% / year	1.5% /year	1.5% / year	-
KPI4	H_2 electrolytic production, flexibility with a degradation <2 % year (in reference to the KPI 3)	5% - 100% of nominal power	Not included as an aim in the project	5% - 150% of the nominal power	15% - 130% of the nominal power	0% - 200% of the nominal power	-
KPI5	H_2 electrolytic production, hot start from minimum to maximum power (in reference to the KPI 4)	1 minute	Not included as an aim in the project	10 seconds	2 seconds	2 seconds	-
	H_2 electrolytic production, cold start	5 minutes	Not included as an aim in the project	2 minutes	20 - 180 minutes	0.5 minutes	20 - x00 minutes

Source: FCH 2 JU

[15] Multi - Annual Work Plan 2014-2020, Fuel Cells And Hydrogen Joint Undertaking (FCH 2 JU), June 2014.
[16] Elygrid Project, FCH JU Programme Review Days 2014, Project Report.
[17] ELYntegration Project, Description of Actions (DoA), 2015.
[18] Study on development of water electrolysis in the European Union, Fuel Cells and Hydrogen Joint Undertaking, February 2014.

The main opportunities identified in the field of hydrogen production and intended for exploration in the framework of the next Plan are the following:

- **Consolidation of a local industrial producer of equipment and hydrogen generation systems based on electrolysis or solutions integrator for hydrogen production by electrolysis**

  There is currently a wide-reaching know-how amongst the sscientific, industrial and business sectors towards establishing the necessary actions for an international positioning and strategic alliances of the FHa with European companies from the sector.

- **Estimation of high infiltration of intermittent renewable energy (wind and solar photovoltaic) in electrical grids in the short to medium term**

  The need for management of electrical systems with high penetration of renewable energy is appreciated, providing hydrogen technologies together with solutions for energy services and network services where electrolysers act as a flexible load and producing hydrogen for later use.

- **Potential for hydrogen production from waste with potential for hydrogen generation in the region**

  The region of Aragon is one with a significant waste generation, including sources like agricultural and livestock and urban sectors, as well as others such as the paper industry. Entities such as the University of Zaragoza have knowledge in the treatment of such waste for the hydrogen production.

- **Financial support from the European Commission through the program FCH 2 JU for hydrogen production projects**

  Currently, through the new programme FCH 2 JU, there is a focus on projects for hydrogen production by electrolysis from renewable energy for energy storage and providing grid services to the electrical network, ensuring a low carbon footprint from waste. Aragon has an important competitive position given the ground covered and the work undertaken in this area.

- **Need for hydrogen generation systems for their integration in the transport sector**

  For the coming years, Europe and other regions of the world, such as California and Japan, have defined, within their energy and economic development strategies, the deployment of the hydrogen fuelling infrastructure, also called Hydrogen fuelling stations or Hydrogen Refuelling Station (HRS), which will require hydrogen generation systems to refuel vehicles. This hydrogen, which is designed to be of renewable origin, will come from water electrolysis.

A. HYDROGEN PRODUCTION

ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
1. Electrolysis	Optimization at the technical and cost level, through simulation and improved design of components and subsystems	HIGH	5 to 7	First design made for TRL 6	Systems developed and tested aligned with the European Indicators for 2020 (TRL 7; CAPEX 2M€/ ton/day)
	Study of mechanisms of degradation of the components and accelerated life. Long-term tests	HIGH	3 to 5	Test protocols developed and validated	Validation of the developed systems, efficiency losses <2%/year by degradation
	Development and optimization of balance of plant (BOP) and auxiliary systems for integration of electrolysers in grid services, isolated applications and storage of energy from renewable sources	HIGH	5 to 7	Design of electrolysis system and auxiliary components in environments of grid services and/or isolated	Redesigns validated, and demonstrated in a relevant environment (TRL 7)
	Development of standardised procedures and tests for the operation of electrolysers	HIGH	Does not apply TRL	Procedures, test protocols and proposal of standardisation developed	Proposals and procedures communicated to standardisation committees at the national level

ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
2. Power electronics development	Development of power electronics optimised for electrolysis applications in isolated systems for < 100 kW power range	MEDIUM	5 a 7	Specified requirements and design checking in conformity with the same ones: validated designs	Collaborative demonstration with electrolyser in relevant environment (TRL 7)
	Power electronics optimisation in electrolysis equipment to provide grid services, in fulfilment of IEC 61000 requirements	MEDIUM			
	To increase the capacity of compaction of the systems to make them more functional and modular	MEDIUM			

ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
3. Hydrogen production from waste	Development of organic waste catalogue (agrifood, livestock, urban and industrial) in Aragon with potential for H2production: quantification, distribution, quality, characterization	MEDIUM	Depending on the waste source, origin and typology the initial TRL will be between 3 and 5. 3 a 6	Action approach of production to validating in a relevant environment (TRL 5) and potential of resources analysed (catalogue, analysis)	At least a project developed in the field of hydrogen production field demonstrative level in the region
	Choice of transformation methods depending on raw material (waste)	MEDIUM			
	Techno-economic analysis of the production lines, according to treatment (biological, thermochemical, biogas or biomethane reforming, gasification, etc.)	MEDIUM			

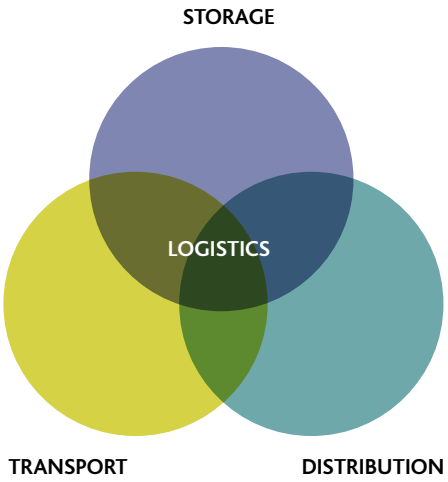
B.

HYDROGEN STORAGE, TRANSPORT AND DISTRIBUTION

B.
HYDROGEN STORAGE, TRANSPORT AND DISTRIBUTION

Once hydrogen is produced, through any of the generation processes described in the previous section, it is necessary to begin to think about the next stage to be resolved: the logistics to have that hydrogen available in the point where it is demanded.

In this area, logistics are comprised of three large segments that are totally industrially independent, but with areas in common and some dependency among themselves in terms of their promotion and development: storage, transportation and distribution.



STORAGE

There are several methods for hydrogen storage: in solid state, liquid and gas. The latter is the most common, as it is the natural state of hydrogen in normal temperature and pressure conditions. In the majority of the production methods used currently, it is obtained from this state.

With regard to the **gas storage**, the development and advancement in the science of new materials have allowed the storage pressure in tanks to be increased. To do this, the use of composites with carbon fibres and kevlar, combined with new designs of deposits of more resistant alloys, allows pressures to reach above 1,000 bars.

Depending on the material used for the manufacture of the tank and its covering, there are four different typologies:

- **Type I:** Those manufactured entirely from metal, usually stainless steel or an alloy of other metals also resistant to the effects of hydrogen.
- **Type II:** Type I tanks reinforced with a resin and carbon fibres winding just in its central part, without covering the two ends.
- **Type III:** Type I tanks fully covered with fibre and resin.
- **Type IV:** It differs from previous ones with regards to the material of the bottle, which is a high density polymer whose winding would be the same as that described in the type III.

In terms of development level of the productive process, out of the four types listed above, only type I has developed this process on a large scale, while the other three types of deposits are manufactured under demand for specific needs.

B.
HYDROGEN STORAGE, TRANSPORT AND DISTRIBUTION

Currently, the standard storage pressure is 200 bars, both in pressure cylinders cages or racks like trailer tows, an aspect that interacts with the interests of the *transport* sector in its development. Therefore, an improvement in the production processes of the deposits type II, III and IV will result in a cost reduction and pose a real possibility of being more efficient and carrying a greater quantity of gas in the same volume. Obviously, this improvement will not occur until there is a demand that justifies the investment, given that the *distribution* sector is the key to set in motion the entire value chain. In this sense, the deployment of Hydrogen fuelling stations, or HRS (Hydrogen Refuelling Station), is expected to increase significantly over the next decade from 2016 to 2025, coinciding with the deployment stage of the fuel cell vehicles (FCEV). From a sectoral point of view, the automotive sector has been positioned and has chosen the pressure of 700 bars as the standard for hydrogen storage in deposits of current generation of fuel cell vehicles. This market will require the development and improvement of the productive processes for tanks type II, III and IV, which will lead to a cost reduction in manufacture and the launch of this new concept of storage in a near future.

In addition to gas storage, technology for the **liquid storage** of hydrogen is available. This technology has not experienced major advances in recent years because of the implied energy requirements. For its implementation, liquid hydrogen is stored at-253 °C. The last solution is the **solid storage** through the use of metal hydrides. This system is only appropriate for working in stationary applications because of its high weight and low pressure.

In addition to these applications, a new technology is used recently known in the industry as LOHC (Liquid Organic Hydrogen carriers). This technology is based on a chemical reaction in which hydrogen in gas state is dissolved in a liquid medium which is able to absorb large quantities of gas and retain their molecules. It is a quite incipient system but expected to increasingly have a leading role as research into this progresses.

For large-scale storage of energy from renewable sources, the underground storage of hydrogen in saline caverns has been explored in Europe. These storage systems are of particular interest when salt domes are in close proximity to electrical networks with high penetration of renewable energy (wind resource close) and at a distance of not more than 250 km of important power consumption nodes (big industrial cities).

During the previous Master Plan, FHa led the European HyUnder Project, which analysed the techno-economic feasibility of this type of installations.

In Spain, it was noted that there are four appropriate locations to locate this type of energy storage system, with one of them being in Aragon. Today, it is seen as the only complementary system to reversible pumping as a system capable of managing electricity networks with high penetration of intermittent renewable sources, wind and solar power. The economic analysis showed that it is from 2025, with a higher hydrogen demand than the current in the transport sector, when a project of these characteristics would be feasible in economic terms. The FHa will keep up with prospects in the market with the hope of finding opportunities for positioning Aragon in this matter.

In Aragon, the company Calvera is a distributor of storage systems. Calvera provided the storage systems currently in operation in the hydrogen refuelling station in Valdespartera (Zaragoza) and in the FHa (Walqa Technology Park, Huesca) in operation since 2008 and 2011 respectively.

[19] State of the Art on Alternative Fuels Transport Systems in the European Union, European Commission, DG MOVE - Expert group on future transport fuels.

B.
HYDROGEN STORAGE, TRANSPORT AND DISTRIBUTION

TRANSPORT

Currently, there are a multitude of possible configurations to transport hydrogen from a generation point to a consumption one. Most of the gas companies have opted for solutions of rack of 12 or 16 bottles of approximately 70 litres and 200 bars. These modules are independent from each other and a normal truck can carry up to 8 separate blocks.

There is also the possibility of designing and manufacturing made-to-measure blocks that fit with the special needs of each client.

It is expected that the next generation of deposits that make up these blocks transported will be type IV, facilitating the movement of large quantities of gas in smaller volumes, and thus decreasing the associated costs.

Trucks for the transportation of gas hydrogen manufactured by Calvera Maquinaria e Instalaciones at its facilities in Epila (Zaragoza) Source: Calvera Maquinaria e Instalaciones

DISTRIBUTION

Concerning hydrogen distribution, the automotive sector is starting to plan the next step for large-scale production of fuel cell electric vehicles (FCEV). Vehicle manufacturers such as Toyota, Honda, Hyundai and Renault have already presented their respective models available for sale to other companies and individuals. Currently, these vehicles are driven in very localised areas due to the need of refuelling points. At European level, the Directive 2014/94 was adopted in 2014, relating to the implementation of an infrastructure for alternative fuels[20], which considered hydrogen as one of them. For this reason, it is not surprising that European countries such as Germany, together with the United States and Japan, are those that are betting more on this technology and bringing together almost 80% of hydrogen fuelling stations in their territories. France has also initiated a national strategy of alternative fuels that encourages the installation of these service stations. Other European countries where hydrogen infrastructure is also being rolled out are Holland, Denmark, the Scandinavian countries and the United Kingdom.

[20] Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure. European Commission. EU Official Journal. L307/1. October 2014.

B.
HYDROGEN STORAGE, TRANSPORT AND DISTRIBUTION

Spain currently has six hydrogen stations with service availability. Two of them are in Aragon (Huesca and Zaragoza), two in Andalusia (Seville), and the other two are in Castilla La Mancha (Albacete and Puertollano).

With a view to enhancing its deployment in the coming years, the development of a network of functional refuelling has been planned, defined in the Alternative Fuel Vehicles (AFV) Strategy developed by the Ministry of Industry, Energy and Tourism (MINETUR). This strategy expects the implementation of 21 hydrogen stations by the year 2020 so that these vehicles can circulate normally throughout the territory with a standard refuelling pressure of 700 bars that may be provided by the majority of the new hydrogen stations. In this sense, the strategy and its implementation in the respective plans, such as the MOVEA, not only consider support for the acquisition of fuel cell vehicles but also the adaptation of those hydrogen stations that have been previously installed to achieve such pressure values. At this refuelling pressure, fuel cell vehicles can reach ranges of over 500 km with a single refuelling. The new advanced refuelling systems can make a fill-up take less than 5 minutes, so the comparison charging time and range would be very similar to that of the current combustion vehicles.

The strategy of hydrogen stations in a meshed grid followed by other countries can serve as a model for action. The proposal raised consists of a 'spine' that links the main cities and 'branches' depending on the specific needs of each area.

Aragon is in a privileged position in that it already has two hydrogen refuelling stations installed in Huesca and Zaragoza. The first would give access to a future hydrogen corridor with France and the second would be located in one of the main logistic centres of southern Europe that is Zaragoza, which is practically the equidistant point between Madrid, Barcelona, Bilbao and Valencia and belongs to one of the major trans-European transport networks. These two stations can be the main artery of the first national meshing.

B. HYDROGEN STORAGE, TRANSPORT AND DISTRIBUTION

The main opportunities identified in the field of hydrogen storage, transport and distribution and what it is desired to explore in the framework of the next Plan are the following:

- **Possibility of development of ambitious demonstration projects that connect the development of a European hydrogen refuelling infrastructure.**

  In the next years, among other actions, the implementation of hydrogen stations and the use of new commercial fuel cell vehicles is expected to take advantage of the existing specific funding programmes such as the FCH 2 JU, the CEF programme or programmes of European funding in transnational and cross-border cooperation as SUDOE or POCTEFA that contemplate the possibility of development of projects of interest for the promotion of hydrogen technologies.

- **Implementation of the transposition at national level of the EU Directive 2014/94 of the European Parliament and of the Council of 22nd October 2014.**

  The transposition of this directive on the implementation of infrastructure for alternative fuels, including refuelling infrastructures for fuel cell vehicles will allow the development of a wider hydrogen stations network in Aragon and connected with the rest of Spain and Europe.

- **Deployment of an infrastructure solutions market of European and international refuelling.**

  In the face of new European mobility plans based on hydrogen technologies and contemplating the development of new refuelling infrastructure, a new opportunity arises for internalization of the know-how generated in the region with the operation of the two existing hydrogen stations and the completion of European projects on hydrogen sizing and design by the FHa.

- **To position Aragon in the European hydrogen corridor network.**

  Aragon holds part of its economic strengths in its strategic location and in the impetus that has been made in the field of logistics during the last decades. To position the region in the main network of trans-European transport corridors thanks to hydrogen technologies and through the realization of projects, as well as implementation plans for hydrogen fuelling infrastructure, is presented as a great opportunity. In this way, the connection of the Aragonese infrastructures with the ones of the French Pyrenean border departments (Midi - Pyrénées and Aquitaine) and of the main surrounding economic centres in Spain (Catalonia, the Basque Country and Navarre, Madrid and the Valencia Community) would be a reality, thus establishing a strategic opportunity for economic growth and development in the region in the short to medium term.

- **Increase in the need for storage, transport and distribution of hydrogen.**

  The deployment of technology brings new requirements in the market for technologies related to the storage, transport and distribution of hydrogen at the European and international level. This represents a great opportunity to evaluate the technologies developed in the Autonomous Community.

B.
HYDROGEN STORAGE, TRANSPORT AND DISTRIBUTION

ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
1. Compression using metal hydrides	Design and manufacture of containers of metal hydrides optimised for rapid loading and unloading (gas distributors, heat exchangers, etc.)	MEDIUM	4 a 7	Product of a stage to 200 bar	Prototype two stages to 1000 bar
	Optimisation of metal alloys to improve thermal conductivity	MEDIUM			
	Study of mechanisms of degradation and accelerated life in metal hydrides. Cycling testing	MEDIUM			
	Development of balances of plant and auxiliary systems	MEDIUM			

ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
2. Study of development of storage systems for the market standards	Study on high pressure container development	MEDIUM	9	Completed studies and conclusions	To be determined
	Study on development of equipment for the standardised test composite containers	MEDIUM			

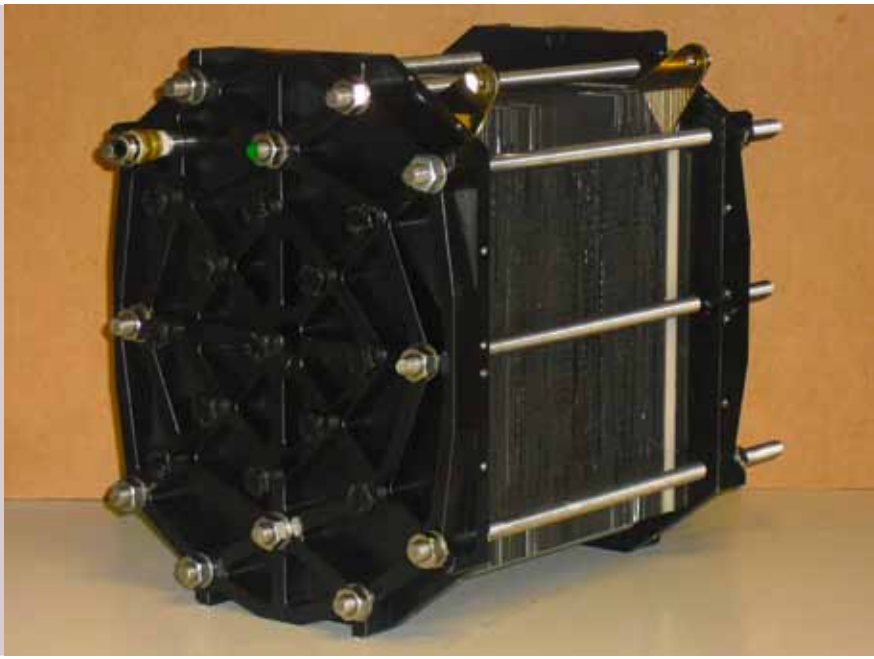
ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
3. Deployment of refuelling infrastructure	Estimation of the evolution of hydrogen demand for transport and evaluation of possible infrastructure (collection of available information, forecast analysis, technological solutions, dimensioning, costs, etc.)	HIGH	8 a 9	5 hydrogen stations operating in Aragon	700 bar technology tested in the region
	Line of hydrogen refuelling station adaptation from 350 bar to 700 bar	HIGH			
	Selection of the best alternative for the deployment in Aragon	HIGH			

C.

HYDROGEN APPLICATIONS

C.
HYDROGEN APPLICATIONS

Thanks to the scalability, capacity and flexibility which the different hydrogen technologies present both in size and format or power, it can be theoretically claimed that their applications can be considered virtually unlimited.



However, in recent years a series of emerging markets have been established in which the first commercial applications are being developed and which constitute niche markets.

In order to facilitate the classification of these applications, three categories must be taken into account: stationary applications, portable applications and vehicular or mobility applications.

STATIONARY APPLICATIONS

Stationary applications through fuel cells have been continuously growing and developing in recent years, and they can be divided mainly into two types: high power applications (hundreds of kilowatts (kW) and megawatts (MW) and low power applications (reaching tens of kilowatts).

With regard to *high power applications*, they are set in the range 200 kW to 1000 kW rated power. The main global manufacturers are Bloom Energy (SOFC), UTC Power (PAFC) and Fuel Cell Energy (MCFC) and they develop their products and applications of generation and cogeneration to be capable of feeding large loads steadily and continuously. Amazon, Coca-Cola or Wallmart[21] are some of the clients that use this type of fuel cell in their facilities and data centres.

In the next step, in terms of size and power, *low power stationary applications* can be found of up to tens of nominal kilowatts. The main applications of this type of equipment are micro-cogeneration systems and units of electric power generation in isolated network systems. Within the category of micro-cogeneration systems, there are units of around 300 W to 2000 W of power connected to a reformer and fed by natural gas from which hydrogen is extracted to be used. This type of battery provides power to supply the thermal and electrical base load basis of a home. With more than 22,000 units sold in Japan, Panasonic and its ENE-FARM Project represent the maximum exponent of this philosophy[22]. At European level, there have been similar initiatives, although with a lower impact, such as the ENE-FIELD Project, that has installed more than 1,000 units in the north of Europe23, and the CALLUX Project[24] in Germany, with a purpose of installing 500 units of fuel cell.

In the field of the off-grid facilities, the powers of both electrolysers as fuel cells are framed in the range of 1 kW to 50 kW, with the most common powers being about 1 kW to 10 kW. The most common technology for both applications is PEM technology, which has been developed exponentially in this area in recent years. Special mention should be made to one of the key applications of fuel cells in isolated systems, as backup batteries for telecommunications systems. This application, initially promoted by the Department of Energy of the United States, through national funds , has more than 1,000 units installed(2015). Some of the key companies in this market are: Heliocentris, Dantherm or Hydrogenics[25].

PORTABLE APPLICATIONS

Finally, in relation to size and power scale, there are the low power portable applications, from few milliwatts up to a few hundred watts, in which fuel cells are a potential substitute for rechargeable batteries. The key technologies in this field are the polymer membrane (PEM) and direct methanol (DMFC), with the latter being used because of the ease of recharging via liquid fuel cartridges (methanol). There are also small electrolysers of tens of watts which are responsible for recharging the hydrogen cartridges used in these applications. Apple is working on fuel cell solutions to increase the autonomy of its mobile phones and laptops, with systems already tested in its iPhone 6 or MacBook[26].

[21] http://www.fuelcelltoday.com
[22] http://www.tokyo-gas.co.jp/techno/english/feature/
[23] http://enefield.eu/
[24] www.callux.net/
[25] The Fuel Cell Industry Review 2015
[26] http://www.telegraph.co.uk/finance/newsbysector/mediatechnologyandtelecoms/11818151/Revealed-the-first-hydrogen-powered-battery-that-will-charge-your-Apple-iPhone-for-a-week.html

C.
HYDROGEN APPLICATIONS

The transport sector or mobility applications are perhaps the most promising field in regard to the hydrogen technology application.

VEHICULAR OR MOBILITY APPLICATIONS

The transport sector or mobility applications are perhaps the most promising field in regard to the hydrogen technologies application. The transport sector is facing problems arising from the use of fossil fuels, such as energy dependence and geopolitical constraints, with large fluctuations in the barrel of oil price on the one hand and the environmental problems that they cause, for example the greenhouse effect, on the other. Therefore, the application of the electrical technology based on hydrogen fuel cells to this sector offers a tangible opportunity to achieve this requirement.

The majority of automotive manufacturers identify the use of hydrogen in fuel cells as the substitute for fossil oil in internal combustion engines, due to the multiple ways of generating hydrogen, its high performance using fuel cells and its zero emissions.

In 2014, a milestone was reached with the sale of the first mass production hydrogen vehicle. Hyundai, a pioneer in the hybrid vehicles market, offered the ix35 model based entirely on electrical propulsion powered by fuel cell for sale in Japan, the United States and some European countries, soon followed by Toyota. At the end of 2015, Honda also introduced Clarity Fuel Cell that, like Hyundai ix35 and Toyota Mirai, will be marketed in Japan, the United States and some European countries. However, there are other vehicle manufacturers such as General Motors, which was a pioneer with projects such as Driveaway Project in which 119 models of HydroGen 4 have been tested since 2007[27]. Nowadays, BMW, Mercedes, Volskwagen and Audi have announced the launch of their models based on fuel cell in the next few years.

[27] http://www.opel.es/acerca-de-opel/noticias-opel/2014/5/laflotapropulsada.html

The typical powers of this type of automotive batteries are around 100 kW rated power, which use PEM technology and are property of each one of the trademarks. Ballard, Hydrogenics and Symbio FC are the main manufacturers of automotive batteries in competition with the big brands of vehicles with their own developments.

Finally, one of the most promising niche markets in the field of mobile applications is the use of fuel cells for the propulsion of material handling vehicles. This application has experienced a boom in the last five years, mainly in the United States where large companies such as Coca-Cola Company or Wallmart[28] have a large fleet of forklifts powered by hydrogen fuel cells operating in industrial installations and large logistic warehouses. The main argument in favour of this application is the simplification of the recharging process, which allows it to be reduced to a few minutes, whilst also avoiding the need for battery duplicates, with the associated space requirements and protocols for waste management, thus resulting in an increase of productivity.

The typical powers of fuel cells for this type of application is between 5 and 8 kW, and hydrogen on-board deposits can be pressurized up to 350 bars. The main companies with a strong presence in this sector are Hydrogencis, Ballard and PlugPower.

[28] http://www.ballard.com/

C.
HYDROGEN APPLICATIONS

The main opportunities identified in the field of hydrogen applications and intended to be explored in the framework of the next Plan are the following:

- **Possibility of technological innovation and development projects with European funding that will transfer the technology created in Aragon to the companies of the sector.**

  The European funding through the Horizon 2020 programme, with initiatives such as FCH 2 JU with specific financing lines of hydrogen, establishes the possibility of carrying out programmes of technological development of products for market penetration that can assume the transfer of technology made in Aragon to interested companies in the sector.

- **Existence of niche markets for hydrogen technologies in the period 2016 to 2020.**

  In a first stage in the technology development, it is expected that the first niche markets are in the integration of fuel cells from stacks. FHa has extensive experience in this field of action through its involvement in specific projects and products intended for the current niche markets for hydrogen technologies such as forklifts, isolated systems, uninterruptible power supply (UPS), amongst others.

- **Promotion of demonstration projects of hydrogen and fuel cell technologies in Aragon.**

  Leading figures in the region have the option to promote demonstration projects in production technologies, including applications such as methanation or Power-to-Gas, or the hydrogen refuelling, given the infrastructure deployment expected in the framework of the European Directive on alternative fuels infrastructure.

C.
HYDROGEN APPLICATIONS

ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
1. PEM Stack development for applications in the transport sector and aeronautics	Development of PEM technology stacks conceptually new and optimisation of the systems that make up the power plant	HIGH	5 to 7 Development of prototypes for different applications of the transport sector	Participation of companies and research centres of Aragon in some project	Know-how established in the Aragonese industry
	Development of on-board new systems of power and control hybrids with high switching frequency and more efficient power converters	HIGH			
	Technology development at regional level	HIGH			

ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
2. Advanced characterisation methods of PEM batteries	Performance of tests of characterisation, operation, life cycle and degradation of PEM technology stacks/modules in specific weather and environmental conditions. Analysis and evaluation of results	HIGH	4 to 6 Development of a test bench to carry out the tests with the established protocol	Test Protocol fully established in, at least, one research centre of Aragon	Know-how spread to other actors in the sector in Aragon
	Post-mortem tests and characterisation of materials	HIGH			

ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
3. SOFC Batteries Development	To develop new materials and designs of SOFC which improve the present characteristics	HIGH	3-4 to 7	SOFC Stack Field Test	1 product into market
	To manufacture a portable SOFC stack using microtubular SOFC cells developed in Aragon: 10W - 200 W, H_2 or hydrocarbons (bioalcohols) as fuel, operation reversible to generate electricity or fuel	HIGH			
	Field tests of portable SOFC stack	HIGH			
	Identify niche applications for the portable SOFC stack	HIGH			

ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
4. 4. Power-to-Gas System Development	Participation in a project at national or European level of Power-to Gas systems based on the production of synthetic natural gas from renewable hydrogen and CO2 or H2 direct injection into the Natural Gas network up to a certain percentage	MEDIUM	4 to 7	Aragon participation in some Project	Feasibility study for a demonstrator in Aragon
	Techno-economic viability study of the implementation of Power-to-Gas systems in Spain	MEDIUM			

C.
HYDROGEN APPLICATIONS

ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
5. Hydrogen integration in isolated grids	Design, development and implementation of projects with hydrogen technologies in isolated networks fed by RES	HIGH	6 to 7	Start of a demonstrator in Aragon	Know-how established in the industrial fabric of Aragon
	Design and optimisation of power electronics and communications and control systems for the production of hydrogen in isolated networks from RES	HIGH			
	Seek opportunities of demonstrators in isolated networks where hydrogen can be somehow integrated, preferably in rural areas. Identification of possible locations /end users	HIGH			

ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
6. Niche applications	Identify niche applications where to apply hydrogen and search for interested end users	HIGH	N/A (wide variety of technologies)	2 products into market	5 products into market
	Technology development of applications to cover the niche markets in the short term	HIGH			
	Development of demonstration projects in the transport sector including vehicle fleets and hydrogen stations in the region	HIGH			

ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
7. Mobility Systems with hydrogen	Demonstration of FCEV commercial technology	HIGH	6 to 7	Participation in project	Demonstrator / Operational vehicles in Aragon

D.

TRANSFER OF TECHNOLOGY, PROTECTION AND ECONOMIC IMPACT

D.
TRANSFER OF TECHNOLOGY, PROTECTION AND ECONOMIC IMPACT

The hydrogen has being used as raw material in the chemical and oil industries, the main core of business today, in its industrial matrix, , with more than 700,000 million normal cubic metres (Nm3) (~60,000 kt) at the global level[29], representing an economic investment of around €50,000 million.

These figures linked, in its majority, to fuel and fertilizer production, are still a long way from the economic results that the use of hydrogen as an energy vector would have. Only 4 % of the hydrogen produced in the world is produced through water electrolysis processes, the technology established as a sustainable way of hydrogen production, and an even smaller percentage from electrolysis with energy from renewable sources, one of the lines of action and one of the main interests of development in the region.

Regardless of the industrial use of hydrogen, sustainable fuel is identified as an "energy vector" due to its versatility for its integration in different applications. Since the 1970s, following the oil crisis of that decade, its implementation as a transport fuel started to be researched in a very initial degree of development. In successive years and through research and development programmes mainly in North America, Japan and Europe, technology has been created for its use in various applications (see section 5c), highlighting its aforementioned use as a transport fuel and as a storage solution for large-scale energy in electricity networks for its subsequent use in stationary and portable applications, mainly through fuel cells to supply electricity and heat.

Nowadays, the resources invested in technology research and development in recent decades have allowed the process of technology transfer between research centres and universities to industry and business to begin. On the one hand, numerous success stories are presented at European level with companies like ITM (UK), Mc Phy (France) or IHT (Switzerland) giving solutions to hydrogen production. On the other hand, companies such as Ballard (Canada), Nedstack (Holland) and Hydrogenics (Germany) are supplying solutions in the fuel cell market. All of these entities have grown or have been based on partnerships and/or alliances from research centres and universities.

In Aragon, the rifts caused by the major financial crisis of recent years have not been alien to the production and services sectors. Thanks to policies aimed at the reindustrialization and strengthening of those sectors, an important opportunity has been detected in the field of research, technology development and innovation to improve competitiveness in the markets in which they are already present and an instrument by which to be able to position themselves in new forums. For this reason, a closer and more intense collaborative relationship between the academic and scientific fields and those of business and industrial development has been detected.

In the hydrogen sector, this same trend has been

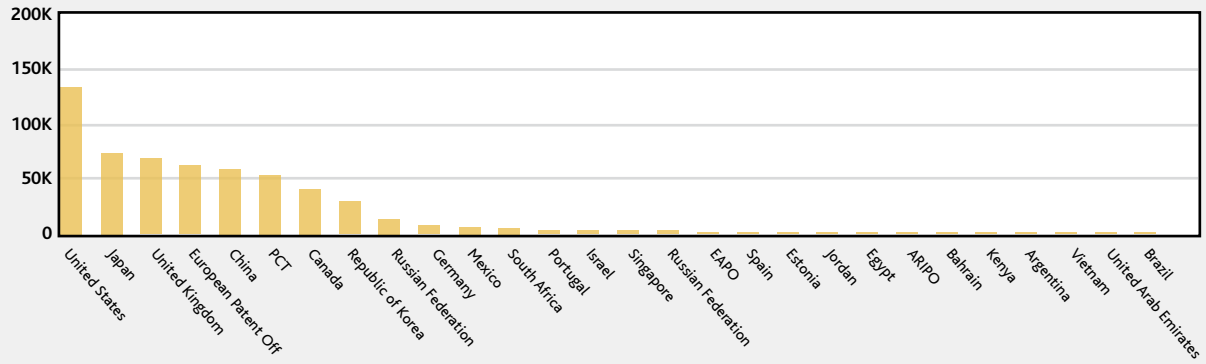
[29] M. Ball, M. Weeda, "The hydrogen economy e Vision or reality?", International Journal of Hydrogen Energy, Vol. 40, 7903-7919, Mayo 2015

D.
TRANSFER OF TECHNOLOGY, PROTECTION AND ECONOMIC IMPACT

observed, where important knowledge has been gained thanks to the major R&D activities carried out in the last decade, although there has not yet been a natural opportunity of being transferred to business and industrial sectors, due to the economic scenary mentioned above. For this reason, the transfer of technology is seen as one of the new challenges to Aragon in the hydrogen sector. In this Master Plan for the period 2016 to 2020, this circumstance has been identified and the Plan itself intends to continue, promote and enhance the channels and the necessary instruments to appraise the technological solutions developed in the field of R&D&I, focusing them on the market through a clear product orientation. The FHa, since its foundation in 2003, has sought to promote R&D initiatives in the region and presents itself as an instrument at the service of the Community to promote the transfer of technology in the field of hydrogen, acting as a catalyst for the interaction between the scientific and industrial sectors.

In this area, it is worth mentioning the importance of the protection of industrial property. In the world today, there are more than 500,000 patents related to hydrogen technologies in all areas. Most noteworthy is the patent production of countries such as the United States, Japan, Canada, the United Kingdom and China or the European Patent Office.

F.07 Patents in the field of hydrogen by countries.

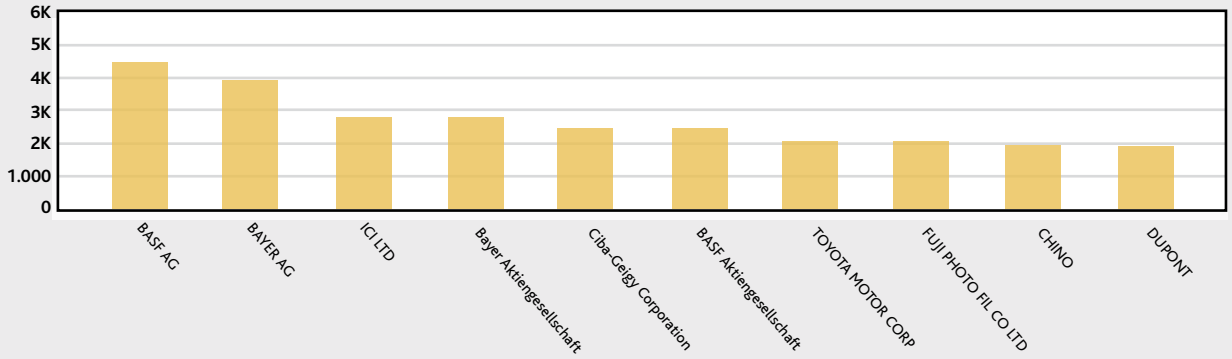


Source: World Intellectual Property Organization (WIPO), 2015

D.
TRANSFER OF TECHNOLOGY, PROTECTION AND ECONOMIC IMPACT

Patent generation is concentrated mainly in multinationals from the chemical sector and companies in the automotive sector such as Toyota, a company that, in 2015, released around 5,700 patents[30] on fuel cells and hydrogen technologies so as to promote the international development of the FCEV industry.

F.08 Patents in the hydrogen sector by companies



Source: World Intellectual Property Organization (WIPO), 2015

[30] http://corporatenews.pressroom.toyota.com/
[31] The Fuel Cell Industry Review 2015

With regard to the economic impact of the new applications of hydrogen technologies, the figures of infiltration into the market of fuel cell products should be highlighted. In 2014, 71,500 units of fuel cells were marketed in the world, for a total of 342.6 MW power installed during that year[31]. Similarly, the acceleration in the launch of fuel cell vehicles into the market, mainly by Toyota, Hyundai and Honda, should also be mentioned, as well as the installation of new hydrogen stations. These actions represent a direct economic impact in the range of thousands of millions of Euros and a remarkable economic impact in employment creation rates.

D.
TRANSFER OF TECHNOLOGY, PROTECTION AND ECONOMIC IMPACT

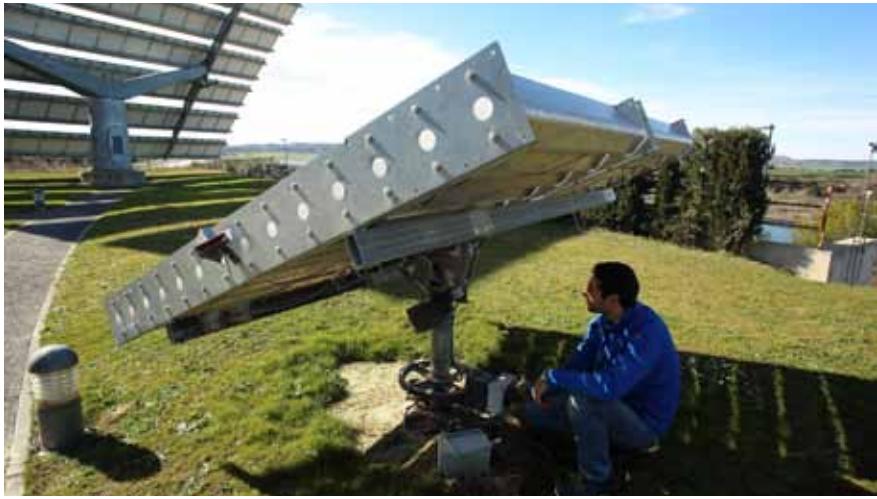
The main opportunities identified in the field of transfer of technology, protection and economic impact and intended to be explored in the framework of this Plan are the following:

- **Technology transversality and the possibility of application to other fields**

  The intention is to increase the presence of hydrogen technologies in the market by providing innovative, efficient and environmentally friendly solutions in sectors as diverse as transport, energy, industrial or residential. These sectors already have some regional leading figures which can benefit from the know-how developed in the FHa and other scientific and technological centres of the Community so as to receive a transfer of technology that generates economic activity, and by extension qualified employment creation and maintenance of population in the territory. In Aragon there is an important presence of intermediary agencies such as the sectoral federations or the sectoral clusters that can promote and facilitate the achievement of this important goal for the region.

- **Intrapreneurship and creation of Start-Ups or Spin-Offs to promote innovative projects**

  Hydrogen is presented as a disruptive technology in the market that represents an excellent environment for entrepreneurship and the creation of economic value and high qualification employment in the region. In the technology and scientific centres of the region, as well as in the University and in the agencies and bodies of the regional Public Administration, there is a human team with the potential to face up to the challenge of entrepreneurship in hydrogen technologies with full guarantees of success.



- **Opportunities in regional, national and European funding programmes**

  The European Union, mainly through its Member States and regions, as well as national initiatives, is throwing its weight behind supporting R&D&I tasks from the basic research stages to innovation and market dissemination of the technology developed as a key instrument for improving the competitiveness of its business and industrial fabric. In the case of national funding, regional programs specific to a sector or a specific activity, national support schemes through the National Research, Development and Innovation Plan, the Centre for the Development of Industrial Technology (CDTI) or the support the MINETUR provides through the Innovative Business Groupings (AEIs), have the clear purpose of promoting innovation among SMES in our country. All of them are clear indications of the drive to promote collaboration between the public and private sectors in order to increase innovative activity.

  In Europe this drive can be further seen, for example, in European programmes such as Horizon 2020 (H2020) that present specific actions –such as its tool INNOSUP- aimed at promoting definitively

the development of an ecosystem which is supportive to innovation in SMES. This great impulse for innovation in Europe is evident not only in the H2020 Programme with the existence of specific programme for its promotion, but also in the main European funding programmes of an environmental nature such as LIFE+ or transnational and cross-border cooperation as SUDOE or POCTEFA. These appreciate the innovative character which is required for the projects to be undertaken in order to meet its objectives from the European Commission.

In this regard, in view of the geographical situation of Aragon, in a special way, the France-Spain-Andorra Cross-border Cooperation Operational Programme (POCTEFA) provides a very interesting support framework that enables hydrogen framework cooperational projects with the south of France and Andorra, as well as with the neighbouring autonomous communities.

- **Regulations development**

  For the advance of technology and its placing on the market, the development of systems of standardisation, regulation and approval is of vital importance, as well as determining the precise legal and regulatory aspects to ensure the correct operation and safety of the user of the technology. These will be the channels and the tools to define the appropriate regulations on the use of hydrogen and its applications. Aragon, through the FHa, is very well positioned in the main standardisation committees in Spain (Committee AEN/CTN 181 of AENOR) and in Europe (hydrogen working group in the CENELEC).

D. TRANSFER OF TECHNOLOGY, PROTECTION AND ECONOMIC IMPACT

The attached table provides details of the actions planned for in the line of transfer of technology, protection and economic impact. As it has been pointed out previously, given the characteristics of this, the associated indicators are of completion and classification and the TRL have not been used.

ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
1. Hydrogen entrepreneurship strengthening	Impetus to start-ups and spin-offs	HIGH	No. of new companies created related to hydrogen technologies	1	3
	Search other funding mechanisms linked to this business creation	HIGH			
	Intrapreneurship	HIGH			

ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
2. Collaborative programmes in the industrial field	Pioneers into practice Programme (programme where the entrepreneur develops his/her ideas in practical environments in enterprises)	HIGH	No. of initiatives for companies related to hydrogen technologies	5	10
	Dissemination activities to search technology hunter	HIGH			
	Initiatives that allow companies to know the capabilities of the FHa and that at the same time the FHa to know the sensitivities of the companies.	HIGH			
	Gift to get bonus, where Aragonese entities of the H_2 sector promote technological development actions initially without costs to then get a common accord benefit from the results (for example: R&D&I funding programmes search)	HIGH			

ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
3. Diversification of the Aragonese companies, the sector of hydrogen	Transfer of technology from research centres to Aragonese companies,	HIGH	No. of companies that diversify and offer solutions with hydrogen	2	4
	Collaboration in the learning process	HIGH			
	Accompaniment until bringing the solution to the market	HIGH			

ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
4. Impetus to standardisation systems	Participation in AENOR committees	MEDIUM	N/A	N/A	N/A
	Participation in European and international level initiatives(For example: CENELEC)	MEDIUM			

ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
5. Economic impact study of hydrogen technologies in the region	Economic impact studies of hydrogen technologies in Aragon in the framework of the milestones review of the Master Plan 2016 - 2020 in its halfway point and after its conclusion (2018 and 2020)	MEDIUM	N/A	Economic impact study of hydrogen in Aragon - 2018	Economic impact study of hydrogen in Aragon - 2018

E.

TRAINING AND AWARENESS

E.
TRAINING AND AWARENESS

Currently, training and awareness in hydrogen and fuel cells matters are carried out, either through one's own initiative or through specific programme proposals, such as those of the FCH 2 JU, carried out by research centres, universities and companies specialized in the sector, which are also stimulating the high level of technological development that these technologies are experiencing.

Didactic room.

Related to training, it is worth mentioning the significant disparities that exist in terms of geographic location. Overall, the training offer is situated mainly in Europe, the USA and Japan. Many of these offers are focused on generic and general concepts with the aim of disseminating knowledge of hydrogen technologies. In addition, there are more specific courses focusing on specific aspects of the hydrogen economy such as product certification through regulations, safety in the handling and use of hydrogen or fuel cells integration.

The training offered in Spain is a purely technical one linked above all to programmes focused on renewable energy, with courses for experts, academics and third cycle university education training, i.e. own degrees, master degrees and doctorate programmes amongst those that particularly stand out. At present, courses for experts are those that present greater demand, mainly due to the extent of audience to whom they are addressed. The objective of this specialization is mainly carried out through master programmes focused on renewable energy, in which there are specific subjects hydrogen technologies, in particular the master degree of the International University Meléndez Pelayo (UIMP) with a large number of subjects focusing on hydrogen and batteries, conducted in collaboration with the Spanish National Research Council (CSIC). It is important to mention that Vocational Training Centres already exist, such as the Integrated Public Centre of Vocational Training Pirámide, CPIFP Pirámide (Huesca), which are starting to provide visibility to the contents related with the hydrogen and fuel cell technologies, as referred to in the academic curricula established by Royal Decree.

In Aragon, the FHa, aware of the importance for any new technology to have good technical support in all links of its value chain, opted for the implementation of activities in this field and today it is a key agent in the delivery of training in these technologies, having established an important partnership with SEAS Estudios Abiertos, which belongs to Grupo San Valero, a leader centre in 100% on-line training in Spanish language. The result of this strategic alliance is that training courses are offered for both the general public and for a more specialized audience through its master programmes in renewable energy with specific subjects on hydrogen.

E.
TRAINING AND AWARENESS

The interest in the training aspects of hydrogen is reflected in the European Union scope through the document *Strategic Energy Technology (SET) Plan Roadmap on Education and Training* developed by the European Commission. This plan establishes the educational actions that must be carried out with the aim of enhancing technologies with low carbon emissions, specifically hydrogen technologies, amongst others. Specifically, actions included are the development and empowerment of relevant educational curricula in the field of hydrogen and the establishment of modules (subjects) on hydrogen in vocational training centres.

With regard to awareness raising of hydrogen technology, the idea which the actions carried out support is to show the general public the strengths and advantages of hydrogen and fuel cell technologies and their potential in the most conducive and appropriate sectors, as well as the elimination of social ill-founded perceptions and the eradication of a series of barriers, neither technical nor economic, which technology is forced to overcome to be incorporated into our daily lives. Given the importance of these aspects, there are also institutional support and funding lines in this field to increase the knowledge of the hydrogen economy. Globally, the key purpose of institutions such as *The International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE)* and the International Energy Agency in the section of hydrogen (IEA-HIA) is the promotion of all technologies through the incorporation of awareness and dissemination activities. Therefore, all these activities that both institutions develop carry associated awareness work, focused on increasing awareness and bringing knowledge to the society. In the USA, it is the Department of Energy (DoE) and various national research laboratories that have established national alliances along with private companies in various sectors, formalising the so-called H2USA. This alliance reflects the efforts by all the participating entities to promote and publicise hydrogen technologies, and in particular those related to transport.

SEAS headquarters.

Other associations that have a strong national awareness activity are the Hydrogen Energy Systems Society (HESS) that operates in Japan, the Australian Association of Hydrogen Energy (AHEE) or the Korean Hydrogen and New Energy Society (KHNFS) with activity in the Republic of Korea.

Activities aimed at raising awareness in Europe are driven by a large number of institutions at the international level such as the FCH JU and HyER. In Spain, it is worth mentioning the Spanish Hydrogen Association (AeH_2), the Spanish Fuel Cell Association (APPICE), the Spanish Hydrogen and Fuel Cell Platform (PTE-HPC), the National Hydrogen Centre (CNH_2) and the FHa as the most active. To enhance the knowledge and awareness surrounding hydrogen technologies on the part of society, the FHa has coordinated and continues to participate very actively in specific European projects to that end, such as Hyproffesionals, KnowHy, Hy4All or NetVET-RE.

KnowHy project meeting.

E.
TRAINING AND AWARENESS

The main opportunities identified in the field of training and awareness and that are intended to be explored in the framework of the next Plan are the following:

- **Raising awareness and implementing training to companies during the phase of deployment of hydrogen technologies.**

  During the next few years, as a result of the deployment in the market of hydrogen technologies, it is expected the execution of demonstration projects that would enable to address the growing business interest in technology in the early stages, in line with the objectives of the European Union, Spain and Aragon. This will, evidently, require efforts for the implementation of training activities, at first glance, to professionals related to the sectors likely to have presence in hydrogen technologies. In a second phase or in parallel, it will be necessary to bring the technology to the end users with greater efforts than at present.

- **Awareness of the Aragonese society through the dissemination and communication of the activities and demonstration projects developed.**

  This opportunity is again linked to the implementation of demonstration projects in the region, where dissemination and communication actions related to hydrogen technologies will be considered in all proceedings to be implemented and through the development of specific communication plans linked to each project.

- **Institutional, business and Aragonese society support during the period 2016 - 2020 defined through this Master Plan.**

  Since the birth of the FHa in 2003, the Community has at its disposal the Hydrogen Master Plan in Aragon, via this entity with a Board composed of public institutions, private companies and social leading figures of relevance that support the development of hydrogen technologies in Aragon and that participate in the development of a roadmap for the regional development of the technology.

- **Development of a national strategy for the implementation of alternative energy vehicles through the MINETUR.**

  As discussed previously, Spain, through the MINETUR, has included hydrogen technologies in the Framework for Action to meet the transposition of the European Directive 2014/94. This milestone will bring the technologies of fuel cell vehicles and hydrogen fuelling stations or hydrogen stations to society and integrate them into the everyday life of its environment.

- **Plans for funding training and awareness projects in the framework of the FCH 2 JU.**

  The FCH 2 JU, through its cross-cutting pillar, supports at European level the thematic of training and awareness of the society and the development of policy, legislative and regulatory frameworks for hydrogen technologies through funding instruments in calls for public competition, which facilitates the development of these collaborative projects.

- **Celebration in Zaragoza of the Hydrogen World Congress in June 2016 (WHEC 2016, World Hydrogen Energy Conference).**

  Since 1974, and on a biennial basis, the World Hydrogen Congress is celebrated, an unmissable and reference event for professionals in the sector. In 2016 the Spanish Hydrogen Association (AeH2), with the collaboration of the Government of Aragon and the FHa, is organising the twenty-first edition of the Congress in the city of Zaragoza. This

event, in which more than 1,200 professionals are expected to participate, will position the principal figures of the region in the hydrogen sector at international and world level.

- **Presence of Aragonese business organisations in the Board of the FHa.**

  The collaboration with these Aragonese entities, either through its membership as members of the Board or through collaborative relationships, promotes the establishment of suitable channels for the dissemination of information activities specific to the nature of the relationship to the companies, the development of feasibility and market studies and the transfer of technology.

FHa didactic room.

E.
TRAINING AND AWARENESS

The attached table provides details of the actions planned in the line of training and awareness in hydrogen technologies. As pointed out previously, given the characteristics of this matter, the associated indicators are of implementation and for that reason classification through the TRL have not been used.

ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
1. Studies on social perception and technology dissemination effectiveness	Perception and social acceptance study for companies	HIGH	Degree of acceptance	Hydrogen technologies are known by at least 50% of SMES in the region	Hydrogen technologies are known and accepted by at least 70% of SMES in the region
	Perception and social acceptance studies for society in general	HIGH	Degree of acceptance	Hydrogen technologies are known by at least 20% of the population of the region	Hydrogen technologies are known and accepted by at least 40% of the population of the region

ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
2. Actions within the WHEC 2016	Competition of ideas on hydrogen and fuel cells technology innovation	MEDIUM	No. of participants	5	NA
	Development of activities in the framework of the "Emprender en la Escuela" Programme	MEDIUM	No. of participants	5	NA
	Demonstration of practical applications close to society presented in the WHEC 2016	MEDIUM	No. of participants	5	NA
	Development of technical visits to projects and entities related with hydrogen in the region	MEDIUM	No. of participants	3	NA

ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
3. Training targeted to hydrogen technologies	Introduction to the entrepreneurship concept	HIGH	No. of entrepreneurs who join entrepreneurship programmes related to hydrogen technologies in Aragon	5	10
	Training actions in hydrogen technologies integrated in the formal education curriculum	HIGH	No. of training actions	3	5
	Development of courses to train the industrial sector and the teachers in hydrogen technologies	HIGH	No. of in-service courses	5	7
	Expansion of the commercial training developed in Aragon to the international market	HIGH	No. of students	50	200
	Inclusion of hydrogen technology in the industrial doctorate programmes	HIGH	No. of doctorate programmes	-	2

06.

MONITORING

06. MONITORING

The Hydrogen Master Plan 2016-2020 monitoring system constitutes a valuable tool to analyse the fulfilment of the proposed objectives. It is, in summary, a key element to learn about its evolution. The definition and implementation of a monitoring system for this Plan has a twofold purpose:

a.) To analyse the effectiveness of the proposed actions and their degree of progress in the Plan time scale.

b.) To establish a monitoring protocol for the FHa's own management structure to enable analysis on a regular basis with the fulfilment of the proposed objectives.

The proposed classification is based on the SMART methodology, an acronym for: Specific, Measurable, Achievable, Relevant, Timely. To do this, the indicators proposed in the Master Plan 2016 – 2020, and which complement the work done in previous plans, are the following:

A.) Monitoring indicators.

B.) Outcome indicators.

C.) Governance/management indicators.

A.) MONITORING INDICATORS

The monitoring indicators proposed aim to analyse the effectiveness in the implementation of activities associated with hydrogen as well as of the actions planned in the Master Plan, allowing the dissemination of hydrogen associated technologies and interventions to be assessed. Two types of monitoring indicators are established:

1. Annual global monitoring indicators that establish in a general way the development of activities in the region linked to hydrogen.

2. Specific monitoring indicators related to lines of work proposed in the Plan. Given the nature of the proposed measures, its monitoring has been established in two periods of the Plan: 2018 and 2020.

a.1. Global monitoring indicators

These indicators expect to analyse the number of performances, human resources and economic activity linked to hydrogen in the region. Its monitoring is expected on an annual basis.

Indicators	Periodicity	Source
No. of funded projects related to hydrogen in Aragon	Annual	Government of Aragon / National Ministries/European Commission
No. of theses in the field of hydrogen	Annual	University of Zaragoza
No. of people trained in hydrogen technologies	Annual	FHa
No. of companies involved in hydrogen technologies	Annual	FHa
No. of professionals dedicated to hydrogen technologies in Aragon	Annual	FHa

a.2. Monitoring indicators by lines of work

In regard to the planned lines of work, the present Master Plan proposes a results-oriented step forward. To do this, it establishes a monitoring system of the actions and activities proposed in two specific periods (2018 and 2020). In order to do that, at those times an analysis of compliance with the proposed milestones for each action will be carried out, evaluating corrective measures or enforcement in the case of underachievement.

06. MONITORING

B.) OUTCOME INDICATORS

Outcome indicators measure the effects caused by the implementation of the Master Plan and its measurement both in monetary terms as through the return obtained. For this purpose, the Plan establishes monitoring at the halfway point and another at the end of its application (biannual).

Indicators	Periodicity	Source
Global investment carried out in hydrogen technologies in Aragon	Biannual	Government of Aragon/National Ministries / European Commission
Overall return obtained in public calls (regional, national and European) in specific projects on hydrogen and fuel cells	Biannual	Government of Aragon/National ministries/European Commission/FHa
Return obtained by companies in public calls (regional, national and European) in specific projects on hydrogen and fuel cells	Biannual	Government of Aragon/National ministries/European Commission/FHa

C.) MANAGEMENT INDICATORS

Management indicators measure globally the performance of coordination activities carried out by the FHa to its members, as well as the level of implementation of the action lines proposed in the Plan in a global way (in this case, without assessing the effectiveness of its implementation that will be the subject of analysis with the previous indicators). An indicator that allows citizens' knowledge on the activities carried out in the region in the field of hydrogen to be measured on a regular basis has also been incorporated.

Indicators	Periodicity	Source
Number of monitoring meetings with the members	Annual	FHa
Number of proposals submitted by the Foundation in the framework of international programmes	Annual	FHa
Number of collaboration agreements with other associations/entities for the development of joint projects	Annual	FHa
Proceedings in progress in respect of total per action line	Annual	FHa
Completed proceedings in respect of the total per action line	Annual	FHa
Proceedings planned to start in the next 12 months	Annual	FHa
Degree of knowledge of the FHa proceedings by part of the citizenship	Biannual	FHa (survey system)

To ensure the effectiveness of implementation of the monitoring system proposed, in the first Master Plan phase of implementation, the proposed indicators will be quantified so that a subsequent measurement of the results achieved can be established on a regular basis.

Additionally, in this new Plan the development of periodic evaluations has been proposed to assess the degree of progress of the proceedings. For the evaluation system, an external model has been planned in two milestones: a mid-term evaluation of the Plan (intermediate) and at the end of the period of implementation of the Plan (final evaluation).

In both types of evaluation, qualitative and participatory tools that complement the quantitative analysis of the proposed monitoring system, such as work groups and online questionnaires, will be applied. The body responsible for the application of this work will be the FHa.

07.

CONCLUSIONS

07. CONCLUSIONS

- **The hydrogen sector is facing new challenges in the period of validity of the new Master Plan 2016 - 2020, with the initial stage of the deployment of the technology.**

  The R&D&I activities at an international level favour the introduction of hydrogen and fuel cell technologies in niche markets for certain applications and the beginning of the development of an infrastructure of hydrogen fuelling stations as fuel for the automotive industry. This fact has not gone unnoticed in Europe, which aims to promote the development of an infrastructure within the European Directive 2014/94 relating to the implementation of an alternative fuel infrastructure. The penetration of hydrogen into the fuel supply networks will be accompanied by some market requirements of hydrogen production systems and transport, storage and distribution solutions.

- **Hydrogen technologies have significant support for their development at European level through the Fuel Cells and Hydrogen Joint Undertaking Programme, which supports the hydrogen and fuel cells technologies with a budget of €1.33 billion for the period 2014 to 2020.**

  In Spain, hydrogen technologies are also widely recognized and accepted as a tool with great potential to achieve the objectives of sustainability in the energy and transport sectors, as reflected in documents such as the National Renewable Energy Action Plan (NREAP) 2011 - 2020 or with the intention of the Ministry of Industry, Energy and Tourism (MINETUR), to transpose the European Directive 2014/94 relating to the implementation of an infrastructure for alternative fuels through its Alternative Fuel Vehicles (AFV) Strategy. This strategy includes hydrogen as one of the sustainable fuels to be considered. The drive for these technologies by MINETUR is evident because the transposition of the Directive to Member States with regard to hydrogen was optional and not compulsory.

  This strategy began to be exploited through the MOVEA Plan, which promotes the acquisition of alternative fuel vehicles. At the regional level, support for the development of hydrogen technologies in Aragon has been a reality since the beginning of the century, with the birth of the Foundation for the Development of New Hydrogen Technologies in Aragon and the inclusion of hydrogen in strategic plans as the Aragon Research and Innovation Strategy for Smart Specialisation RIS3 Aragon, the Energy Plan of Aragon (PLEAR 2013 - 2020) or the Aragon Spatial Strategy.

- **The results from the previous Master Plan 2011 to 2015 show that the region has been positioned in the main focus of the research, development and innovation activity (R&D&I) in Europe, the FCH 2 JU, participating in 6 projects, as well as in other forums of the sector in Europe and Spain.**

  Aragon also has been very active in the field of training and raising awareness during the period. The overall results of the period 2011 - 2015 are 96 funded projects related to hydrogen technologies in Aragon, 8 directed theses, more than 180 people trained and 250 professionals dedicated in the sector, with an economic activity in the period of €6 million.

- **The new Master Plan 2016 - 2020 is structured into five lines of work: production; storage, transport and distribution; applications; transfer of technology, protection and economic impact; and training and raising awareness.**

  With regard to the previous Master Plan 2011 – 2015, the different actions of hydrogen production are included in a single line, in the same way as applications with hydrogen and fuel cells, the section of raising awareness and training is strengthened with a specific line and a new line for technology transfer is created.

This approach is presented with the aim of facing the latest challenges, which the new Master Plan 2016 – 2020 is going to be developed to address, with the following noteworthy objectives:

• To strengthen R&D&I actions the regional level, with the FHa acting as a catalyst and developer of research and development activities together with Aragonese universities and technological centres.

• To promote transfer of technology between scientific centres and industry to generate value based on the R&D&I results.

• To participate in the development of the new hydrogen fuelling infrastructure in Europe.

• To continue raising awareness about the benefits of hydrogen technologies in the Aragonese Society in aspects such as environmental sustainability.

• To train Aragonese future technicians in the sector in the operation and maintenance of hydrogen and fuel cells systems.

- **The Hydrogen Master Plan 2016 - 2020 comes with an approach clearly geared toward the achievement of results.**

  To do this, the specific objectives of each action line and the general development objectives are assigned to milestones of achievement to be reviewed in the mid-term of the implementation period of the Master Plan, in 2018, and after its completion in 2020.

- **Finally, it should be noted during the start-up period of this Plan, the World Hydrogen Congress (World Hydrogen Energy Conference WHEC 2016) will be held from 13 to 16 June 2016 in Zaragoza, which is a reflection of the positioning of Aragon in this matter.**

  The Congress represents a great international opportunity to bring together the leading figures of hydrogen and fuel cell technologies and it is an unmissable event for professionals in the sector.

08.

ACKNOWLEDGMENTS

08.
ACKNOWLEDGMENTS

Once again, the **Hydrogen Foundation in Aragon** wishes to express its appreciation to all those who have contributed to the review and preparation of the new **Aragon Hydrogen Master Plan 2016-2020.**

The Foundation also wants to express its gratitude to all the work group participants summoned, to the effect that, thanks to their knowledge and dedication, the updating and adaptation of the strategic lines of work and planned interventions have been made possible. It equally wants to extend its thanks to all the Board Members for their support during the path started by the Foundation in 2003.

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AeH2:	Spanish Hydrogen Association.
AENOR:	Spanish Association for Standardisation and Certification.
AAHE:	Australian Association for Hydrogen Energy.
ALINNE:	Alliance for Energy Research and Innovation.
APPICE:	Spanish Fuel Cell Association.
UAV:	Unmanned Aerial Vehicle.
EC:	European Commission.
CEF:	Connecting Europe Facility.
CENELEC:	Comité Européen de Normalisation Electrotechnique.
CH4:	Methane.
CIRCE:	Energy Resources and Consumptions Research Centre.
CNH2:	National Hydrogen Centre.
CO:	Carbon Monoxide.
CO_2:	Carbon Dioxide.
CPIFP- Pirámide:	Integrated Public Center of Vocational Training Pirámide.
CSIC:	Spanish National Research Council.
DMFC:	Direct Methanol Fuel Cell.
DoE:	Department of Energy.
EEA Grants:	European Economic Area Grants.
EERR:	Energías Renovables.
EHEC:	European Hydrogen Energy Conference.
ELYGRID:	(Project) Improvements to Integrate High Pressure Alkaline Electrolysers for Electricity/H2 Production from Renewable energy to Balance the Grid.

ELYntegration:	(Project) Grid Integrated Multi Megawatt High Pressure Alkaline Electrolysers for Energy Applications.
FHa:	Foundation for the Development of New Hydrogen Technologies in Aragon.
FCH JU:	Fuel Cell and Hydrogen Joint Undertaking.
FCH 2 JU:	Fuel Cell and Hydrogen Joint Undertaking 2.
ERDF :	European Regional Development Fund.
FluMaBack:	(Project) Fluid Management component improvement for Back up fuel cell systems.
ESF:	European Social Fund.
GHG:	Greenhouse Gas.
LPG:	Liquefied Petroleum Gas.
CNG:	Compressed Natural Gas.
LNG:	Liquefied Natural Gas.
HESS:	Hydrogen Energy Systems Society.
HFP:	European Hydrogen and Fuel Cell Technology Platform.
HIA:	Hydrogen Implementing Agreement.
HRS:	Hydrogen Refueling Station.
Hy4All:	(Project) Hydrogen for all of Europe.
HyER:	European Association for Hydrogen and fuel cells and Electro-mobility in European Regions.
HyUnder:	(Project) Assessment of the potential, the actors and relevant business cases for large scale and seasonal storage of renewable electricity by hydrogen underground storage in Europe.
KHNFS:	Korean Hydrogen and New Energy Society.
R&D:	Research and Development.
R&D&I:	Research, Development and Innovation.
I3A:	Aragón Institute of Engineering Research.

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IBERCONAPPICE:	Ibero-American Conference on Hydrogen and Fuel Cells.
IEA:	International Energy Agency.
INYCOM:	Instrumentación y Componentes.
IPHE :	International Partnership for Hydrogen and Fuel Cells in the Economy.
JTI:	Joint Technology Initiatives.
KnowHy:	(Project) Improving the Knowledge in Hydrogen and Fuel Cell Technology for Technicians and Workers.
LIFE+:	Financial Instrument for the Environment.
LIFTEC:	Laboratory of Research in Fluid Dynamics and Combustion Technologies.
LOHC:	Liquid Organic Hydrogen Carriers.
HyRaMP:	European Regions and Municipalities. Partnership for Hydrogen and Fuel Cells.
HyUnder:	Assessment of the potential, the actors and relevant business cases for large scale and seasonal storage of renewable electricity by hydrogen underground storage in Europe.
MAIPU:	Multi - Annual Implementation Plan.
MCFC:	Molten Carbonate Fuel Cell.
MINETUR:	Ministry of Industry, Energy and Tourism.
MOVEA Plan:	Plan for promoting mobility with Alternative Fuel Vehicles.
NEW-IG:	New Energy World Industrial Grouping.
N.ERGHY:	New European Research Grouping for Hydrogen and Fuel Cells.
N_2:	Nitrogen.
ESEP:	Energy Savings and Efficiency Action Plan.
PAFC:	Phosphoric Acid Fuel Cell.
PANER:	National Action Plan on Renewable Energy (Spain).
PEM:	Proton Exchange Membrane fuel cell.

REP:	Renewable Energy Plan.
PLEAR:	Energy Plan of Aragon.
PTEHPC:	Spanish Hydrogen and Fuel Cell Platform.
PtG:	Power to Gas.
SME:	Small and Medium Enterprise.
POCTEFA	France-Spain-Andorra Cross-border Cooperation Operational Programme.
RIS3 Aragón:	Aragón Research and Innovation Strategy for Smart Specialisation.
SAI:	Sistemas de Alimentación Ininterrumpida.
SET:	Strategic Energy Technology.
SHFCA:	Scottish Hydrogen and Fuel Cells Association.
SOFC:	Solid Oxide Fuel Cell.
TRL:	Technology Readiness Level- Nivel de Madurez Tecnológica.
EU:	European Union.
AFV:	Alternative Fuel Vehicle.
WHEC:	World Hydrogen Energy Conference.

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