Hydrogen In Gas GridS: a systematic validation approach at various admixture levels into high-pressure grids

Introduction to the HIGGS project

Laura Abadia (FHa)

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 875091 'HIGGS'. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

Background of the project

Why do we need Hydrogen in the gas grid?

How to counter climate change is on top of the agenda

- Worldwide: Paris Agreement
- EU: “Green Deal”

Hydrogen is considered one of the key actors:

- Allows linking key sectors
- Main contributor to allow a wider penetration of renewable sources – by decarbonising the gas grid
- Provides large scale storage options
- Can absorb the excess of renewable electricity production and provide flexibility to the electricity grid

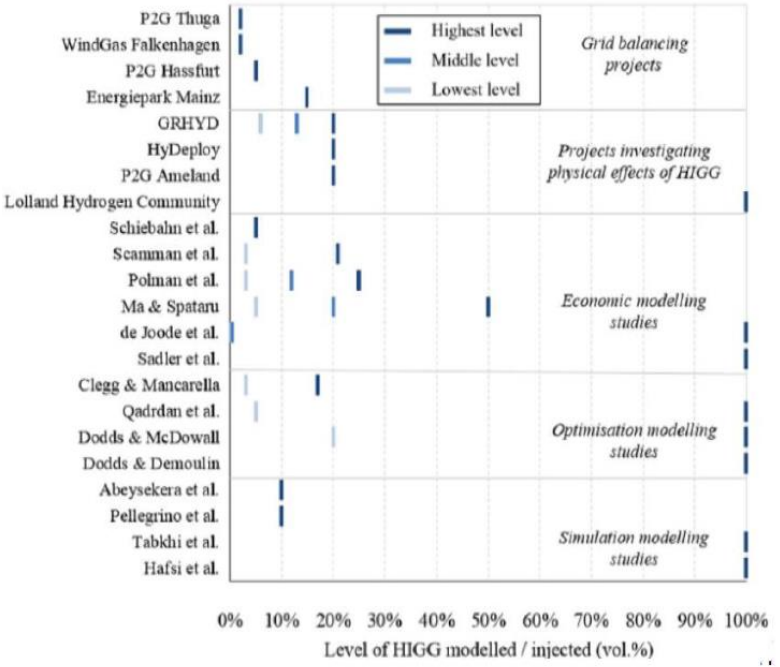
Hydrogen acceptance of the Natural Gas infrastructure is elementary to elevate the potential!

Background of the project

Why do we focus on the high pressure grid?

1. IEA 2003 report: 12% admixture – compromise between investment cost and CO2 emissions reduction
2. NREL suggests 20% in DSO and even higher in TSO
3. Other suggests 10% for the Grid, as is (with regional exeptions)
4. Numerous demo-projects have been done, but mainly linked to the distribution grid.

Consolidated knowledge across EU for hydrogen tolerance in high pressure grid is needed

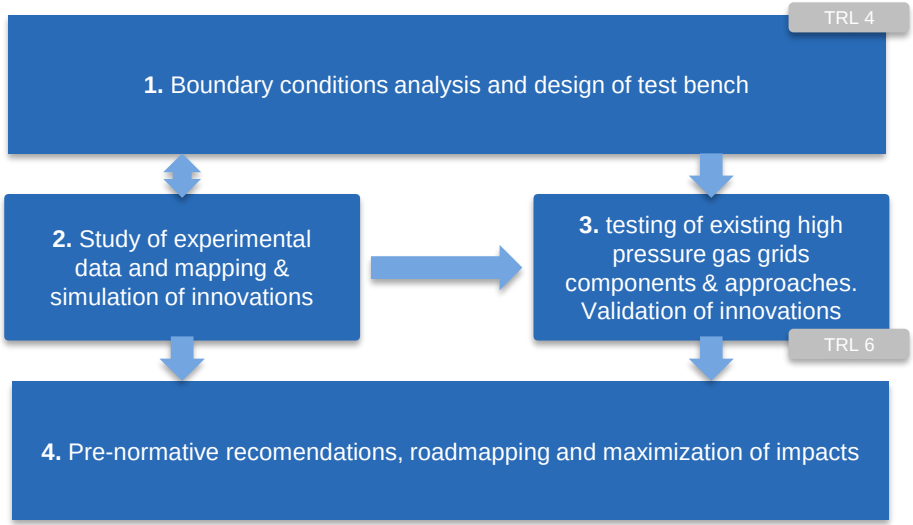


Background of the project

Pave the way to decarbonisation of the gas grid by…

covering the gaps of knowledge of the impact that high levels of hydrogen could have on the gas infrastructure, ist components and ist management.

1. Set up and operate a research and development platform reproducing all the components of a high-pressure network and allowing testing of various technology developments for various H2/CH4 admixtures
2. Revision of technical, legal and regulatory barriers
3. Techno-economic models
4. Development of a dissemination and exploitation plan, interaction and synergies with other related projects and activities



Key Data:

- Start: January 2020
- Duration: 36 month
- FCH-JU (Grant N. 875091)
- Hydrogen concentration levels: up to 100% (Static/Dynamic)
- Pressure Levels 40-80 bar

Fha – Foundation for the development of new hydrogen technologies in Aragon

DVGW - German Technical and Scientific Association for Gas and Water

HSR – Hochschule für Technik Rapperswil

Redexis

Tecnalia

ERIG – European Research Institute for Gas and Energy Innovation

HIGGS

Hydrogen in Gas Grids

WP 2 - Legal, regulatory and technical aspects

identification and follow-up

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 875091 'HIGGS'. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

Legal, regulatory and technical aspects - identification and follow-up

Main Objective is to…

…provide updated information to HIGGS on present

- **regulations,**
- **standards and**
- **certifications**

for the equipment and infrastructure of high pressure grids, together with

- **components characteristics**

to identify and follow up those critical aspects where HIGGS will continue the investigations and needed innovations with respect to the current state of the art

Specific Objectives are:

1. **Investigation** on the present regulations, standardizations and certifications (RSC) of the EU
   a) on limitations with respect to hydrogen concentrations in the gas system
   b) on the corresponding standards.
2. **survey** on existing equipment in natural gas grids.
3. **Identification of and recommendations** for most critical RSC bottlenecks
4. **Setup of mitigation measures** for existing gas appliances and gas system

-> enabling the end users and operators to operate the entire gas system safely without forcing the operators/owners to replace equipment and appliances before their end-of-life, when it comes to higher hydrogen concentrations in natural gas.

How will the objectives be achieved

Tasks carried out in the Workpackage

- **Mapping and update of RCS at EU level: barriers and enablers**
- **Detailed look at Natural Gas equipment and infrastructure**
  - Inventory and quantification of existing assets
  - Hydrogen sensitivity of assets elements with good knowledge availability
  - Covering gaps on hydrogen sensitivity knowledge base

INVENTORY AND QUANTIFICATION OF NATURAL GAS TRANSMISSION FACILITIES' SURVEY	
Operator, Association or Organism Name:	
Type:	Transmission Operator / Association / Organism / ...
Country(s) for which information is provided:	

PIPELINE									
Length (km) depending on pipe steel quality and on diameter									Len
Diameter	API 5L Gr B	API 5L Gr X42	API 5L Gr X60	API 5L Gr X70	API 5L Gr X80	Other (to be specified)	Other (to be specified)	TOTAL	≤ 59 bar
2"								0,00	
3"								0,00	
4"								0,00	
6"								0,00	
8"								0,00	
10"								0,00	
12"								0,00	
14"								0,00	
16"								0,00	
18"								0,00	
20"								0,00	
22"								0,00	
24"								0,00	
26"								0,00	
28"								0,00	
30"								0,00	
32"								0,00	
34"								0,00	
36"								0,00	

Present and near future activities

Data collection and analysis

Gathering information on NG equipment and infrastructure in quantities:

- Pipeline materials, age and length
- Installations in the gas net like
  - Compressors
  - Underground storages
- Replace time
- Present hydrogen sensitivity
- Preparing dedicated information on the most sensitive assets

→ Necessary for the material tests

Mapping and updating Regulations, Codes and Standards in the EU

- Review State-of-the-Art documents from
  - CEN-CENELEC Sector Forum Energy Management
  - AFNOR
  - Marocgaz
  - DVGW
- Strong observation on the regulation to hydrogen injection (concentration)
  - Present
  - Near future
  - future

HIGGS

Hydrogen in Gas Grids

WP 3 - Design, preparation and commissioning of testing facilities

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 875091 'HIGGS'. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

Background

Need for research

- After hydrogen is produced, the goal is to **transport** it with the minimum investment. **Current gas grid** is a possibility

- However, the different components of the gas grid are not designed for the transport of high amounts of hydrogen and the **impact**of transporting high amounts of this gas **is unknown.** R&D is therefore necessary to check the technical readiness of the gas infrastructure and decide suitable modification measures.

→ Infrastructure and auxiliary facilities:

Pipelines Positions Scraper traps
Regulation and metering stations Compressor stations
Storage Gas analysis and sensors Flow measurement
Seals welding connections

- Lastly, once transport is done, there is the need to **extract** hydrogen from the **admixture.** Precesses based on **membranes** are considered as the most promising technologies for <20% H2/CH4 content.

Design, preparation and commissioning of testing facilities

Main Objective is to…

…To develop the **R&D platform** where the **experimental validation** of components will be carried out during HIGGS project.

Specific Objectives are:

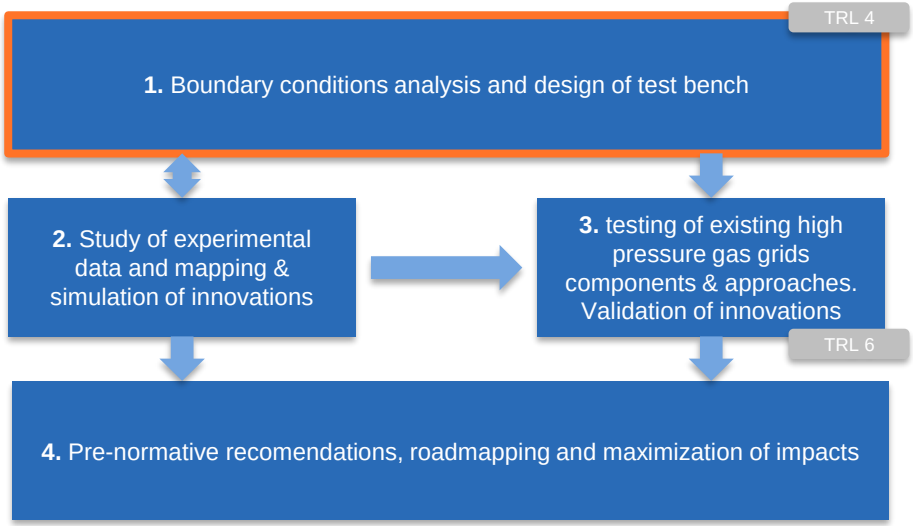
Desing and implementation of a R&D testing platform composed of:

- **a testing loop** designed to work up to 80 bar, including the main **components** needed to recreate the operational environment **of a high-pressure gas grid,** with continuous control of parameters such as gas quality, flow and pressure.
- a **hydrogen purification prototype** based on **membrane technology for separation of H_2/CH_4** mixture at high pressure including first lab-scale testing of its components
- **an injection platform** that recreates the **injection of** different flows **electrolytic H_2 into a natural gas** with variable compositions

How will the objectives be achieved

Tasks carried out in the Workpackage
(FHA, Redexis, Tecnalia)

- **Design and selection of components**
- **Permits, licenses and site preparation**
- **Procurement, assembly and commissioning**
- **Study on needs for adaptations, maintenance and update of the platform**



Outlook and next steps

Design parameters for…

- **Hydrogen**
  - 0-100% Hydrogen
  - Total gas flow in the loop ≈ 56 Nm^3/h
  - Maximum H_2 feeding rate: 0.8 kg/h
  - Purity: >99,99% (corresponding to electrolytic hydrogen)

- **Natural Gas**
  - Operating pressure
    - 40-80 bar
  - Impurities depending on te origin to simulate
    - CO_2
    - H_2S
    - Etc.

HIGGS

Hydrogen in Gas Grids

WP 4 - Systematic and experimental validation

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 875091 'HIGGS'. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

Background

Need for research

- The biggest concern for safety when admixing hydrogen into the natural gas (NG) grid is related to **materials deterioration and embrittlement (HE)**.
- Hydrogen can cause degradation of **metallic components** of the gas grids, especially when present for long periods and at high concentrations and pressures.
- This phenomenon is **not only limited to piping** but should be also considered for other elements of the infrastructure (piping, valves, compressors, storage tanks, industrial equipment etc.)
- A **comprehensive mapping of the materials** used in the gas-networks is needed to document the materials sensitivity to hydrogen.

Systematic and experimental validation

Main Objective is to…

… to define a **comprehensive mapping of the materials** used in the gas-networks and their sensitivity to hydrogen presence.

Specific Objectives are:

1. **Define a laboratory test protocol** to assess the behaviour of metallic alloys in presence of high pressure hydrogen/NG mixtures.
2. **Identify and test existing materials** used for the natural gas grid.
3. **Provide recommendations for material to be used in high pressure hydrogen/NG mixtures.**

HIGGS

Hydrogen in Gas Grids

WP 5 - Techno-economic modelling and validation, enablers and interoperatibility

Dr. Luiz Carlos R. de Sousa - HSR

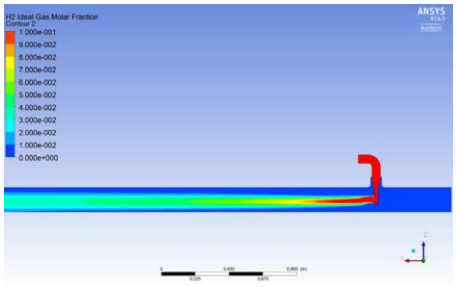
FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

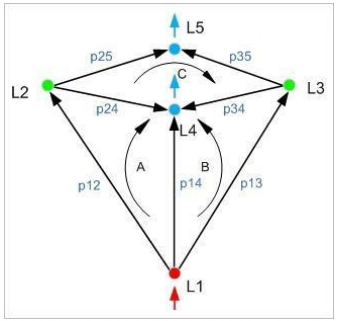
This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 875091 ‘HIGGS’. This Joint Undertaking receives support from the European Union’s Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

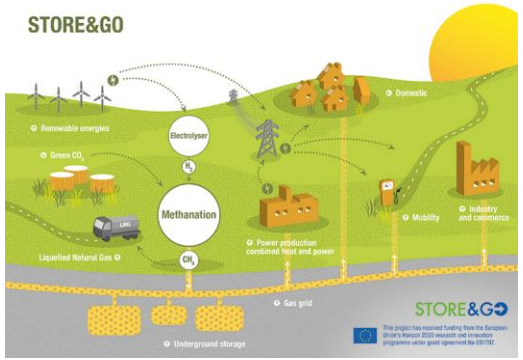
Background

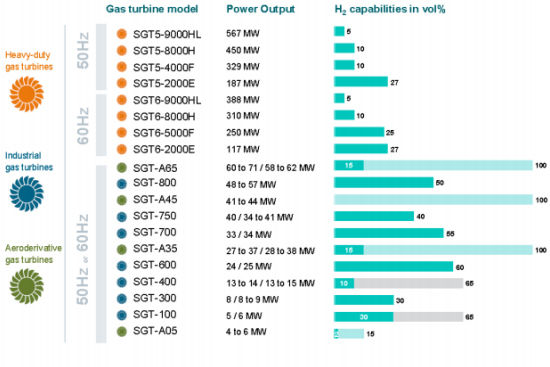
Modelling for many purposes

- Existing grid models do not contemplate H_2 mixtures
- Mixing, resulting composition and gas quality at different points in the grid with changes over time
  - Meet customers requirements
  - Impact of grid elements on H_2 levels
- What level of H_2 can be allowed where
  - Existing equipment limitations
- Manage intermittent & dynamic H_2 sources
  - Direct injection or power-to-methane or …
- Need for additional CAPEX
  - e.g. instruments, separation equipment …
- Business cases for higher hydrogen levels









Unrestricted © Siemens AG 2018

Techno-economic modelling and validation, enablers and interoperatibility

Main Objective is to…

…develop **operation strategies** and **business implications** of increased and variable contents of hydrogen in the high-pressure transmission grid. Show how **increased hydrogen content** in the high pressure gas grid can contribute to the overall goals of **reduced carbon emissions** from the energy sector

Specific Objectives are:

1. **Define case studies** for operator of high pressure gas grids, gas buyers or gas producers injecting hydrogen.

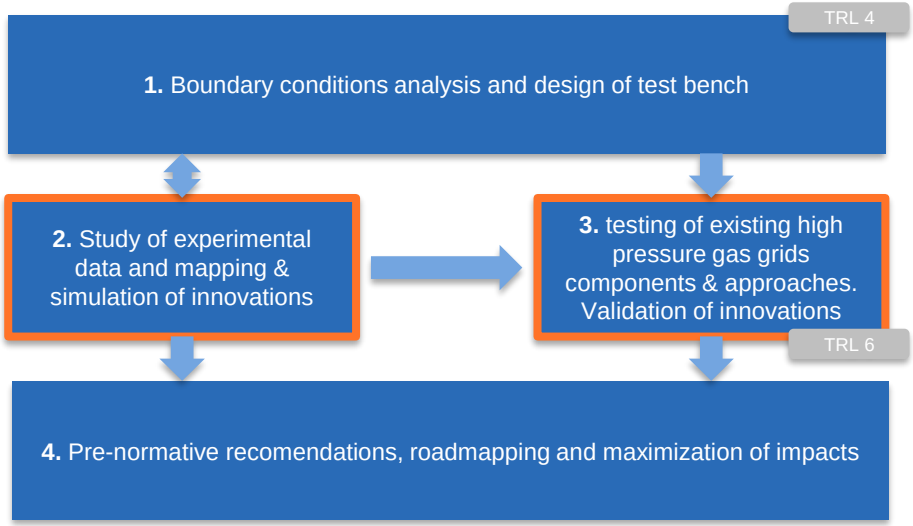
2. **Define generic structures** of the high-pressure transmission grid relevant in the European context.

3. **Compile a numerical model** to describe technical operation and business impacts of high pressure grid.

How will the objectives be achieved

Tasks carried out in the Workpackage

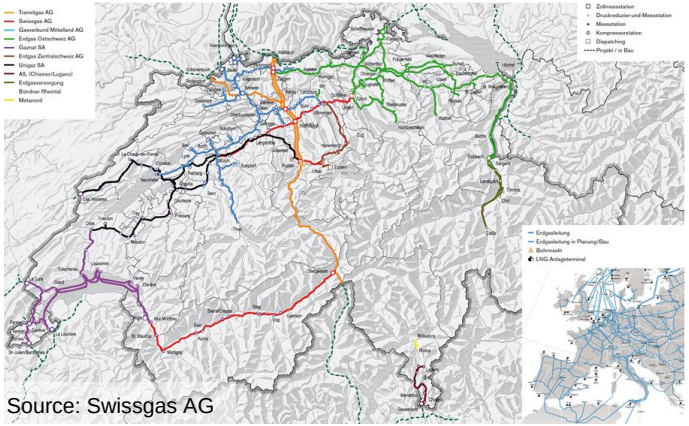
- **Baseline and case studies definition**
- **Techno-economic modelling**
  - Modelling not considering future gas separation technologies
  - Modelling including technology innovations needed
  - Techno-economic assessment of the gas separation technology
- **Evaluation of results and compilation of recommendations**



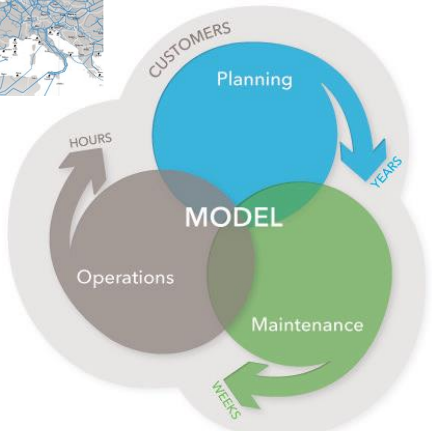
Outlook and next steps

Initiate Activities at HSR

- Initiate literature study
- Review grid modelling software
- Identify elements for HPGN topology
- Start mapping HPGN stakeholders
  - Operators
  - Customers
  - Hydrogen producers



Source: Swissgas AG



Source: DNV GL AS

WP 6 - Description of pathway towards integrating H2 in EU gas networks

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 875091 ‘HIGGS’. This Joint Undertaking receives support from the European Union’s Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

Description of pathway towards integrating H2 in EU gas networks

Main Objective is to…

…establish a compilation of the main findings and assessments during the project, in the form of a document with a pathway to enable higher concentrations of hydrogen in the natural gas transmission grid

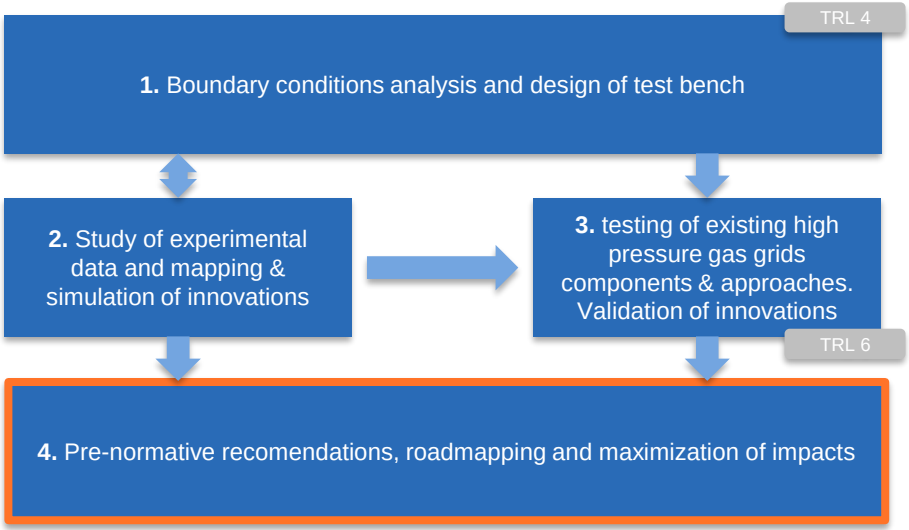
Specific Objectives are:

1. **Documenting the potential** of hydrogen injection as enabler towards EU policies on decarbonisation.
2. **Establishing a list of potential issues**, barriers and facilitators for cross-border and interoperability in the gas grids.
3. **Make a summary of the recommendations** for admixture and injection facilities, towards establishing an optimal design.
4. **Updating the recommendations on regulations codes and standards** for further development and higher acceptance of hydrogen in the gas grid

How will the objectives be achieved

Tasks carried out in the Workpackage

- **Potential for H2 injection: alignment with EU policies**
- **Interoperability, cross-border issues and gas market management and strategies**
- **Preparing a pathway and set recommendations towards a higher acceptance of H2 in EU gas grid network**
  - Optimal design for H2 injection and mixing systems
  - Gas market and operation considerations
  - Regulations, codes, standards



HIGGS
Hydrogen in Gas Grids

Thank you for your attention!

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 875091 'HIGGS'. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.