Fuel Cell and Hydrogen Technological Challenges: Future opportunity

Jesús Javier Martín Pérez
National Hydrogen Center

www.cnh2.es

Hydrogen as storage vector for Energy Storage, Brainstorming Workshop on 14th June 2017 Perpignan

INDEX

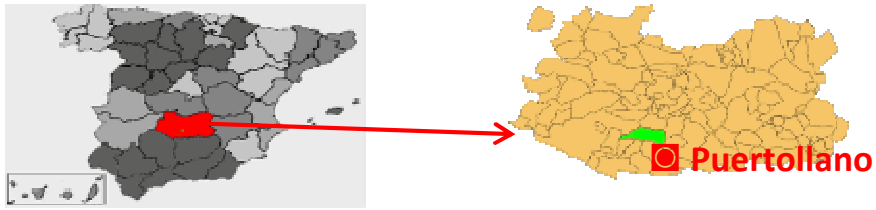
Centro Nacional del Hidrógeno

www.cnh2.es

National Hydrogen Center (CNH2)

- **Public Research Organization** founded as a Consortium by the Spanish Ministry of Economy, Industry and Competitiveness and the Castilla La Mancha region, 50/50.

Its headquarters are established in:



- Oriented to the development of all types of technology related with hydrogen and fuel cells (laboratories, test benches, experimentation stations, fuel cells, storage systems, engineering, safety, standardization…). The objectives are:

- To perform research, experimentation and validation of prototypes and devices.
- To develop and scale up processes.
- To homologate, certify and verify components and systems.
- To foster hydrogen and fuel cell technologies at Spanish and international level.
- To grant the access of scientists and private companies to their equipment and facilities.
- To be the main link between different research centers and private companies in the scope of hydrogen and fuel cells.
- To promote and boost the use of the technologies by conducting social perception studies, dissemination and educational activities focused on applications.

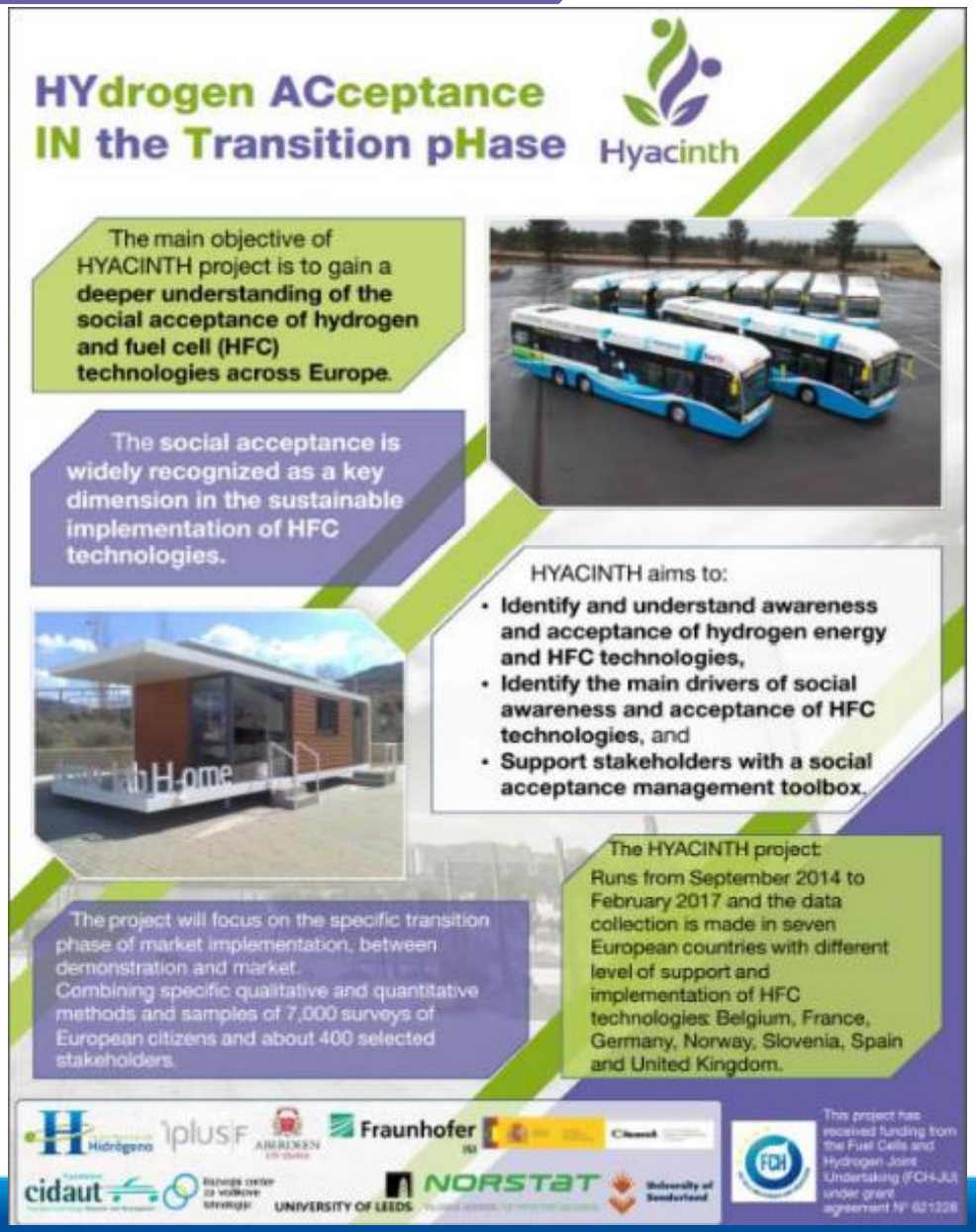
GOBIERNO DE ESPAÑA · MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD · UNIÓN EUROPEA · "Una manera de hacer Europa" · Castilla-La Mancha

INDEX

THE HYACINTH PROJECT

CONTEXT:

- Among the ***alternative technologies to generate low-carbon heat and electricity*** and to replace fossil-fuel based vehicles, residential fuel cells (micro-CHP) and hydrogen fuel cell vehicles (FCEV) ***are receiving support towards commercialization in many countries***.
- It is assumed that both applications ***have mass-market potential*** and will have a ***significant impact on reducing emissions and primary energy consumption*** (Ammermann et al., 2015).
- ***Public and consumer acceptance will likely play a role in the successful adoption*** of hydrogen and fuel cell ***applications***.



Centro Nacional del Hidrógeno

HYACINTH PROJECT DETAILS

www.cnh2.es

DESIGN METHODS

Studies:

1. Public awareness and acceptance of FCH technologies across Europe.
2. Stakeholder acceptance of FCH technologies across Europe

Toolbox:

To help promoters and decision makers integrate issues related to social acceptance into their developments

HYACINTH project

PUBLIC
Public awareness and acceptance of FCH technologies across Europe:

STAKEHOLDERS
Stakeholder acceptance of FCH technologies across Europe:

Survey
1000 participants
7 European countries

Survey
333 participants
5 European countries

Semi-structured interviews
145 participants
5 European countries

Social Acceptance Management Toolbox (SAMT):
To help promoters and decision makers integrate issues related to social acceptance into their developments

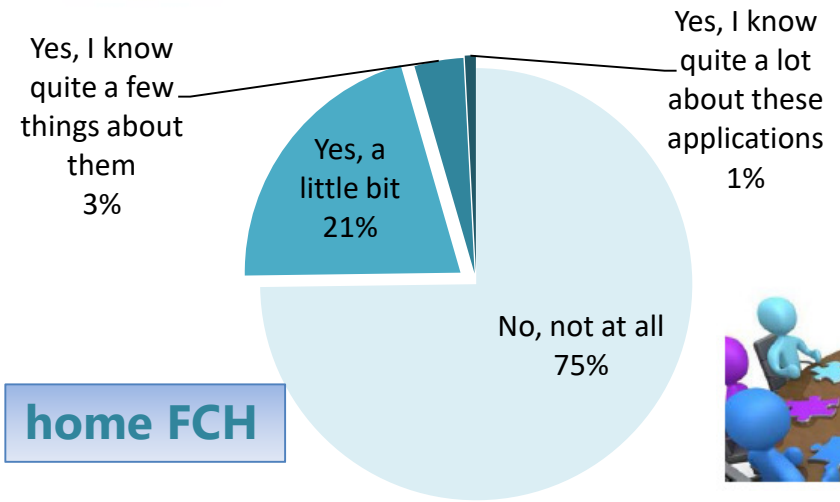
This project has received funding from the Fuel Cells and Hydrogen Joint Undertaking (FCH-JU) under grant agreement Nº 621228

Centro Nacional del Hidrógeno

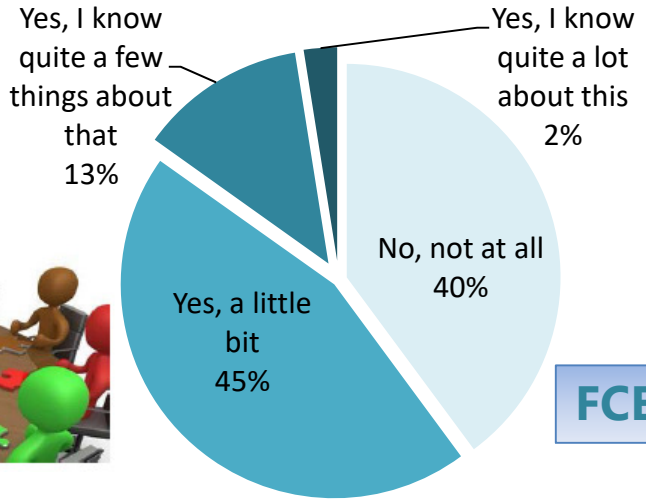
PUBLIC SURVEY- RESULTS:
AWARENESS OF HOME FUEL CELLS & FCEVS

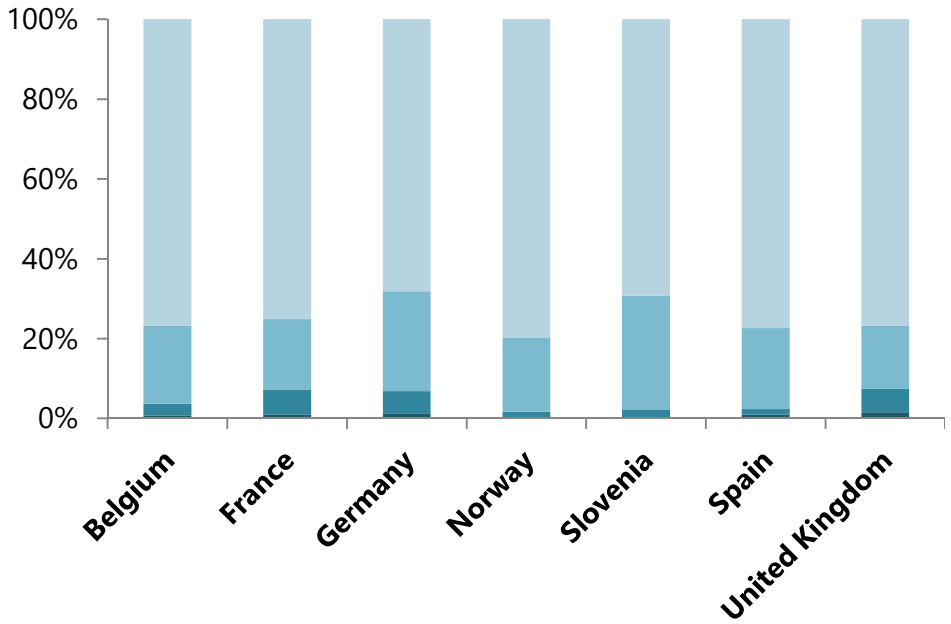
www.cnh2.es

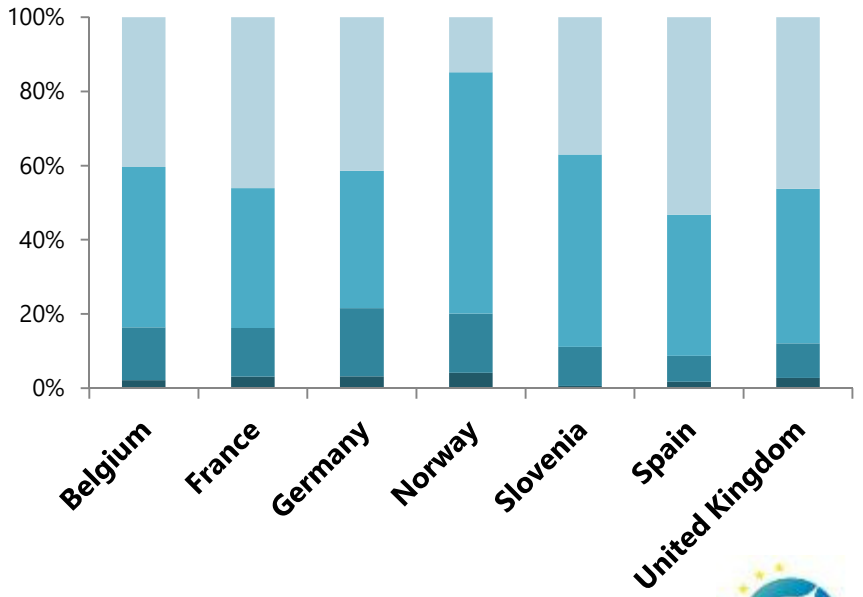
home FCH



FCEV







This project has received funding from the Fuel Cells and Hydrogen Joint Undertaking (FCH-JU) under grant agreement Nº 621228

Centro Nacional del Hidrógeno

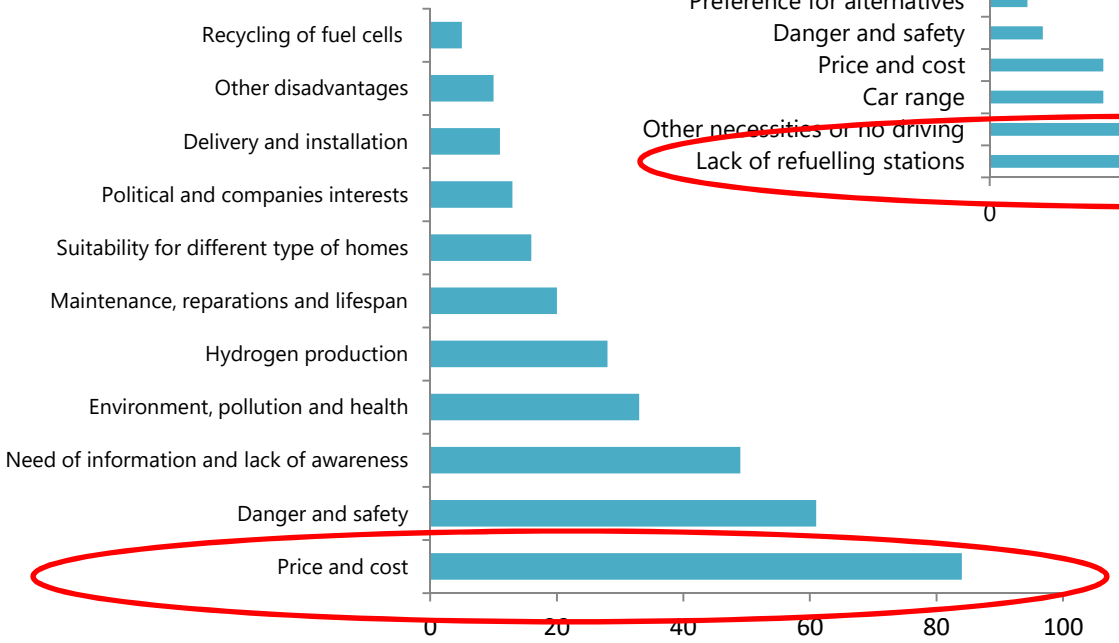
www.cnh2.es

PUBLIC SURVEY- RESULTS:

RESPONDENTS' REASONS FOR NOT WILLING TO BUY A HOME FCH & FCEV

Hyacinth

home FCH

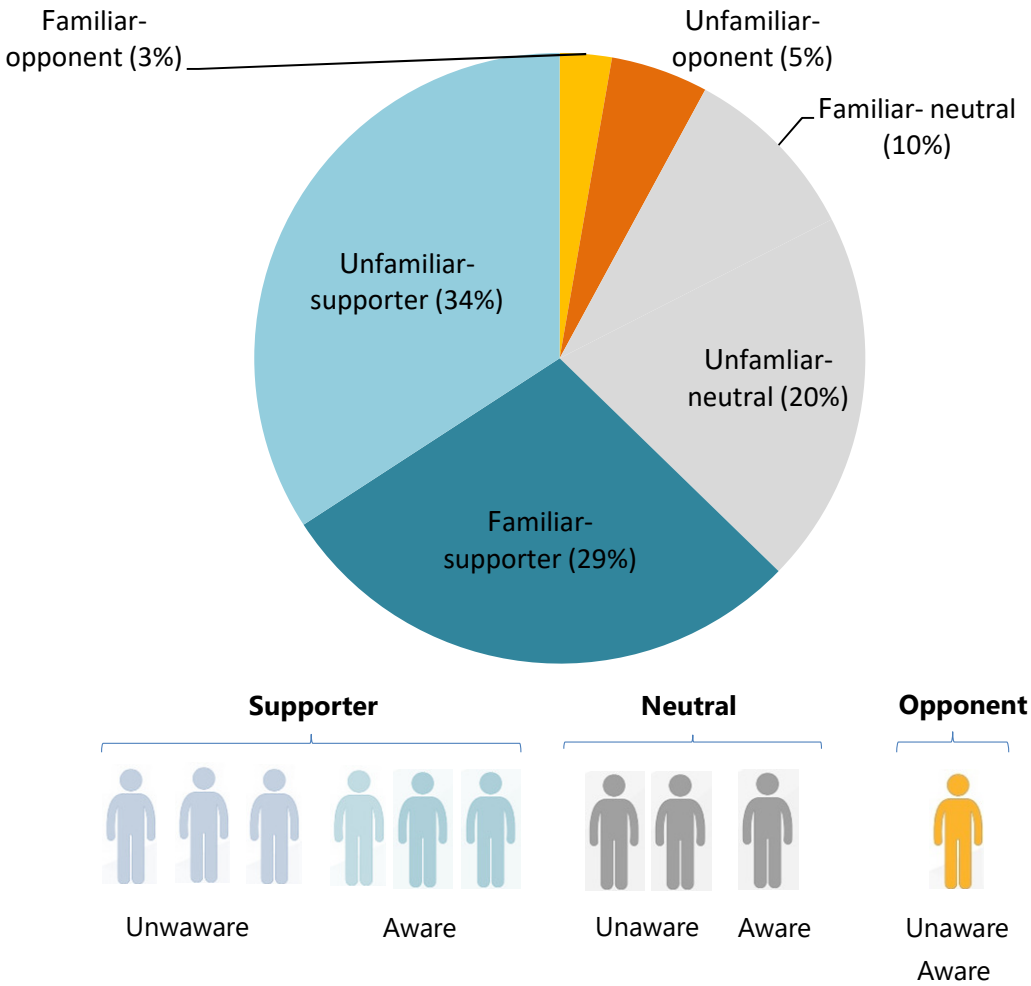


FCEV

This project has received funding from the Fuel Cells and Hydrogen Joint Undertaking (FCH-JU) under grant agreement Nº 621228

www.cnh2.es

PUBLIC SURVEY- RESULTS:
SUPPORTERS AND OPPONENTS (ALL COUNTRIES, BOTH APPLICATIONS)

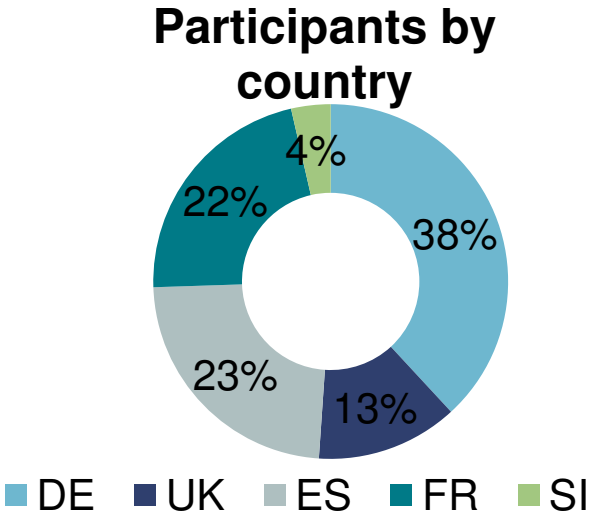


This project has received funding from the Fuel Cells and Hydrogen Joint Undertaking (FCH-JU) under grant agreement Nº 621228

STAKEHOLDER SURVEY- METHOD AND RESULTS

www.cnh2.es

- **Survey content**:
  - Innovation systems rationale: successful technologies require stakeholder alignment
  - Stakeholder perceptions of hydrogen technologies
  - In-depth evaluation of either
    - Small static hydrogen fuel cell applications
    - Hydrogen fuel cell electric vehicles (FCEVs)
  - Perception of other actors in the innovation system
  - Factors influencing future market development



- **Questionnaire survey** during **spring 2016**
- Population: **selected stakeholders** in **5 countries**
- Implementation: **Online questionnaire** (by Norstat)

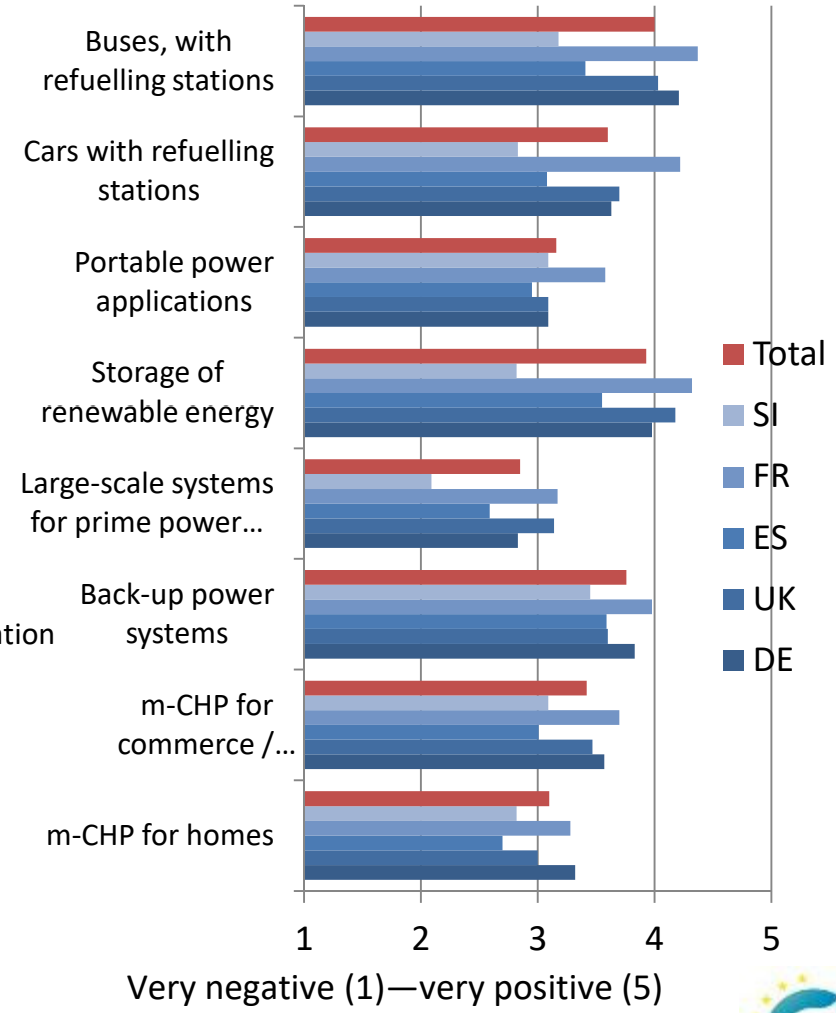
This project has received funding from the Fuel Cells and Hydrogen Joint Undertaking (FCH-JU) under grant agreement Nº 621228

STAKEHOLDER SURVEY- METHOD AND RESULTS

www.cnh2.es

- 88 % think that FCH are a good or a very good solution for energy and environmental challenges (no country differences)
- Most positive future expectations about H2-buses and H2 as a means of storage for renewable energy
- Respondents are in favour to further governmental support for FCH technologies.

What are your expectations regarding the medium-term (5-10 years) market implementation in your country?



- Heterogeneous affiliations:
  - Around **33% from private companies** (49% FR and 67% SL)
  - Around 15% from public and government organisations, education and other non-profit (DE, SP).
- Plenty of experience:
  - **>25% have 11+ years of work experience**
  - >21% 5-10 years of experience
- Different fields of expertise: multiple answers were allowed:
  - **>50% work in research**
  - 30% on H2 production
  - 25% in systems integration

This project has received funding from the Fuel Cells and Hydrogen Joint Undertaking (FCH-JU) under grant agreement Nº 621228

Static applications

- **Most challenging**: cost disadvantages
- **Less challenging**: safety issues and technological maturity.
- Public acceptance, regulatory issues
- Support for research and development is favoured over funding for demonstration project and subsidies on purchase prices.
- Professionals from the same sector and researchers are perceived as most familiar, the public's familiarity lowest.

Mobile applications

- **Most challenging**: providing refuelling points followed by costs
- **Less challenging**: safety
- They favour FCEVs over other drivetrains / fuels. The highest competition → battery electric vehicles
- Public funding: Support for research and development and <u>providing infrastructure is most important</u>; demonstration project and subsidies for vehicles less relevant.
- Professionals from the same sector and researchers are perceived as most familiar, the public's familiarity lowest.

This project has received funding from the Fuel Cells and Hydrogen Joint Undertaking (FCH-JU) under grant agreement Nº 621228

Perceptions of hydrogen supply and use

Strengths:

- **Environmental performance of hydrogen** (despite the scepticism of the inefficiency of combining multiple conversion processes)
- Versatility: **energy storage vector for renewable energy supply** (per se and in relation to electrical grid balancing)

Weaknesses:

- Cost
- Limited awareness among regulators and government
- Inadequate or excessive regulation
- Competition from alternative technologies
- Lack of commercial support and lack of markets
- Immaturity and durability
- General lack of infrastructure
- Perceived safety issues

Key expectations:

- Positive view: market development expected by many in the relatively near term.
- Uncertain future for hydrogen and a high degree of conditionality on government policy support.

Recommendations:

- More government and political support is required
- Need to inform and engage stakeholders
- Additional R&D to reduce costs

This project has received funding from the Fuel Cells and Hydrogen Joint Undertaking (FCH-JU) under grant agreement Nº 621228

Perceptions of static applications

Strengths:

- H2FCs for portable power (could also be bracketed with the potential for uninterruptible power)
- **Integration with existing infrastructure** (UK respondents only)
- Efficiency of fuel cells (reducing the pressure on the electrical network)
- **The capacity to offer domestic and non-domestic CHP, power and heat, including high power**.

Weaknesses

- Cost & Investment costs
- Complexity of the system and its components
- Perceived and 'actual' safety
- Competition from alternative technologies
- The challenge of finding commercial partners

Key expectations (mixed):

- Expectations expressing a positive inevitability for the technology
- Uninterruptible supply systems as one such niche (German respondents only)
- Stationary uses being more likely than mobile uses (UK respondents only)
- Hydrogen being used as a storage medium as key to the take-up of static applications (UK respondents only)

Recommendations:

- Government support
- Regulatory support particularly relating to issues of safety

This project has received funding from the Fuel Cells and Hydrogen Joint Undertaking (FCH-JU) under grant agreement Nº 621228

Perceptions of mobile applications

Strenghts:

- Operational performance: long range, **short refill times**, high torque, strong performance generally and relative to alternatives
- **Ease integration with existing infrastructure**
- **Suitability for specific fleets**

Expectations:

- **Specific vehicle fleets being the first to use FCH technology**
- Niche uses first or only
- **Tighter emissions standards driving FCH use**
- Battery electric vehicle (BEV) with FCH being the most likely option
- **Transport corridors being first to support FCHs**

Weaknesses:

- **Financial cost**
- Perceived competition with other technologies
- Lack of infrastructure
- Limited awareness and support by regulators and government
- Inadequate or excessive regulations, codes or standards
- Safety

Recommendations:

- **Governmental, political and regulatory support**
- **R&D to support cost reductions**
- **Commercial partner support**
- **More communication and engagement generally, including of publics**
- **Investment in refuelling infrastructure**

This project has received funding from the Fuel Cells and Hydrogen Joint Undertaking (FCH-JU) under grant agreement Nº 621228

- **Less than half of the population** in the seven countries **is aware of the existence of hydrogen and fuel cell technologies** in the context of energy production.
- **Public awareness** is significantly **lower for residential applications** and higher for hydrogen fuel cell vehicles.
- **The majority of the population** in the seven studied countries have **a positive initial attitude towards HFC technologies**. The label associated to hydrogen and fuel cells seems to invoke positive feelings and thoughts among respondents.
- **Variation across countries**: associated with **differing levels of government investment** in R&D programmes.
- **R&D stakeholders** have a strong **positive appraisal of HFC technologies**, but with limitations:
  - cost and limited regulatory, political and commercial support;
  - competition from other technologies and inter-related obstacles.
- **Stakeholders view:** medium to **long term** rather than near term.
- **HFC technologies view**: **realistic niche potential in the shorter term**
  - uninterruptible power, auxiliary power and high power demand such as fork lifts and heavy goods vehicles

This project has received funding from the
Fuel Cells and Hydrogen Joint Undertaking (FCH-JU) under grant agreement Nº 621228

Centro Nacional del Hidrógeno

STRATEGIC ROADMAP FOR H&FC

www.cnh2.es

OBJECTIVES

	2020	2025	2030
FCEV	40.000	200.000	800.000
HRS	160	320	

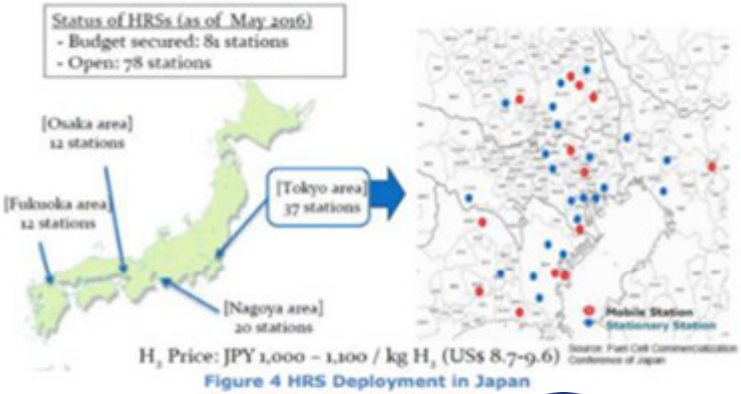


Figure 4 HRS Deployment in Japan

- H2 Price in HRS: 8,9-9,6 USD/kg.

NEDO

MANUFACTURERS

- TOYOTA MIRAI: solds 3.500 (65.000 €)
- HONDA CLARITY: launched in 2016 (67.000 €)

Comparative deployment of HRS between 2015-2030

	Alemania	Reino Unido	Países Bajos	Francia	Dinamarca	California	Japón	Corea del Sur
2015-2020	100	65	20	22	15	68	100	43
2020-2025	400	300	80	355	185	100	1000	168
2025-2030	900	1100	200	600				500

% of HRS respect to conventional service stations

	Alemania	Reino Unido	Países Bajos	Francia	Dinamarca	California	Japón	Corea del Sur
Estaciones de repostaje	14.000	8.600	4.200	12.000	1.975	10.000	34.000	13.000
2015-2020	0,7%	0,8%	0,5%	0,2%	0,8%	0,7%	0,3%	0,3%
2020-2025	2,8%	3,5%	1,9%	3,0%	9,4%	1,0%	2,9%	1,3%
2025-2030	6,2%	12,8%	4,8%	5,0%				3,8%

Average for 2020: 0,5% Average for 2015: 2,5% Average for 2030: 5%

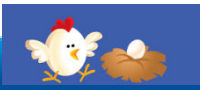
Comparative deployment of FCEV between 2015-2030

	Alemania	Reino Unido	Países Bajos	Francia	Dinamarca	California	Japón	Corea del Sur
2015-2020	10.000	20.000	1.500	1.000	1.000	20.000	15.000	5.000
2020-2025	100.000	300.000	15.000	100.000	100.000		100.000	50.000
2025-2030	1.800.000	1.600.000	150.000	800.000	300.000		500.000	

H2PiyR Project -INTERREG: Next building of 4 new HRS (Zaragoza, Huesca capital, Fraga-Huesca, Tarragona). There will be a total of 10 HRS.

HyMIC Project -CEF mechanism: Model for the deployment of hydrogen infrastructures in the Iberian corridors. Partners: Enagas, AeH2, Calvera, FHA, CNH2, Toyota, IDIADA, ZoiloRios, H2B2, Indho, Abengoa and Scalegas.

"THE CHICKEN -OR- THE CHICKEN EGG"



Centro Nacional del Hidrógeno

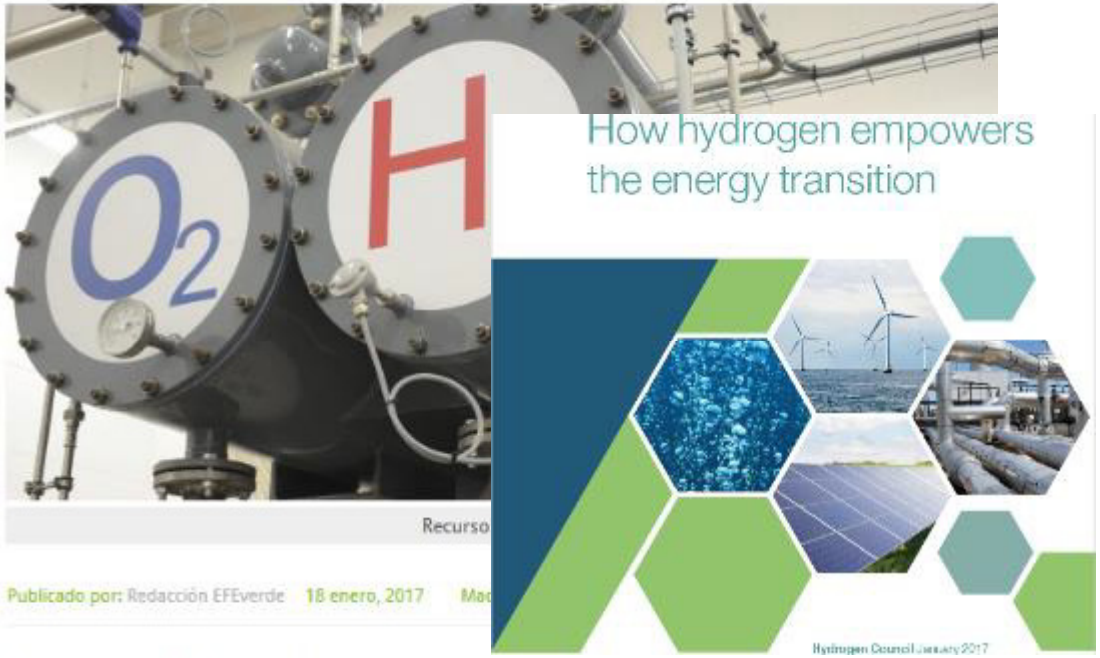
HYDROGEN COUNCIL

www.cnh2.es

ENEGÍA HIDRÓGENO

EL NUEVO "CONSEJO DEL HIDRÓGENO" SE PRESENTA EN DAVOS

- **Trece empresas líderes mundiales en el ámbito de la energía, el transporte y la industria han presentado en Davos una iniciativa global para promover conjuntamente la transición energética hacia el hidrógeno.**



Publicado por: Redacción EFEverde 18 enero, 2017

El "Consejo del hidrógeno" se ha presentado durante el foro económico de Davos como la primera iniciativa mundial en este campo integrada por representantes de 13 empresas y entidades, que buscan situar el hidrógeno como una de las soluciones clave de la transición energética.

AIR LIQUIDE Creative Oxygen · ALSTOM · AngloAmerican · BMW GROUP · DAIMLER · ENGIE · HONDA · HYUNDAI · Kawasaki · THE LINDE GROUP · TOTAL · TOYOTA

- **Thirteen** leading energy, transport and industry **companies** have **launched a global initiative** to voice a united vision and long-term ambition **for hydrogen to foster the energy transition.** The CEOs of the participating companies used the occasion of the World Economic Forum in Davos to kick off this important activity.
- A report entitled "***How Hydrogen empowers the energy transition***" – commissioned by the Hydrogen Council – sets out the vision of the Council and the key actions it considers fundamental for **policy makers to implement**, to fully unlock and empower the contribution of hydrogen to the energy transition

INDEX

- NATIONAL HYDROGEN CENTER (CNH2)
- FUEL CELL AND HYDROGEN TECHNOLOGICAL CHALLENGES
  - HYACINTH PROJECT. RESULTS.
  - STRATEGIC ROADMAP FOR FCH.
  - HYDROGEN COUNCIL.
- **FUTURE OPPORTUNITIES**
  - EUROPEAN CALLS.
    - JTIS. FCH 2JU.
      - TOPICS 2017
    - OTHER EXAMPLES OF EUROPEAN CALLS
      - LIFE 2014-2020
      - INTERREG SUDOE
- CONCLUSIONS

FUTURE OPPORTUNITIES

www.cnh2.es

Centro Nacional del Hidrógeno

LA COOPERACIÓN TERRITORIAL EUROPEA

Cooperación Tecnológica internacional en I+D

IBEROEKA

BILATERALES

UNILATERALES

eurostars™

LIFE+

European Institute of Innovation & Technology

Creating 5 new KICs

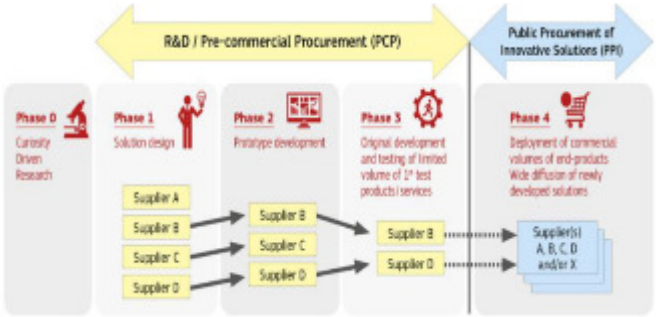
2018 EIT Urban Mobility

HORIZON 2020

FCH 2 JU

- TRANSPORT PILLAR
- ENERGY PILLAR
  - Hydrogen production
  - Stationary Fuel Cells
- CROSS-CUTTING

Compra pública innovadora



New Energy World JU

Smart, green and integrated Transport

4 áreas generales

FAST TRACK TO INNOVATION

EUROPEAID

PROGRAMA IBEROAMERICANO

CYTED

CIENCIA Y TECNOLOGÍA PARA EL DESARROLLO

era-net TRANSPORT

EGVI European Green Vehicles Initiative

cPPP

Vehículos ecológicos

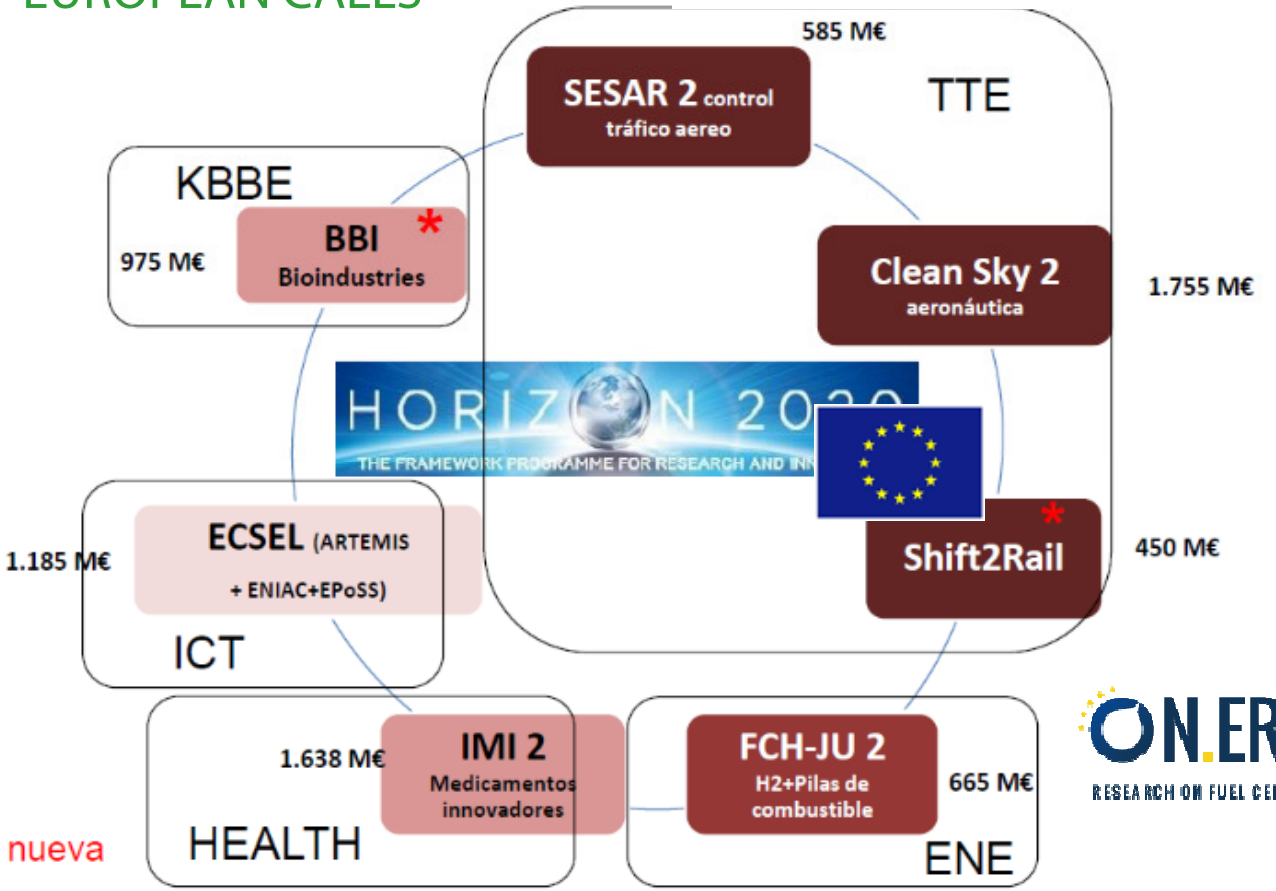
Centro Nacional del Hidrógeno

www.cnh2.es

FUTURE OPPORTUNITIES

JTIs (PPPs institucionales)

·EUROPEAN CALLS



* nueva

ON.ERGHY
RESEARCH ON FUEL CELLS & HYDROGEN

Hydrogen Europe

New Energy World JU
fuel cells & hydrogen for sustainability

FUTURE OPPORTUNITIES

FCH 2 JU Objectives

(COUNCIL REGULATION (EU) No 559/2014 of 6 May 2014 establishing the FCH 2 JU)

Reduce the production cost of fuel cell systems to be used in transport applications, while increasing their lifetime to levels which can compete with conventional technologies

Increase the electrical efficiency and the durability of the different fuel cells used for power production to levels which can compete with conventional technologies while reducing costs

Increase the H2 production energy efficiency mainly from water electrolysis & renewable sources while reducing costs, so that the combined system of the H2 production and the conversion using the fuel cell system can compete with the alternatives for electricity production available on the market

Demonstrate on a large scale the feasibility of using H2 to support renewable energy sources integration into the energy systems, incl. through its use as a competitive energy storage medium for electricity produced from renewables

Reduce the use of the EU-defined “critical raw materials”, for instance through low-platinum or platinum-free resources and through recycling or reducing or avoiding the use of rare earth metals

FUTURE OPPORTUNITIES

Transport Pillar

Main focus:

- Continue support large demonstrations in various road transport applications with a focus on large fleets and new transport modes (urban garbage trucks).
- Complementary research activities in key technologies for the cost reduction of fuel cell vehicles.
- **Topics (2017):**

Topic	Type of Action	Ind. Budget M EUR
FCH-01-1-2017: Development of fuel cell system technologies for achieving competitive solutions for aeronautical applications	RIA	5
FCH-01-2-2017: Towards next generation of PEMFC: Non-PGM catalysts	RIA	2.75
FCH-01-3-2017: Improvement of compressed storage systems in the perspective of high volume automotive application	RIA	4
FCH-01-4-2017: Demonstration of FC material handling and industrial vehicles	IA	42.5
FCH-01-5-2017: Large scale demonstration in preparation for a wider roll-out of fuel cell bus fleets (FCB) including new cities – Phase two		
FCH-01-6-2017: Large scale demonstration of Hydrogen Refueling Stations and Fuel Cell Electric Vehicle (FCEV) road vehicles operated in fleet(s)		
FCH-01-7-2017: Validation of Fuel Cell Trucks for the Collect of Urban Wastes		

FUTURE OPPORTUNITIES

Energy Pillar
Hydrogen Production

Main focus:

- Aim for breakthroughs in electrolysis to increase H2 from RES: Novel concepts and upscaling.
- Innovative concepts: game changer and reversible electrolysers; testing according to protocols of JRC for FCH JU; largest single electrolysers demo to date (10 MW); liquid organic hydrogen carrier.
- **Topics (2017):**

Topic	Type of Action	Ind. Budget M EUR
FCH-02-1-2017: Game changer Water Electrolysers	RIA	2
FCH-02-2-2017: Game changer High Temperature Steam Electrolysers	RIA	3
FCH-02-3-2017: Reversible Solid Oxide Electrolyser (rSOC) for resilient energy systems	RIA	3
FCH-02-4-2017: Highly flexible electrolysers balancing the energy output inside the fence of a wind park	IA	5
FCH-02-5-2017: Demonstration of large electrolysers for bulk renewable hydrogen production	IA	10
FCH-02-6-2017: Liquid organic hydrogen carrier	RIA	2.5
FCH-02-12-2017: Demonstration of fuel cell-based energy storage solutions for isolated micro-grid or off-grid remote areas	IA	5

FUTURE OPPORTUNITIES

www.cnh2.es

Energy Pillar
Stationary Fuel Cells

Main focus:

- To use innovative design and manufacturing in order to improve performance and lower the cost of fuel cells; to repeat the success story of residential fuel cell systems in the commercial segment.
- Innovative concepts: Flexible fuel cell power plants for grid support, transportable FC gensets for urban applications, next generation SOFC stack.
- **Topics (2017):**

Topic	Type of Action	Ind. Budget M EUR
FCH-02-7-2017: Development of flexible large fuel cell power plants for grid support	RIA	4
FCH-02-8-2017: Step change in manufacturing of Fuel Cell Stack Components	RIA	3
FCH-02-9-2017: Development of next-generation SOFC stack for small stationary applications	RIA	3
CH-02-10-2017: Transportable FC gensets for temporary power supply in urban applications	IA	12.5
FCH-02-11-2017: Validation and demonstration of commercial scale fuel cell core systems within a power range of 10-100kW for selected markets/applications	IA	

Cross-cutting Activity Area
Call 2017 Overview

Main focus:

- 4 topics addressing Regulations, Codes and Standards by means of Pre-Normative Research.
  - 3 topics focus on storage, transport and suplly of hydrogen.
  - 1 topic focused on performance and durability of fuel cells.
- **Topics (2017):**

Topic	Type of Action	Ind. Budget M EUR
FCH-04-1-2017: Limiting the impact of contaminants originating from the hydrogen supply chain	RIA	6.25
FCH-04-2-2017: Harmonisation of hydrogen gas trailers	CSA	
FCH-04-3-2017: European Higher Training Network in Fuel Cells and Hydrogen	CSA	
FCH-04-4-2017: PNR for a safe use of liquid hydrogen	RIA	
FCH-04-5-2017: Definition of Accelerated Stress Testing (AST) protocols deduced from understanding of degradation mechanisms of aged stack components in Fuel Cell systems	RIA	2.5

Centro Nacional del Hidrógeno

FUTURE OPPORTUNITIES

www.cnh2.es

zero HYTECHPARK

LIFE 2014-2020 – Priority Areas

- **Environment sub-programme**
  - Environment & Resource Efficiency (ENV-RE)
  - Nature & Biodiversity (NAT, BIO)
  - Environmental Governance & Information (GIE)
- **Climate Action sub-programme**
  - Climate Change Mitigation (CCM)
  - Climate Change Adaptation (CCA)
  - Climate Change Governance & Information (GIC)

Stronger emphasis on:

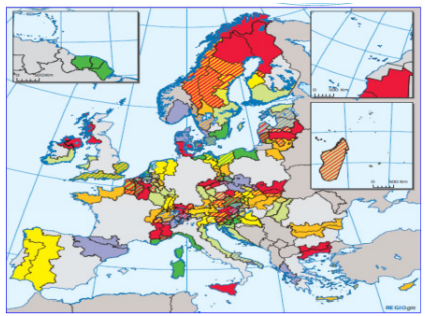
1. Long term sustainability of the project.
2. Replicability and transferability.
3. Impacts (impacts indicators)

Opportunities for project funding under the 2017 call for proposals on close-to-market environmental solutions, biodiversity, and climate change adaptation and mitigation.

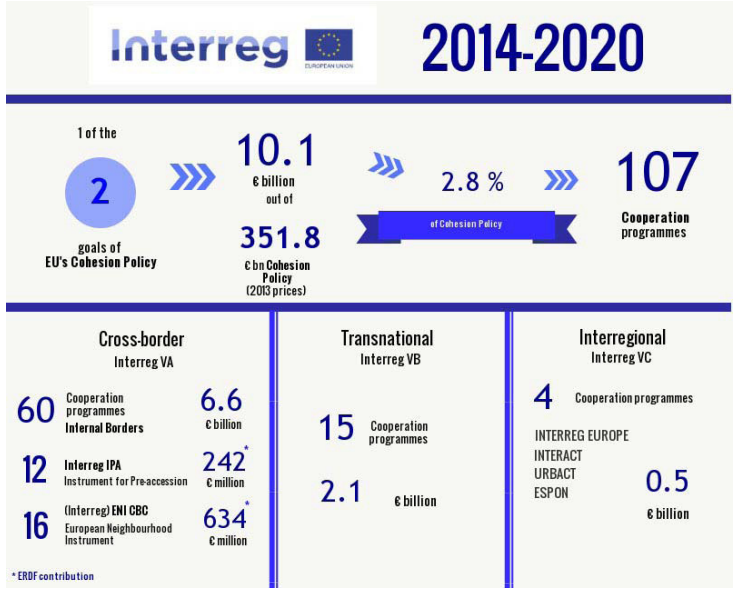
1. Achieving a building with virtually no CO2 emissions.
2. Promoting sustainable mobility.
3. Dissemination the technologies used to the general public and interested scientific and industrial sectors in particular.

FUTURE OPPORTUNITIES

www.cnh2.es



- It supports regional development in Southwest Europe financing transnational projects through the European Regional Development Fund (ERDF) with a total budget of 141 million Euros.
- The Programme promotes ***transnational cooperation to solve common problems in Southwest Europe***, such as low investment in research and development, weak competitiveness of the small and medium-sized enterprises and exposure to climate change and environmental risks.



Eligible regions

The projects approved must be organised by public or private partners from regions of different Southwest European countries. *The eligible regions* ***are all the Spanish Autonomous Communities*** (except Canary Islands), ***the six Southwestern regions of France, all continental regions of Portugal, United Kingdom (Gibraltar) and the Principality of Andorra.***

INDEX

Centro Nacional del Hidrógeno

www.cnh2.es

CONCLUSIONS

"It is increasingly understood that the success of innovative energy technologies is dependent not only upon the technical characteristics of these technologies, but equally on supportive social, political and economic contexts (EC, 2014 and 2015; OECD, 2014)."

FCH

New Energy World JU
fuel cells & hydrogen for sustainability

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING (FCH JU)

Multi - Annual Work Plan 2014 - 2020

"Not legally binding"

Centro Nacional del Hidrógeno

Thank you for your attention!.

www.cnh2.es

CNH2es

@cnh2_es

CNH2 Centro Nacional del Hidrógeno

jesus.martin@cnh2.es