# Plataforma Tecnológica Española del Hidrógeno y de las Pilas de Combustible

PTE HPC

## *ITPs en el sector del hidrógeno y de las pilas de combustible*

### “Impulso de Iniciativas Tecnológicas Prioritarias en Energías Verdes”

*Sevilla, a 20 de junio de 2018*

GOBIERNO DE ESPAÑA

MINISTERIO DE ECONOMÍA, INDUSTRIA Y COMPETITIVIDAD

# Tres ITPs identificadas desde la PTE HPC:

Producción de $H_2$ Renovable

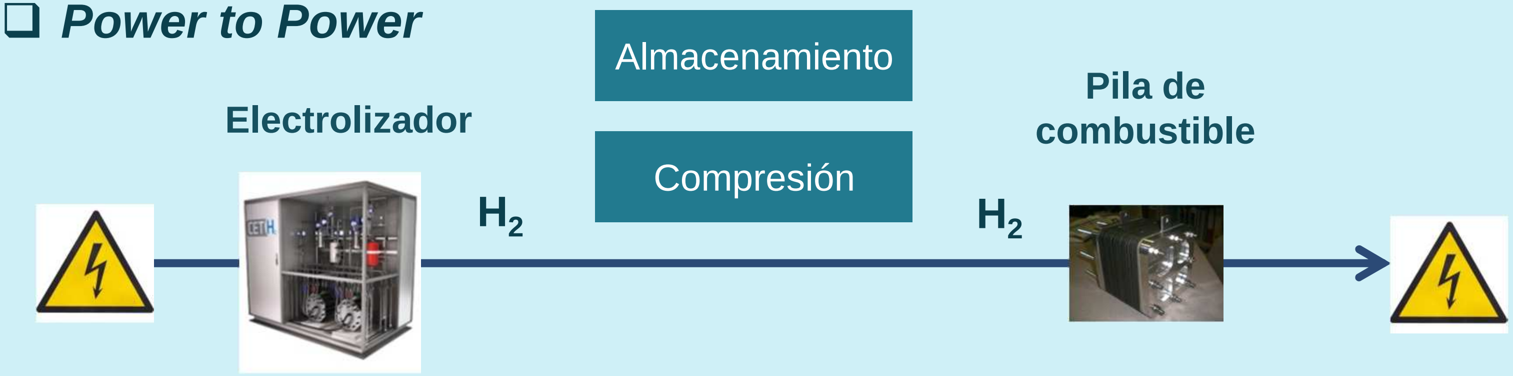
Infraestructura de Suministro de $H_2$

Almacenamiento de Energía con Tecnología de $H_2$

# Alcance y objetivos

## ¿En qué consiste?

- ❑ ***Power to Power***



Almacenamiento

Compresión

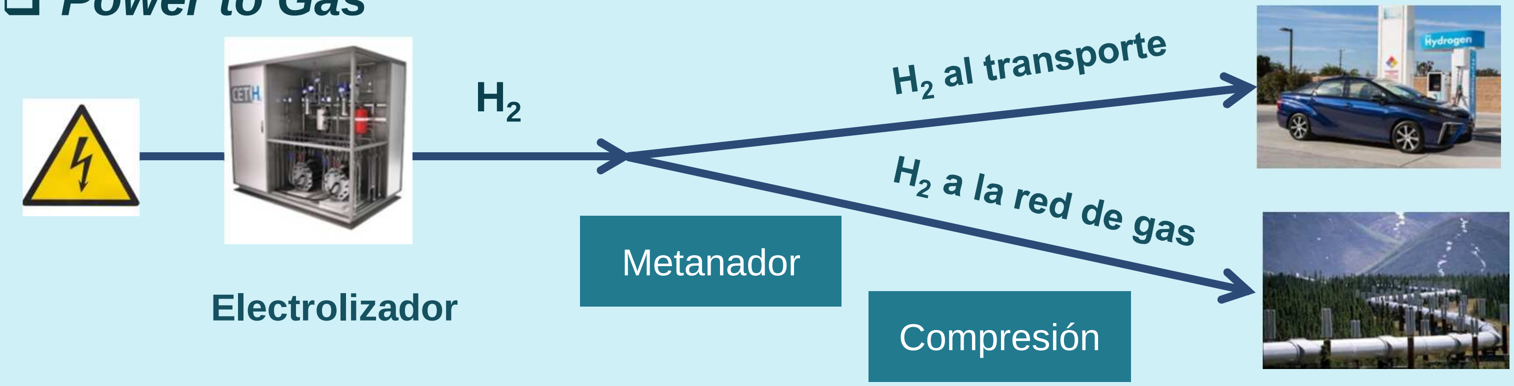
**Electrolizador**

**$H_2$**

**$H_2$**

**Pila de combustible**

- ❑ ***Power to Gas***



**$H_2$**

**$H_2$ al transporte**

**$H_2$ a la red de gas**

Metanador

Compresión

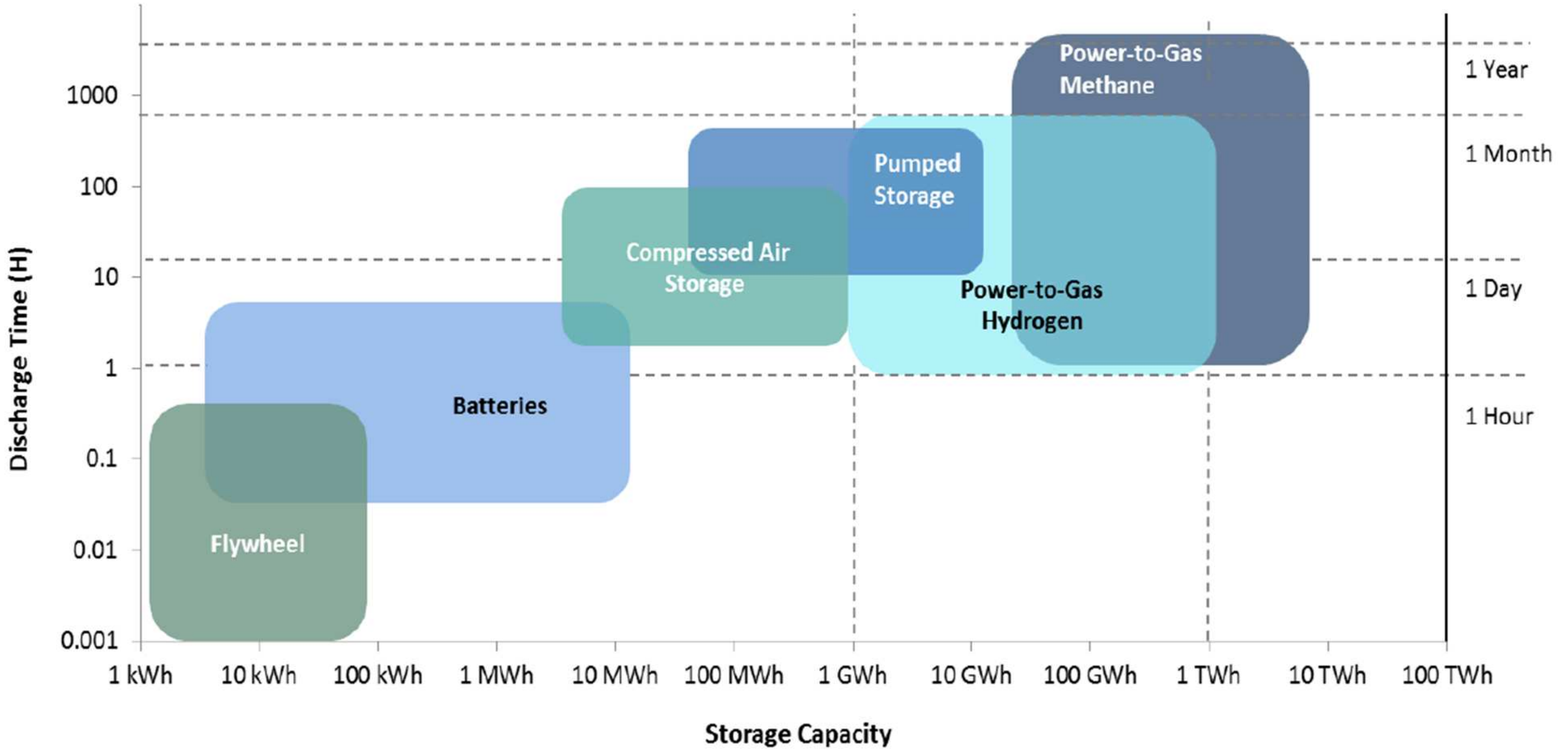
**Electrolizador**

# Alcance y objetivos

## Objetivos generales

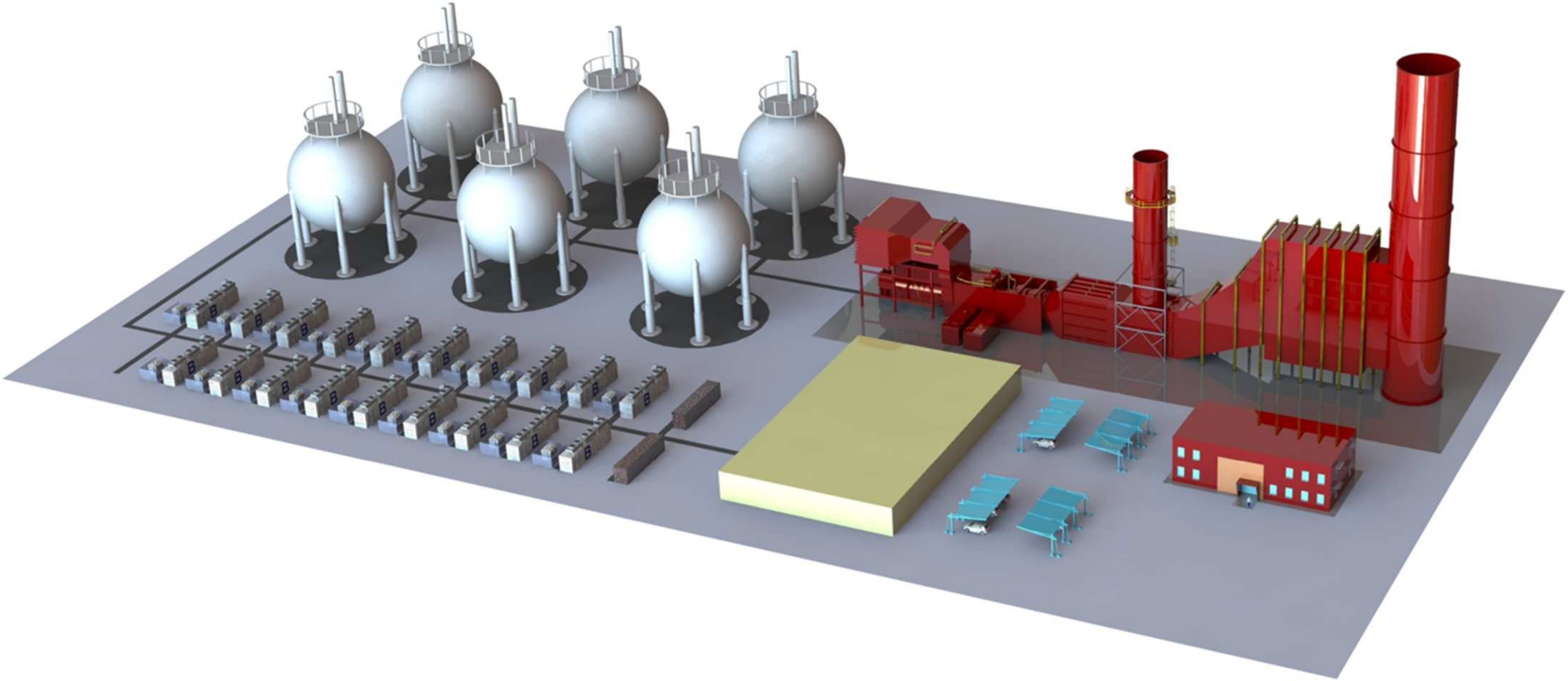
- ✓ **Desacoplar** generación y demanda electricidad.
- ✓ **Gestión** de EERR.
- ✓ Impulsar el mercado de las EERR.
- ✓ Incrementar la **sostenibilidad** del sistema eléctrico.
- ✓ Fomento del uso de **recursos locales** → menor dependencia exterior.

## Alcance y objetivos

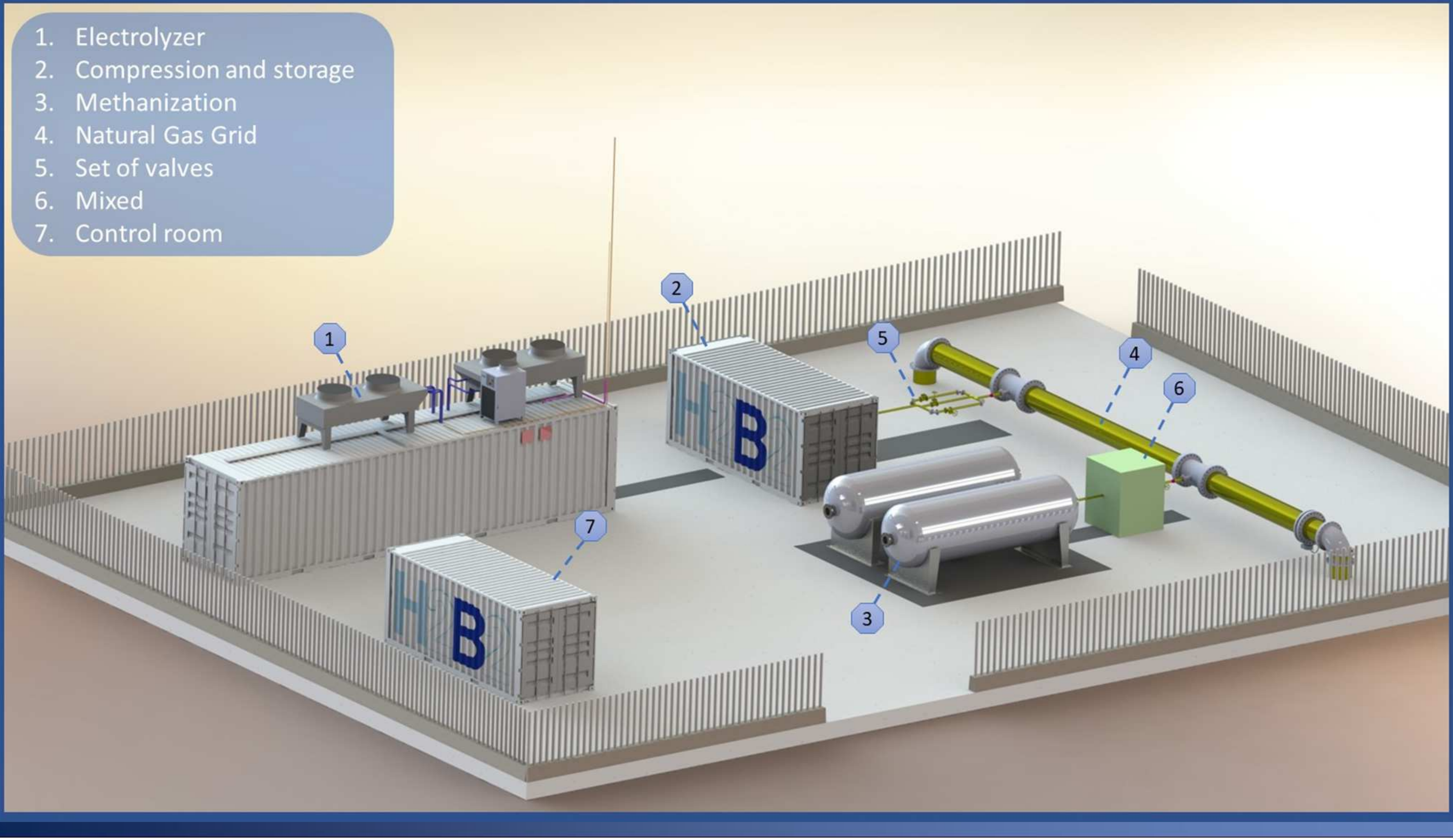


Fuente: Fraunhofer ISE, 2015

# Alcance y objetivos



# Alcance y objetivos

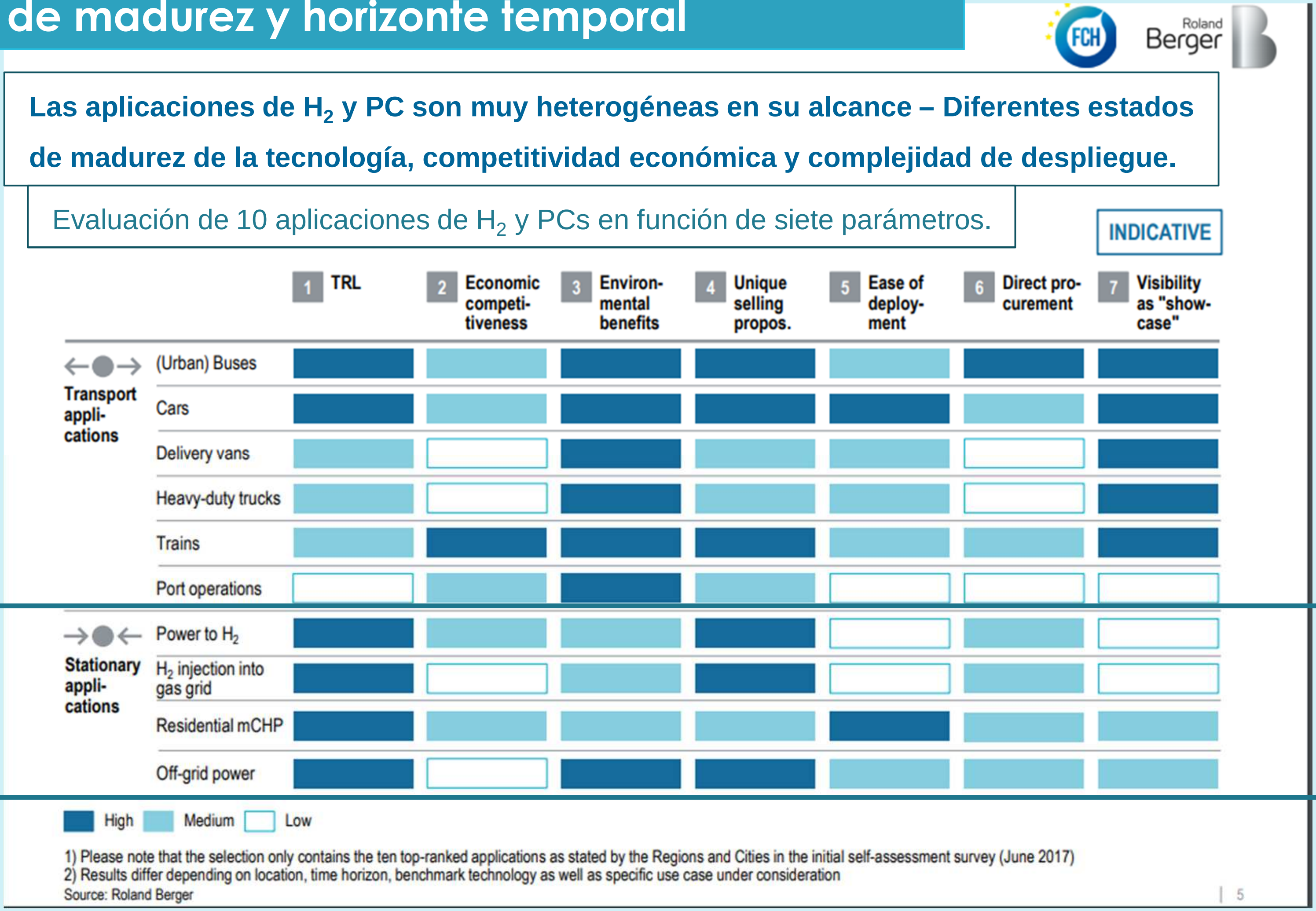


1. Electrolyzer
2. Compression and storage
3. Methanization
4. Natural Gas Grid
5. Set of valves
6. Mixed
7. Control room

# Oportunidades detectadas para su desarrollo

- ✓ **El almacenamiento de energía en forma de hidrógeno permite disponer de un vector energético limpio, reduciendo las emisiones y mejorando la sostenibilidad de sectores como: eléctrico, gasista, industrial y transporte.**
  - ✓ **(SECTOR ELÉCTRICO) Power-to-power:** ↓ combustibles fósiles en pro de las EE.RR. (gestionabilidad).
  - ✓ **(SECTOR GASISTA) Power-to-gas:** producción de biometano (inyección en la red GN o para transporte).
  - ✓ **(SECTOR INDUSTRIAL) Almacenamiento verde** (sector intensivo en energía y sujeto a regulaciones GEI).
  - ✓ **(SECTOR TRANSPORTE) Combustible alternativo verde** (hidrógeno o biometano).
- ✓ **Otras:**
  - ✓ Desarrollo, fabricación, instalación y montaje de depósitos de almacenamiento de hidrógeno.
  - ✓ Creación de una infraestructura desplegada en torno a las estaciones de suministro actuales y los productos industriales.
  - ✓ Ingeniería básica y de detalle de instalaciones.
  - ✓ Almacenamiento de hidrógeno en la red de gas natural.
  - ✓ Generación de empleo en sectores de bienes de equipo (tuberías y racores, valvulería, compresores, aparellaje eléctrico, instrumentación y control, etc.)
  - ✓ Integración con EE.RR. para suplir la variabilidad de estas.

# Grado de madurez y horizonte temporal



**Las aplicaciones de $H_2$ y PC son muy heterogéneas en su alcance – Diferentes estados de madurez de la tecnología, competitividad económica y complejidad de despliegue.**

Evaluación de 10 aplicaciones de $H_2$ y PCs en función de siete parámetros.

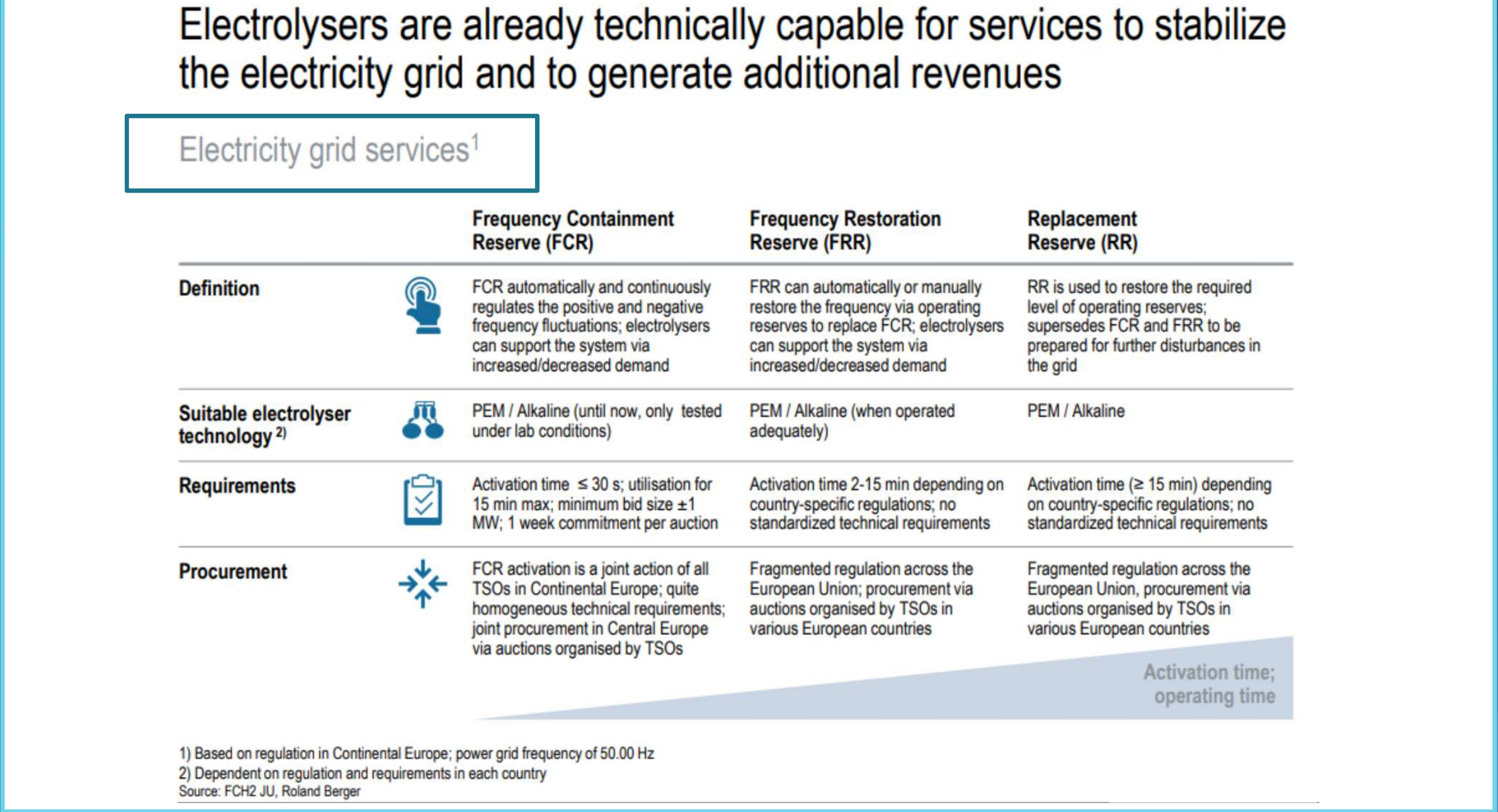
INDICATIVE

| | | 1 TRL | 2 Economic competitiveness | 3 Environmental benefits | 4 Unique selling propos. | 5 Ease of deployment | 6 Direct procurement | 7 Visibility as "showcase" |
|---|---|---|---|---|---|---|---|---|
| Transport applications | (Urban) Buses | ■ | ▨ | ■ | ■ | ▨ | ■ | ■ |
| | Cars | ■ | ▨ | ■ | ■ | ■ | ▨ | ■ |
| | Delivery vans | ▨ | □ | ■ | ▨ | ▨ | □ | ■ |
| | Heavy-duty trucks | ▨ | □ | ■ | ▨ | ▨ | □ | ■ |
| | Trains | ▨ | ■ | ■ | ■ | ▨ | ▨ | ■ |
| | Port operations | □ | ▨ | ■ | ▨ | □ | □ | □ |
| Stationary applications | Power to $H_2$ | ■ | ▨ | ▨ | ■ | □ | ▨ | □ |
| | $H_2$ injection into gas grid | ■ | □ | ▨ | ■ | □ | ▨ | □ |
| | Residential mCHP | ■ | ▨ | ▨ | ▨ | ■ | ▨ | ▨ |
| | Off-grid power | ■ | □ | ■ | ■ | ▨ | ▨ | ▨ |

■ High ▨ Medium □ Low

1) Please note that the selection only contains the ten top-ranked applications as stated by the Regions and Cities in the initial self-assessment survey (June 2017)
2) Results differ depending on location, time horizon, benchmark technology as well as specific use case under consideration
Source: Roland Berger

# Grado de madurez y horizonte temporal



## Electrolysers are already technically capable for services to stabilize the electricity grid and to generate additional revenues

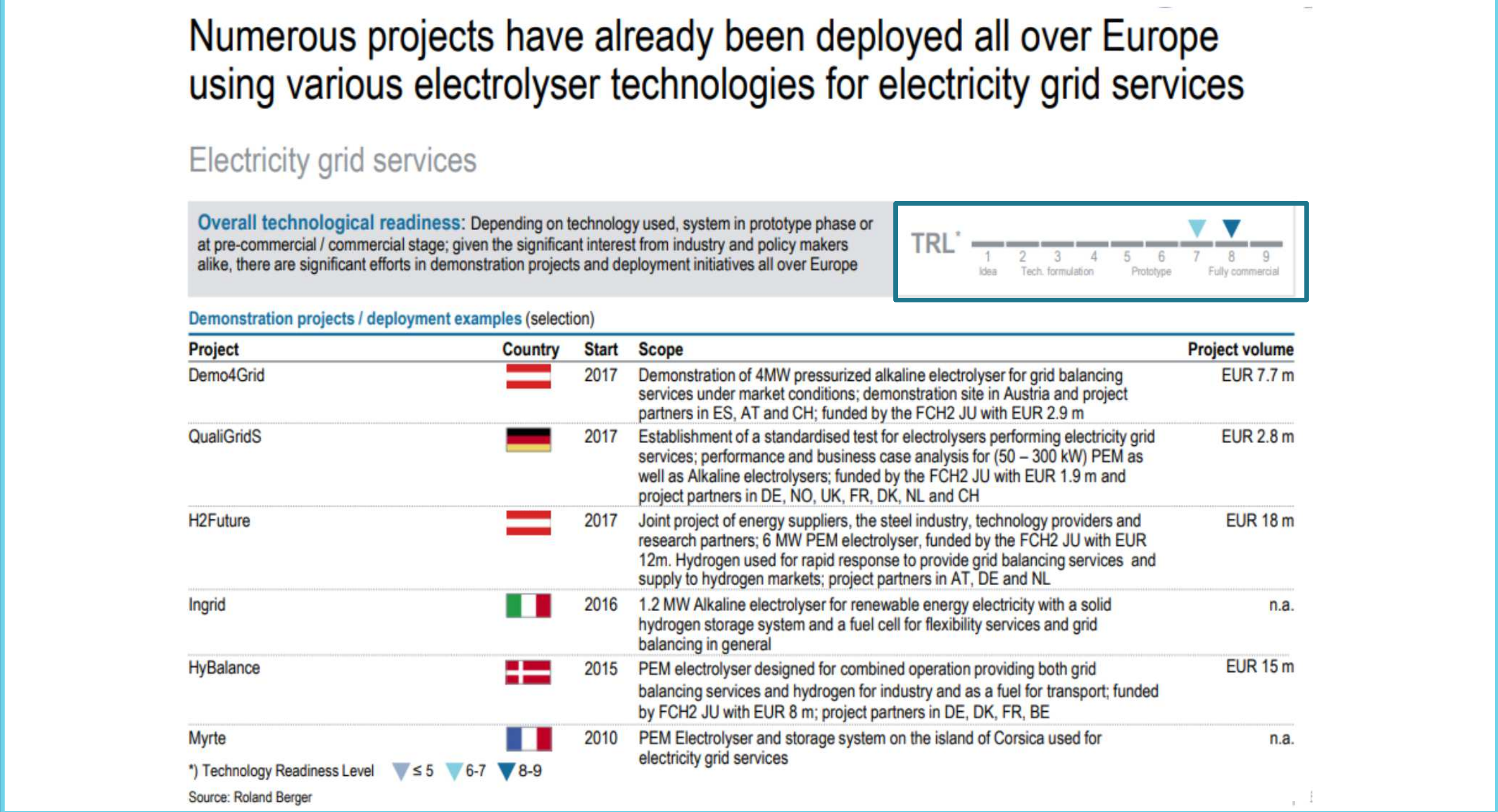
Electricity grid services[1]

| | Frequency Containment Reserve (FCR) | Frequency Restoration Reserve (FRR) | Replacement Reserve (RR) |
|---|---|---|---|
| **Definition** | FCR automatically and continuously regulates the positive and negative frequency fluctuations; electrolysers can support the system via increased/decreased demand | FRR can automatically or manually restore the frequency via operating reserves to replace FCR; electrolysers can support the system via increased/decreased demand | RR is used to restore the required level of operating reserves; supersedes FCR and FRR to be prepared for further disturbances in the grid |
| **Suitable electrolyser technology 2)** | PEM / Alkaline (until now, only tested under lab conditions) | PEM / Alkaline (when operated adequately) | PEM / Alkaline |
| **Requirements** | Activation time ≤ 30 s; utilisation for 15 min max; minimum bid size ±1 MW; 1 week commitment per auction | Activation time 2-15 min depending on country-specific regulations; no standardized technical requirements | Activation time (≥ 15 min) depending on country-specific regulations; no standardized technical requirements |
| **Procurement** | FCR activation is a joint action of all TSOs in Continental Europe; quite homogeneous technical requirements; joint procurement in Central Europe via auctions organised by TSOs | Fragmented regulation across the European Union; procurement via auctions organised by TSOs in various European countries | Fragmented regulation across the European Union, procurement via auctions organised by TSOs in various European countries |

Activation time; operating time

1) Based on regulation in Continental Europe; power grid frequency of 50.00 Hz
2) Dependent on regulation and requirements in each country
Source: FCH2 JU, Roland Berger

# Grado de madurez y horizonte temporal



## Numerous projects have already been deployed all over Europe using various electrolyser technologies for electricity grid services

### Electricity grid services

**Overall technological readiness:** Depending on technology used, system in prototype phase or at pre-commercial / commercial stage; given the significant interest from industry and policy makers alike, there are significant efforts in demonstration projects and deployment initiatives all over Europe

**Demonstration projects / deployment examples** (selection)

| Project | Country | Start | Scope | Project volume |
|---|---|---|---|---|
| Demo4Grid | 🇦🇹 | 2017 | Demonstration of 4MW pressurized alkaline electrolyser for grid balancing services under market conditions; demonstration site in Austria and project partners in ES, AT and CH; funded by the FCH2 JU with EUR 2.9 m | EUR 7.7 m |
| QualiGridS | 🇩🇪 | 2017 | Establishment of a standardised test for electrolysers performing electricity grid services; performance and business case analysis for (50 – 300 kW) PEM as well as Alkaline electrolysers; funded by the FCH2 JU with EUR 1.9 m and project partners in DE, NO, UK, FR, DK, NL and CH | EUR 2.8 m |
| H2Future | 🇦🇹 | 2017 | Joint project of energy suppliers, the steel industry, technology providers and research partners; 6 MW PEM electrolyser, funded by the FCH2 JU with EUR 12m. Hydrogen used for rapid response to provide grid balancing services and supply to hydrogen markets; project partners in AT, DE and NL | EUR 18 m |
| Ingrid | 🇮🇹 | 2016 | 1.2 MW Alkaline electrolyser for renewable energy electricity with a solid hydrogen storage system and a fuel cell for flexibility services and grid balancing in general | n.a. |
| HyBalance | 🇩🇰 | 2015 | PEM electrolyser designed for combined operation providing both grid balancing services and hydrogen for industry and as a fuel for transport; funded by FCH2 JU with EUR 8 m; project partners in DE, DK, FR, BE | EUR 15 m |
| Myrte | 🇫🇷 | 2010 | PEM Electrolyser and storage system on the island of Corsica used for electricity grid services | n.a. |

*) Technology Readiness Level ▽ ≤ 5 ▽ 6-7 ▼ 8-9

Source: Roland Berger

## Grado de madurez y horizonte temporal

### Hydrogen into gas grid applications provide a sustainable solution for renewables-based storage and transformation of energy grids

Hydrogen into gas grid

**Brief description:** Hydrogen can be converted from renewable energy sources and injected into existing natural gas grids for initial (or long-term) storage and subsequent use in a range of different applications (power generation, heat provision, transport applications such as gas-fuelled urban buses or passenger cars)

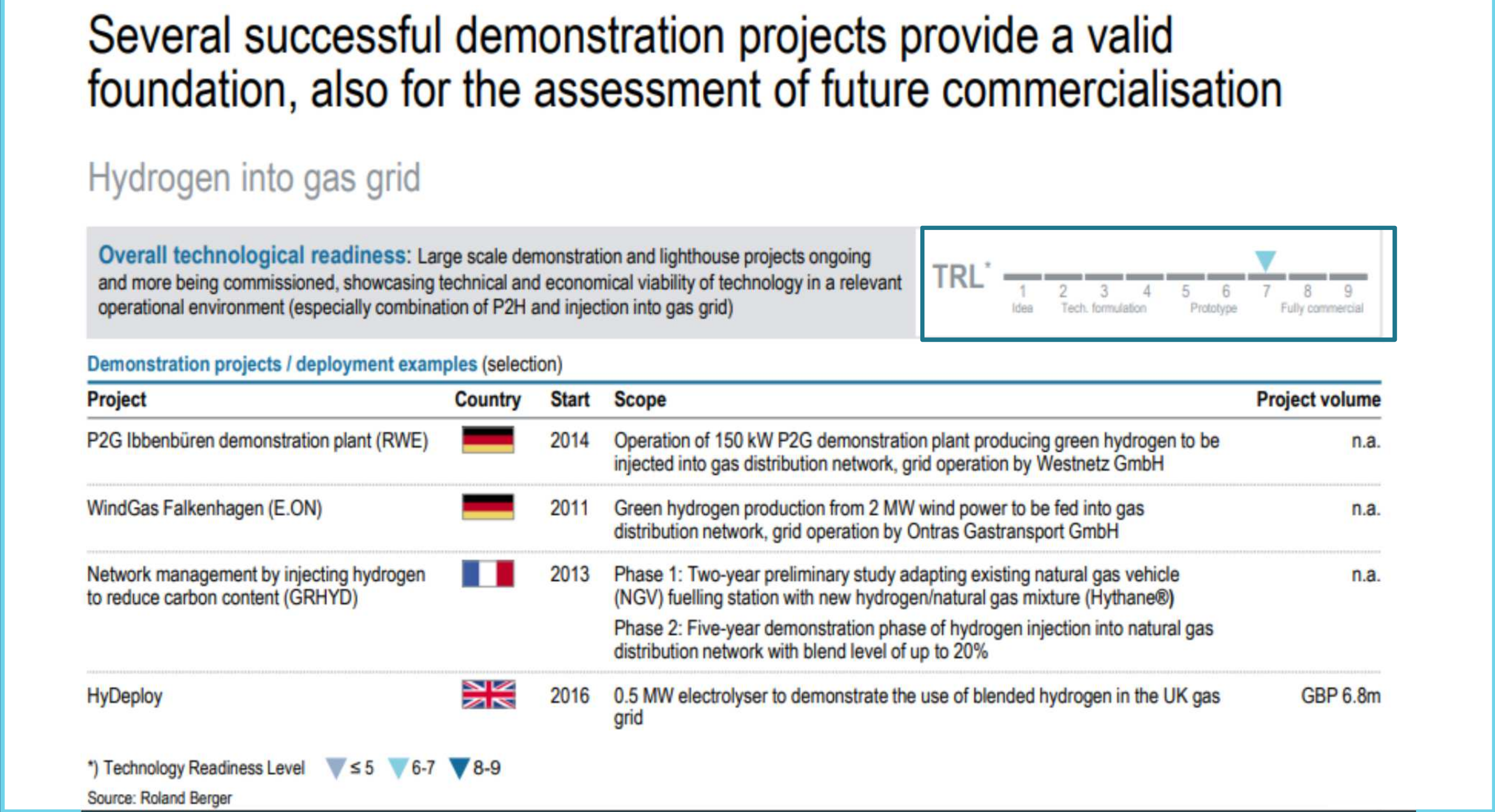
**Use Case:** Cities and regions can inject (or call for / incentivise the injection of) green hydrogen (i.e. from power-to-hydrogen P2H sources) into gas grids to further promote renewable energy sources, decarbonise the gas grid and provide long-term energy storage solutions

**Fuel cells in commercial buildings**

| | |
|---|---|
| Key components | Electrolyser, fuel cell, blending/injection system |
| Electrolysis technology for P2H | Alkaline (ALK), PEM, (Solid Oxide) |
| $H_2$ production efficiencies | 50-83 $kW_{el}$/kg (2013), 36-63 $kW_{el}$/kg (2030) |
| Cost of $H_2$ production for P2H | *dep. on electrolyser size, technology, power input price, etc.* |
| Maximum $H_2$ blend level | 5 – 20% (potentially even 25%, dep. on gas infrastructure) |
| Hydrogen provider | E.on, RWE, Thüga |
| Gas distributors | Private and municipal utilities (e.g. German Stadtwerke), gas TSOs or DSOs |
| Typical customers | Public and private utilities, public and private TSOs or gas shippers, ultimately e.g. passenger car fleet operators |
| Competing technologies | Other energy storage (e.g. pump storage, batteries) |

Source: Roland Berger, FCH2 JU

## Grado de madurez y horizonte temporal



# Several successful demonstration projects provide a valid foundation, also for the assessment of future commercialisation

## Hydrogen into gas grid

**Overall technological readiness:** Large scale demonstration and lighthouse projects ongoing and more being commissioned, showcasing technical and economical viability of technology in a relevant operational environment (especially combination of P2H and injection into gas grid)

**Demonstration projects / deployment examples** (selection)

| Project | Country | Start | Scope | Project volume |
|---|---|---|---|---|
| P2G Ibbenbüren demonstration plant (RWE) | 🇩🇪 | 2014 | Operation of 150 kW P2G demonstration plant producing green hydrogen to be injected into gas distribution network, grid operation by Westnetz GmbH | n.a. |
| WindGas Falkenhagen (E.ON) | 🇩🇪 | 2011 | Green hydrogen production from 2 MW wind power to be fed into gas distribution network, grid operation by Ontras Gastransport GmbH | n.a. |
| Network management by injecting hydrogen to reduce carbon content (GRHYD) | 🇫🇷 | 2013 | Phase 1: Two-year preliminary study adapting existing natural gas vehicle (NGV) fuelling station with new hydrogen/natural gas mixture (Hythane®)<br>Phase 2: Five-year demonstration phase of hydrogen injection into natural gas distribution network with blend level of up to 20% | n.a. |
| HyDeploy | 🇬🇧 | 2016 | 0.5 MW electrolyser to demonstrate the use of blended hydrogen in the UK gas grid | GBP 6.8m |

*) Technology Readiness Level ▼ ≤ 5 ▼ 6-7 ▼ 8-9

Source: Roland Berger

## Grado de madurez y horizonte temporal

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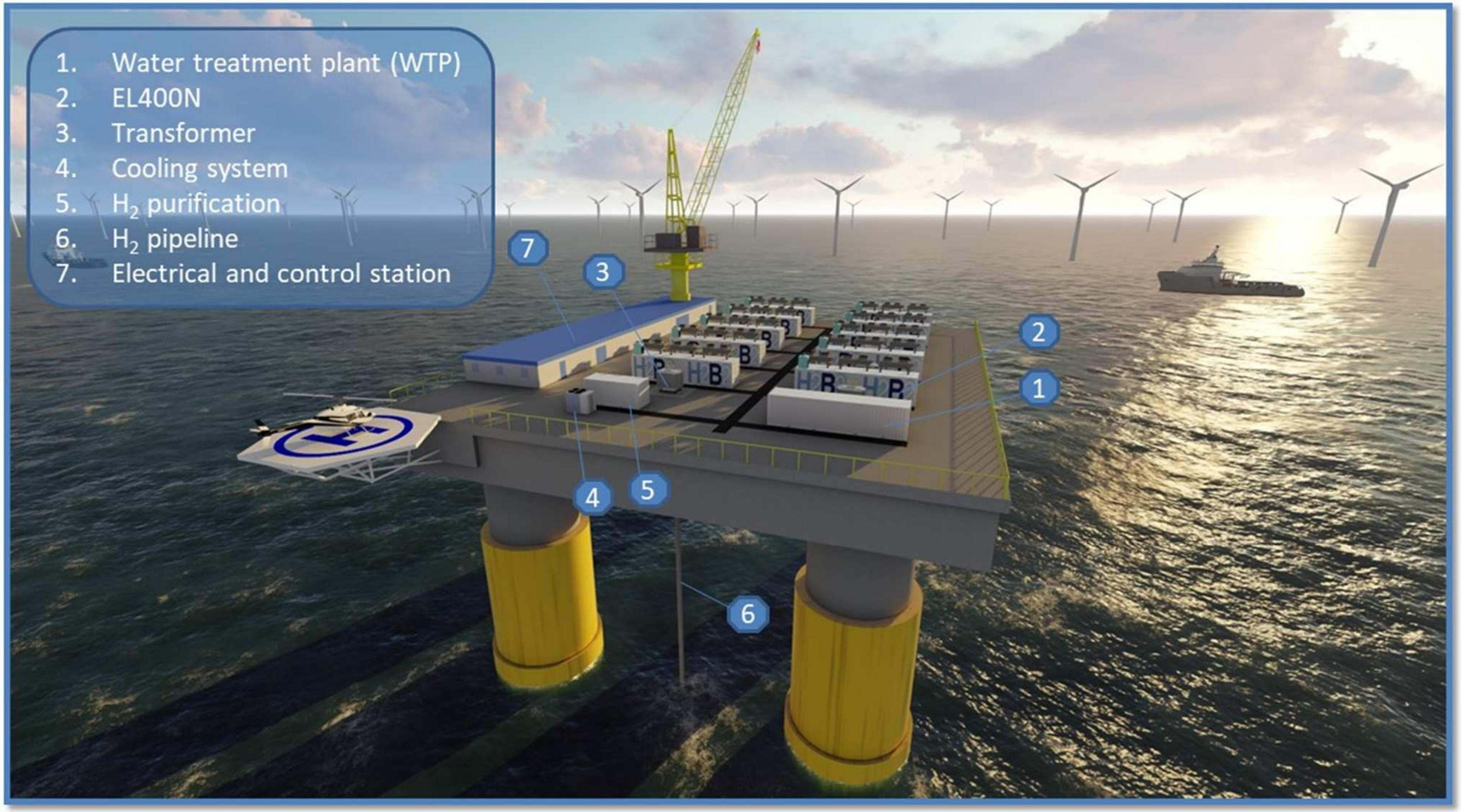
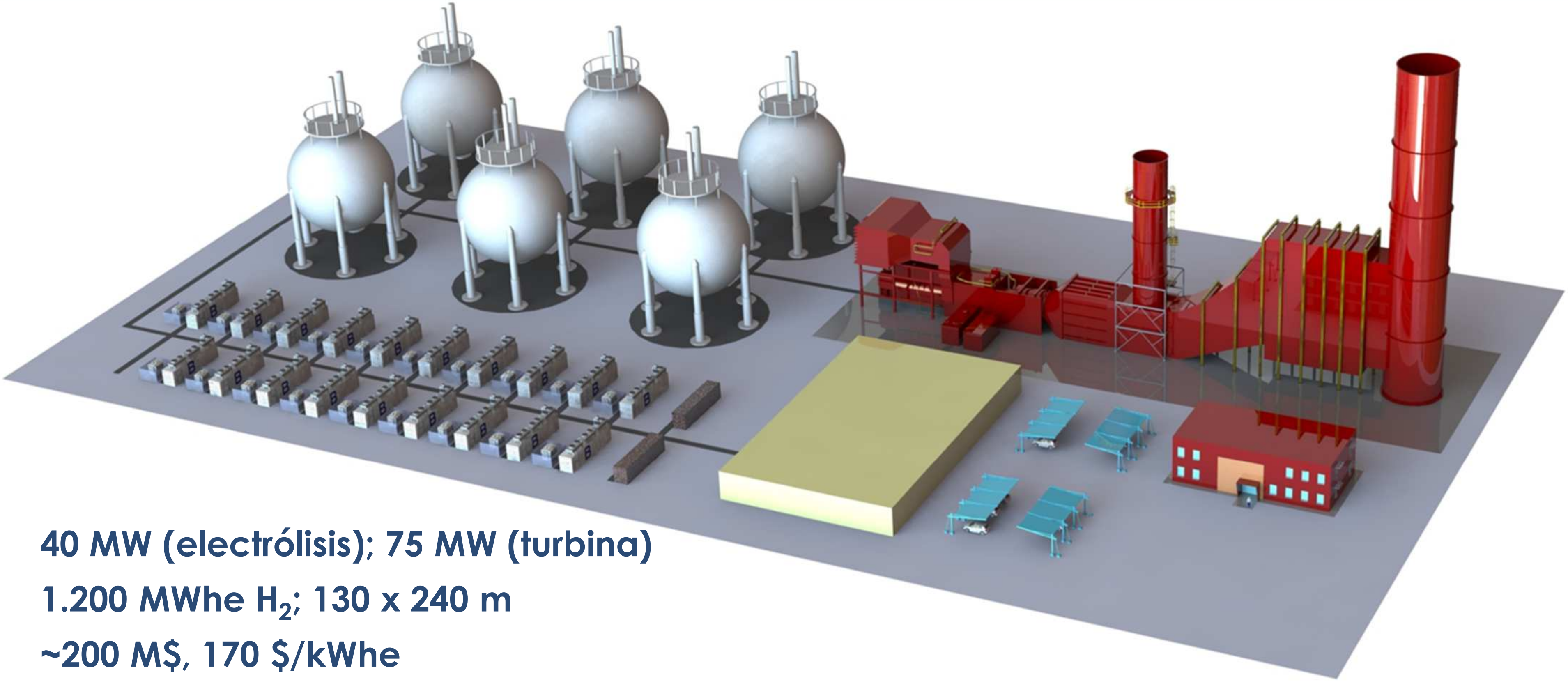


1. Water treatment plant (WTP)
2. EL400N
3. Transformer
4. Cooling system
5. $H_2$ purification
6. $H_2$ pipeline
7. Electrical and control station

# Grado de madurez y horizonte temporal



**40 MW (electrólisis); 75 MW (turbina)**

**1.200 MWhe $H_2$; 130 x 240 m**

**~200 M$, 170 $/kWhe**

# 3 Estrategias: Innovación, Industria, Energía

- ✓ Sistemas de **alta capacidad** de almacenamiento de energía (L73)
- ✓ **Nexo** entre las diferentes redes energéticas: electricidad, calor, combustible
- ✓ **Conocimiento**: ↑ nº de grupos de investigación andaluces
- ✓ Refuerzo y utilización de **infraestructuras** existentes
- ✓ Marco normativo y de regulación
  - **Definición** clara de lo que se considera almacenamiento energético
  - Retribución al **servicio** que da el almacenamiento. Mercado de servicios auxiliares al sistema eléctrico
  - Nuevos **agentes**
  - Normativa

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ESTRATEGIA DE INNOVACIÓN DE ANDALUCÍA 2020

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ESTRATEGIA INDUSTRIAL DE ANDALUCÍA 2020

ESTRATEGIA ENERGÉTICA DE ANDALUCÍA 2020

Andalucía, eficiente por naturaleza

# Muchas gracias por la atención

PTE
HPC

**África Castro**

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*Sevilla, a 20 de junio de 2018*

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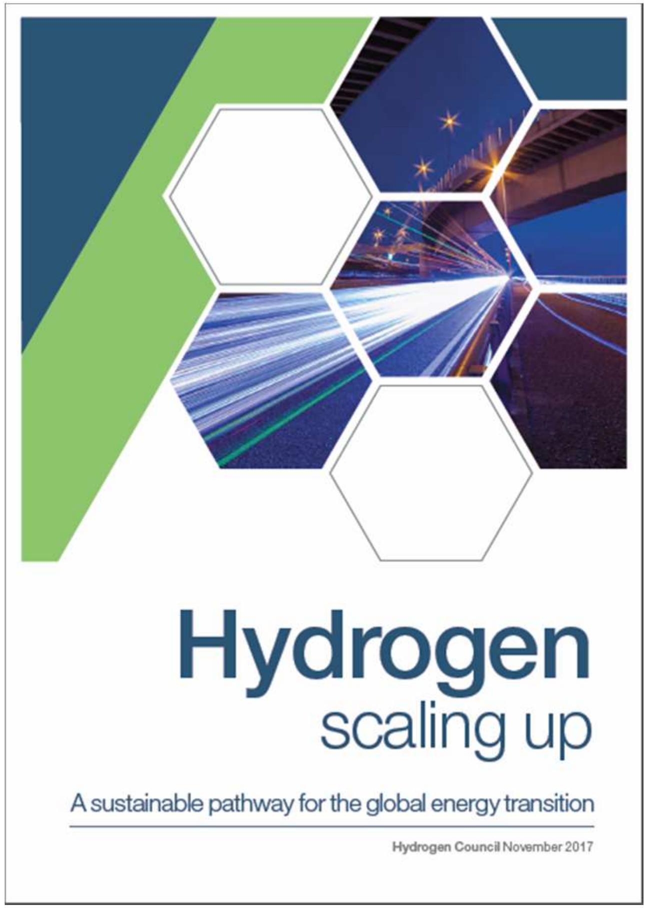
# VISIÓN DE LA ECONOMÍA DEL HIDRÓGENO A 2050

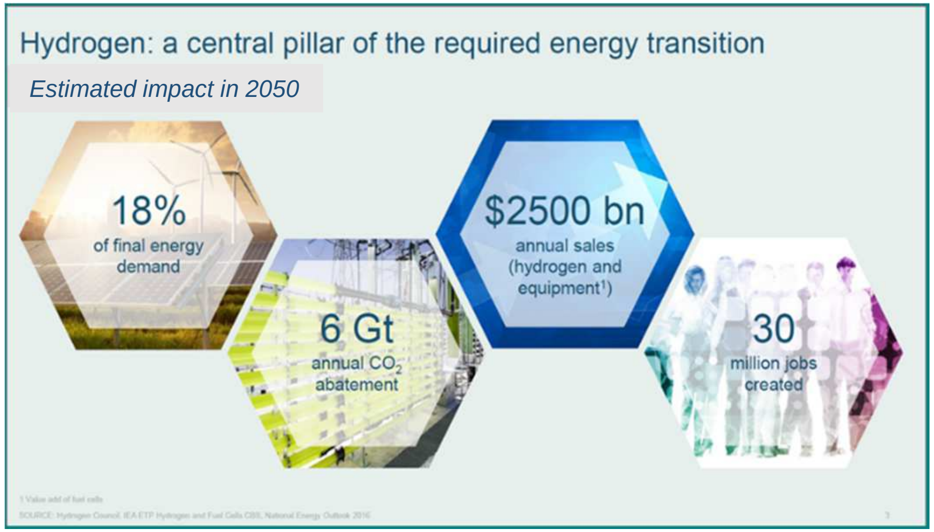
**Hydrogen Council**
(Noviembre 2017)


Hydrogen
scaling up
A sustainable pathway for the global energy transition
Hydrogen Council November 2017

This study is the first comprehensive, ambitious Hydrogen roadmap

**Objectives of the study**

- First **comprehensive quantified vision** and **roadmap** for deployment
- Not a forecast, but an **ambitious yet realistic** scenario
- Answers the question “How could hydrogen contribute to **achieving the two degree scenario**?”


Hydrogen: a central pillar of the required energy transition

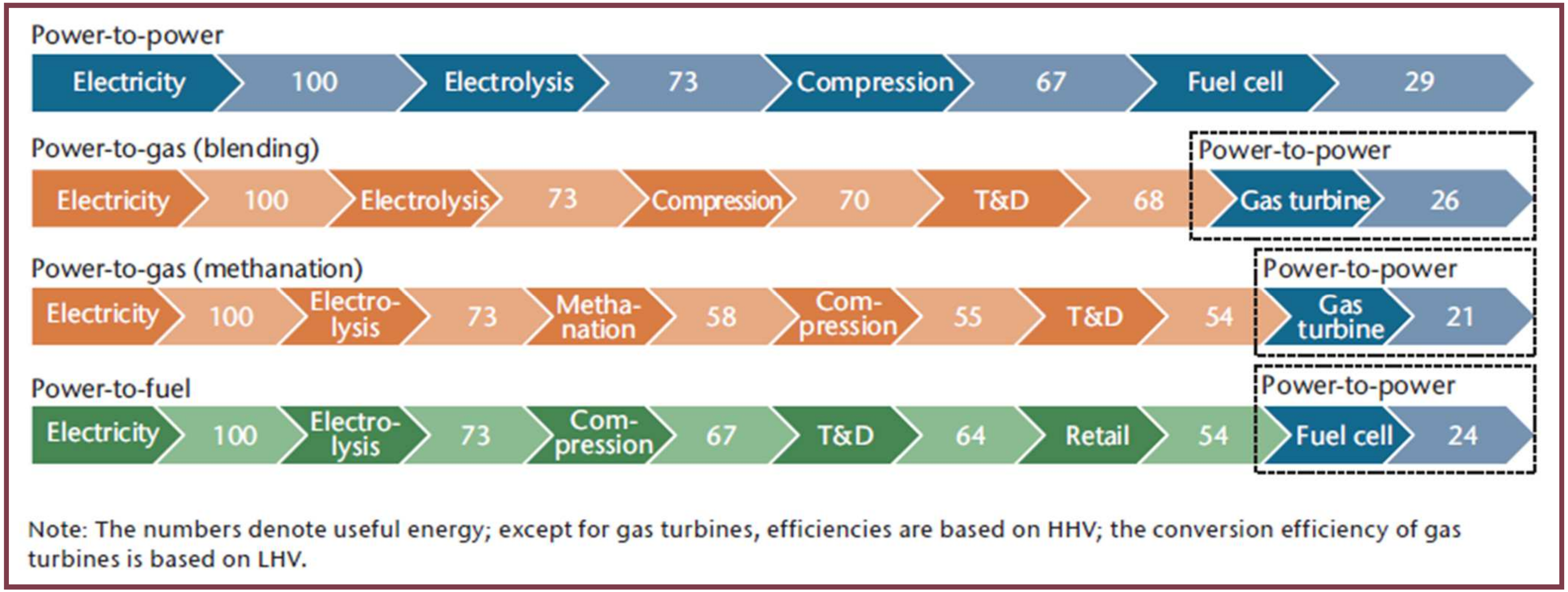
*Estimated impact in 2050*

1 Value add of fuel cells

SOURCE: Hydrogen Council; IEA ETP Hydrogen and Fuel Cells CBS, National Energy Outlook 2016

3

## Almacenamiento de energía con tecnología de H2



Note: The numbers denote useful energy; except for gas turbines, efficiencies are based on HHV; the conversion efficiency of gas turbines is based on LHV.

Fuente: "Technology Roadmap. Hydrogen and Fuel Cells". IEA. 2015

## Almacenamiento de energía con tecnología de H2

**Max. 20-30%vol**
- ❑ Fragilización del acero

**~20%vol**
- ❑ Dinamarca

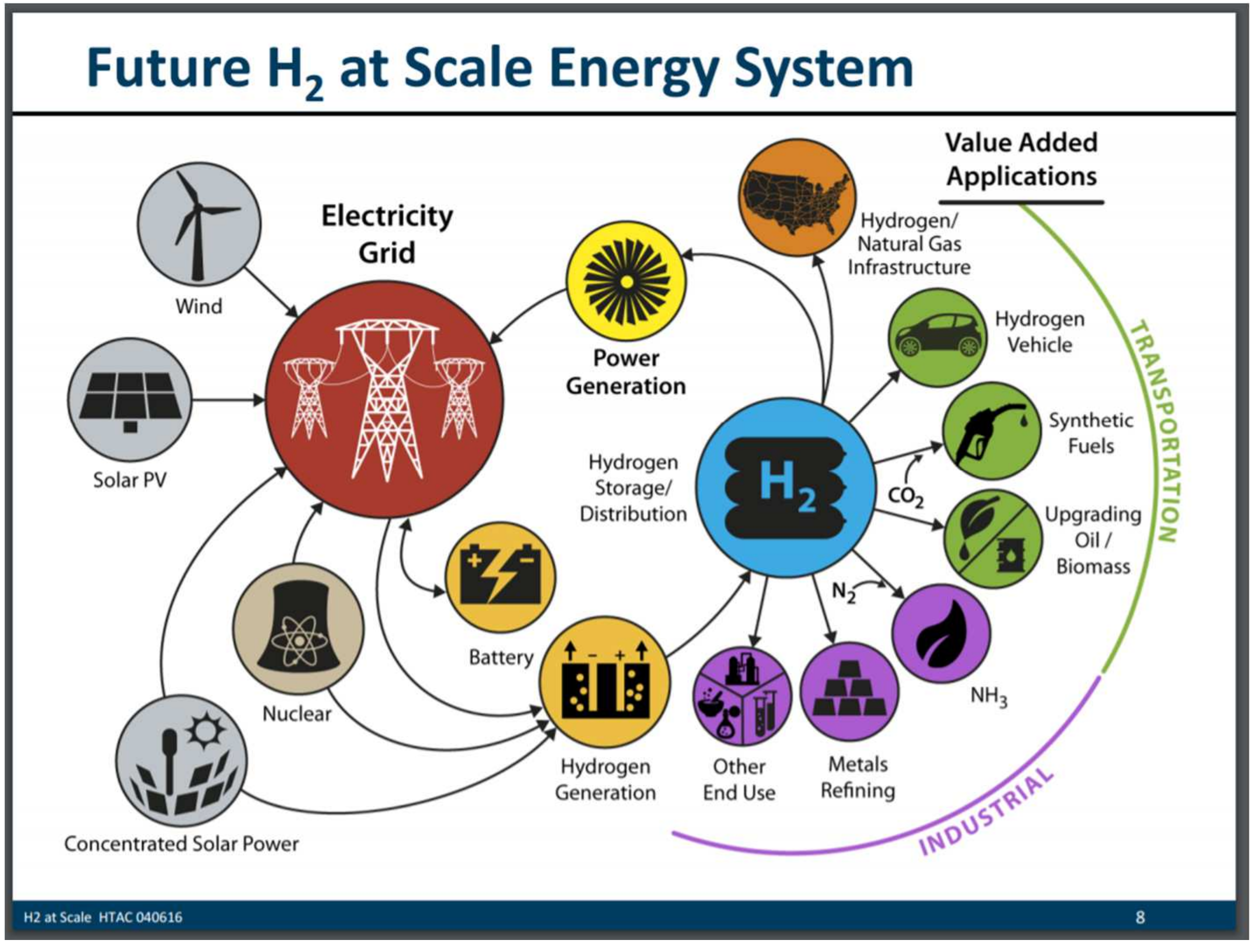
**~10%vol**
- ❑ Alemania

**6%vol**
- ❑ Francia

**~2%vol**
- ❑ Tanques GNC

**0.1%vol**
- ❑ Reino Unido

- ➢ Regulación nacional: Nivel máximo de inyección de hidrógeno **% (vol)**
- ➢ **TSO y DSOs** tomando el liderazgo



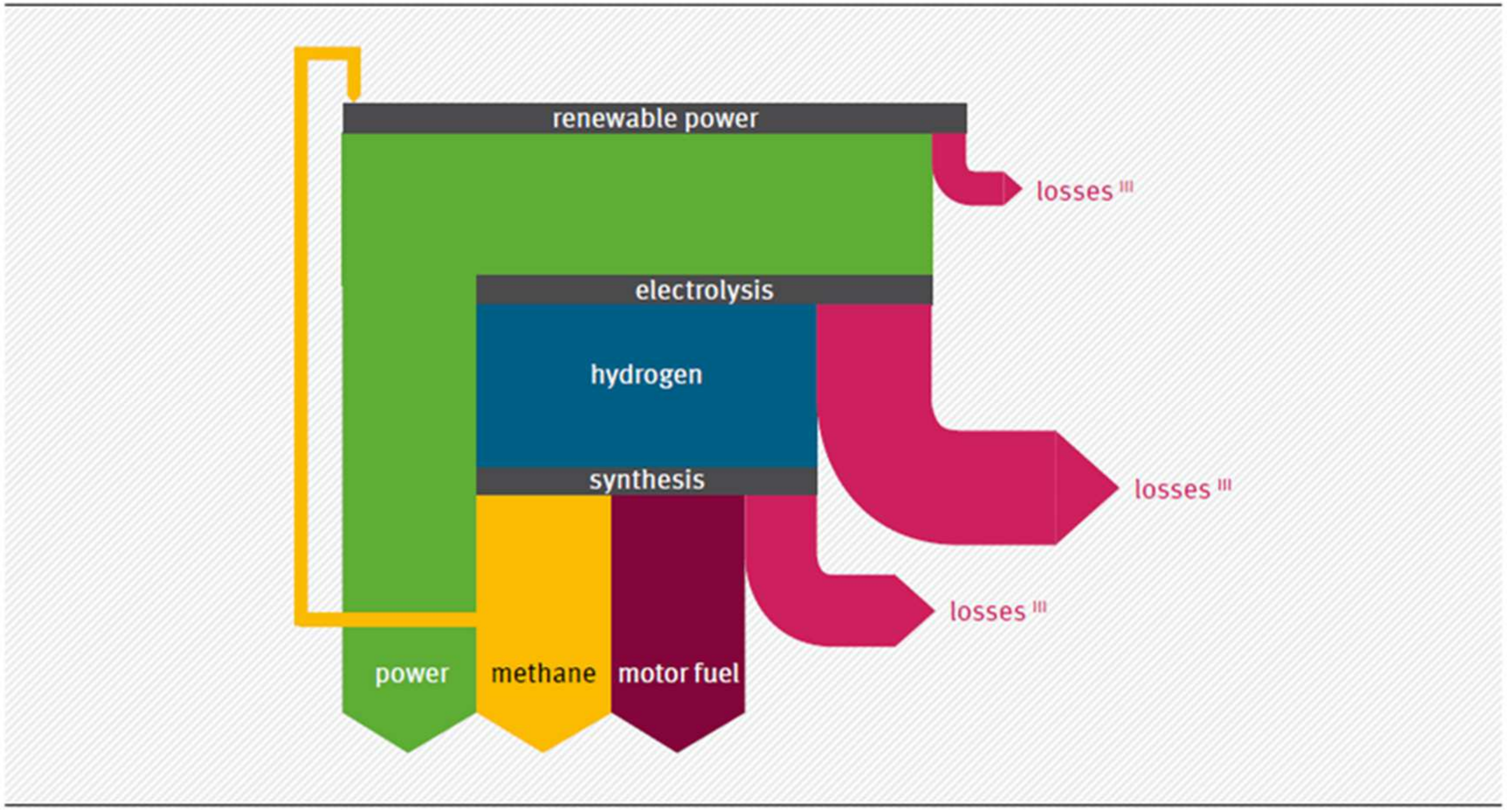
Future $H_2$ at Scale Energy System

H2 at Scale HTAC 040616

8

EEUU:
**descarbonización**
de la economía

# Alemania: **Sistema energético** basado en la electricidad y el hidrógeno, producidos a partir de EERR, en 2050



# Oportunidades detectadas para su desarrollo

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Andalucía se mueve con Europa

Unión Europea

Andalucía se mueve con Europa

ESTRATEGIA INDUSTRIAL
DE ANDALUCÍA
2020

CONSEJERÍA DE EMPLEO, EMPRESA Y COMERCIO

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ESTRATEGIA ENERGÉTICA
DE ANDALUCÍA 2020
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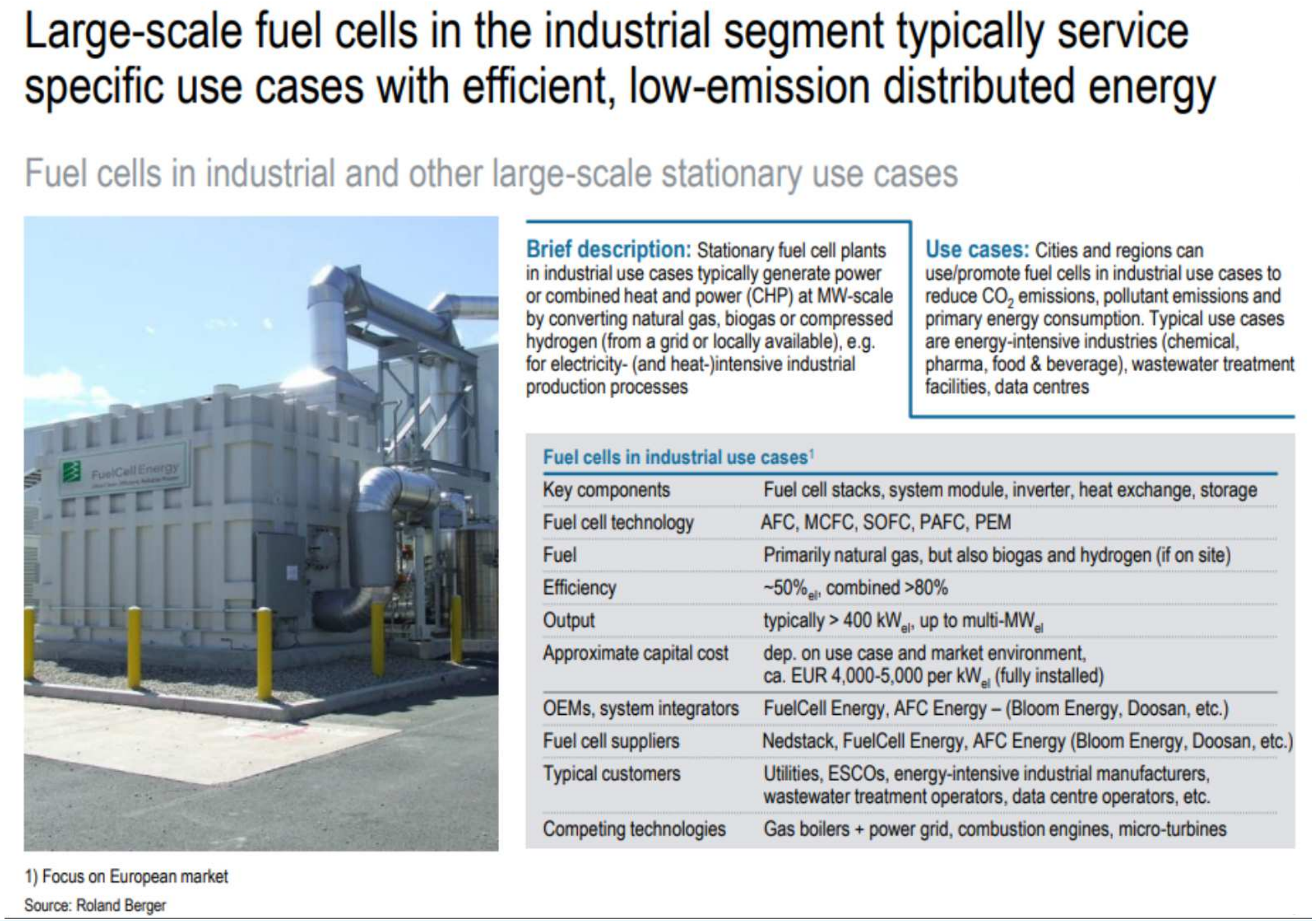
# Grado de madurez y horizonte temporal



## Large-scale fuel cells in the industrial segment typically service specific use cases with efficient, low-emission distributed energy

### Fuel cells in industrial and other large-scale stationary use cases

**Brief description:** Stationary fuel cell plants in industrial use cases typically generate power or combined heat and power (CHP) at MW-scale by converting natural gas, biogas or compressed hydrogen (from a grid or locally available), e.g. for electricity- (and heat-)intensive industrial production processes

**Use cases:** Cities and regions can use/promote fuel cells in industrial use cases to reduce $CO_2$ emissions, pollutant emissions and primary energy consumption. Typical use cases are energy-intensive industries (chemical, pharma, food & beverage), wastewater treatment facilities, data centres

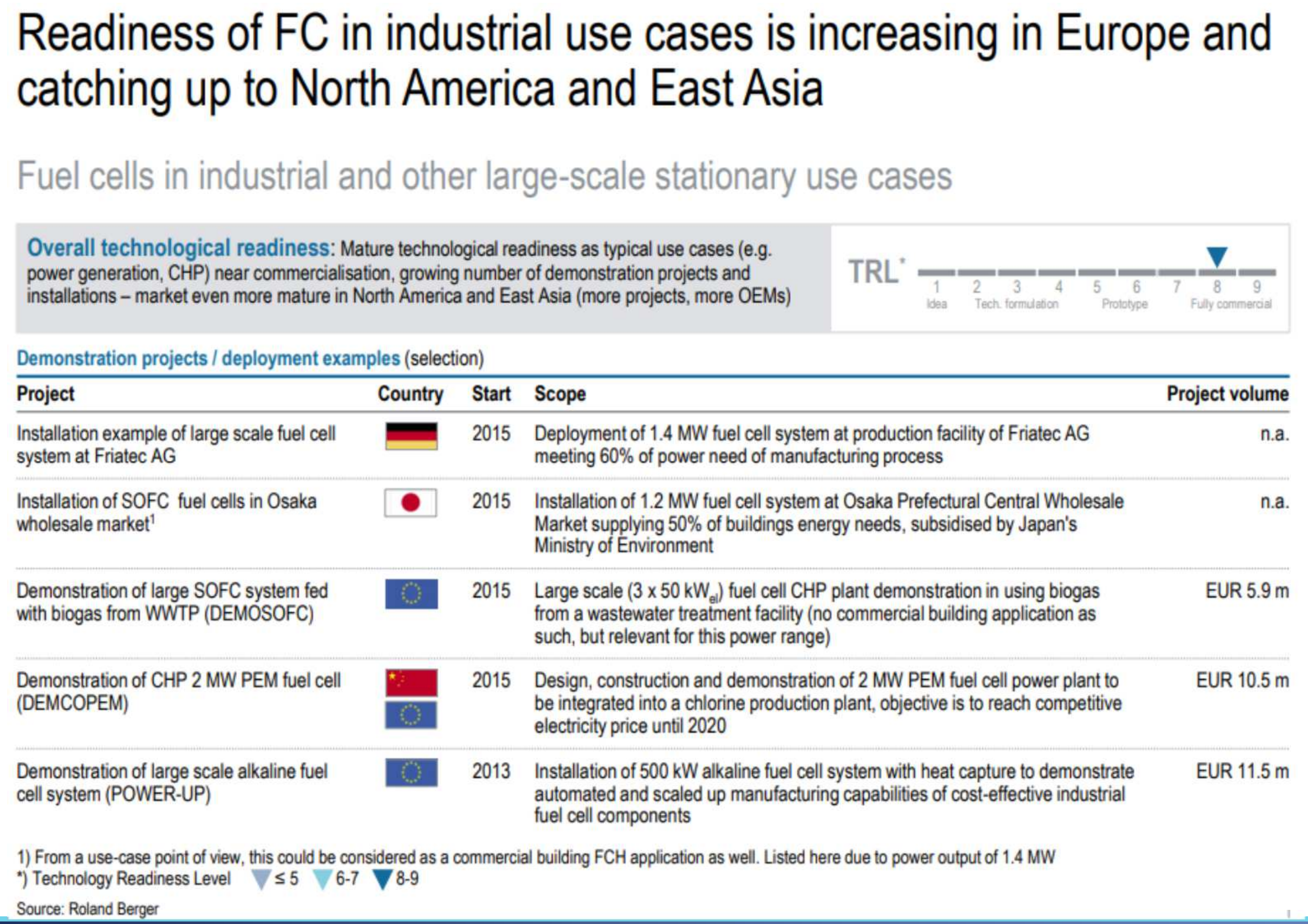
**Fuel cells in industrial use cases**[1]

| | |
|---|---|
| Key components | Fuel cell stacks, system module, inverter, heat exchange, storage |
| Fuel cell technology | AFC, MCFC, SOFC, PAFC, PEM |
| Fuel | Primarily natural gas, but also biogas and hydrogen (if on site) |
| Efficiency | ~50%$_{el}$, combined >80% |
| Output | typically > 400 kW$_{el}$, up to multi-MW$_{el}$ |
| Approximate capital cost | dep. on use case and market environment, ca. EUR 4,000-5,000 per kW$_{el}$ (fully installed) |
| OEMs, system integrators | FuelCell Energy, AFC Energy – (Bloom Energy, Doosan, etc.) |
| Fuel cell suppliers | Nedstack, FuelCell Energy, AFC Energy (Bloom Energy, Doosan, etc.) |
| Typical customers | Utilities, ESCOs, energy-intensive industrial manufacturers, wastewater treatment operators, data centre operators, etc. |
| Competing technologies | Gas boilers + power grid, combustion engines, micro-turbines |

1) Focus on European market

Source: Roland Berger

## Grado de madurez y horizonte temporal



### Readiness of FC in industrial use cases is increasing in Europe and catching up to North America and East Asia

Fuel cells in industrial and other large-scale stationary use cases

**Overall technological readiness:** Mature technological readiness as typical use cases (e.g. power generation, CHP) near commercialisation, growing number of demonstration projects and installations – market even more mature in North America and East Asia (more projects, more OEMs)

**Demonstration projects / deployment examples** (selection)

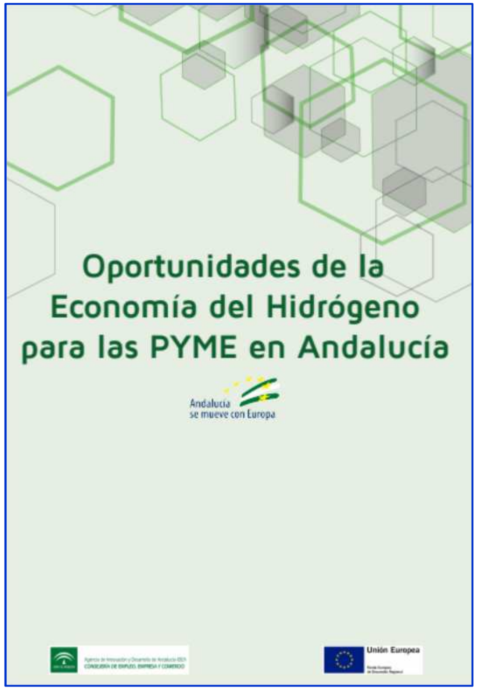
| Project | Country | Start | Scope | Project volume |
|---|---|---|---|---|
| Installation example of large scale fuel cell system at Friatec AG | 🇩🇪 | 2015 | Deployment of 1.4 MW fuel cell system at production facility of Friatec AG meeting 60% of power need of manufacturing process | n.a. |
| Installation of SOFC fuel cells in Osaka wholesale market[1] | 🇯🇵 | 2015 | Installation of 1.2 MW fuel cell system at Osaka Prefectural Central Wholesale Market supplying 50% of buildings energy needs, subsidised by Japan's Ministry of Environment | n.a. |
| Demonstration of large SOFC system fed with biogas from WWTP (DEMOSOFC) | 🇪🇺 | 2015 | Large scale (3 x 50 $kW_{el}$) fuel cell CHP plant demonstration in using biogas from a wastewater treatment facility (no commercial building application as such, but relevant for this power range) | EUR 5.9 m |
| Demonstration of CHP 2 MW PEM fuel cell (DEMCOPEM) | 🇨🇳<br>🇪🇺 | 2015 | Design, construction and demonstration of 2 MW PEM fuel cell power plant to be integrated into a chlorine production plant, objective is to reach competitive electricity price until 2020 | EUR 10.5 m |
| Demonstration of large scale alkaline fuel cell system (POWER-UP) | 🇪🇺 | 2013 | Installation of 500 kW alkaline fuel cell system with heat capture to demonstrate automated and scaled up manufacturing capabilities of cost-effective industrial fuel cell components | EUR 11.5 m |

1) From a use-case point of view, this could be considered as a commercial building FCH application as well. Listed here due to power output of 1.4 MW

*) Technology Readiness Level ▽ ≤ 5 ▽ 6-7 ▼ 8-9

Source: Roland Berger

## Más información



Oportunidades de la Economía del Hidrógeno para las PYME en Andalucía

Andalucía se mueve con Europa

Estrategia de desarrollo del hidrógeno en Andalucía en el ámbito de la Ris3

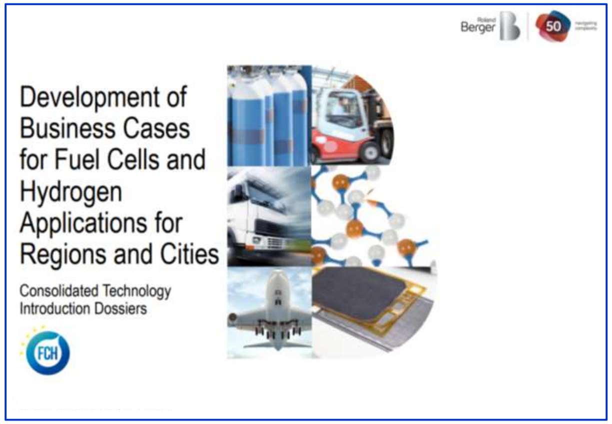
Andalucía se mueve con Europa

PLANIFICACIÓN DEL DESPLIEGUE DE LAS ESTACIONES DE SERVICIO DE HIDRÓGENO NECESARIAS PARA FACILITAR EL USO DE ESTE GAS COMO COMBUSTIBLE EN ANDALUCÍA

Andalucía se mueve con Europa

http://www.aeh2.org/index.php?option=com_content&view=article&id=94&Itemid=37&lang=es

## Más información



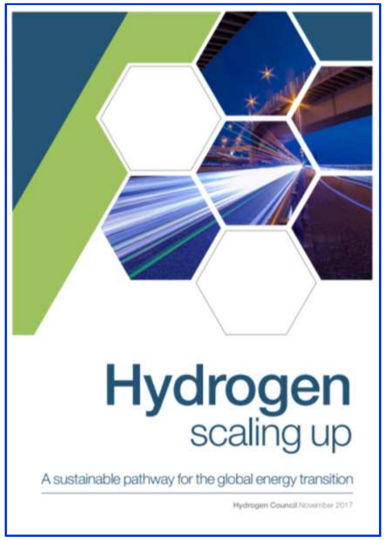
Development of Business Cases for Fuel Cells and Hydrogen Applications for Regions and Cities

Consolidated Technology Introduction Dossiers

http://www.fch.europa.eu/page/presentations-2

http://hydrogencouncil.com/wp-content/uploads/2017/11/Hydrogen-Scaling-up_Hydrogen-Council_2017.compressed.pdf

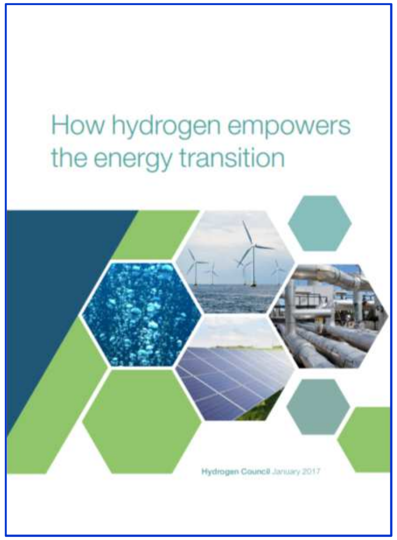
http://aeh2.org/images/stories/AEH2/Docs_Externos/20170109-hydrogen-council-vision-document.pdf



Hydrogen scaling up

A sustainable pathway for the global energy transition

Hydrogen Council November 2017



How hydrogen empowers the energy transition

Hydrogen Council January 2017