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#SESAAU2019

Analysis of the existing barriers and of the suggested solutions for the implementation of Power to Gas (P2G) in Italy

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Introduction and state of the art

Analysis of the barriers

The proposed solutions

Project started....

Conclusions

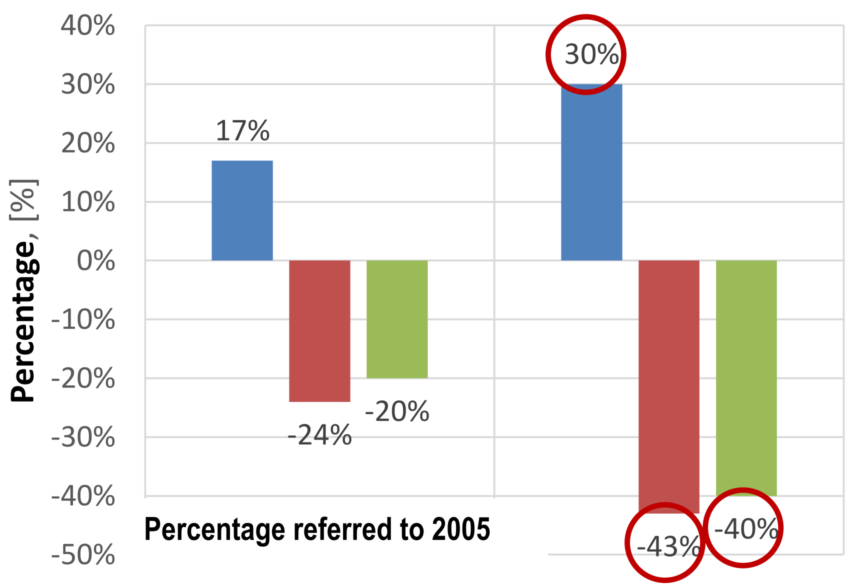
Italian Energy and Climate Plan

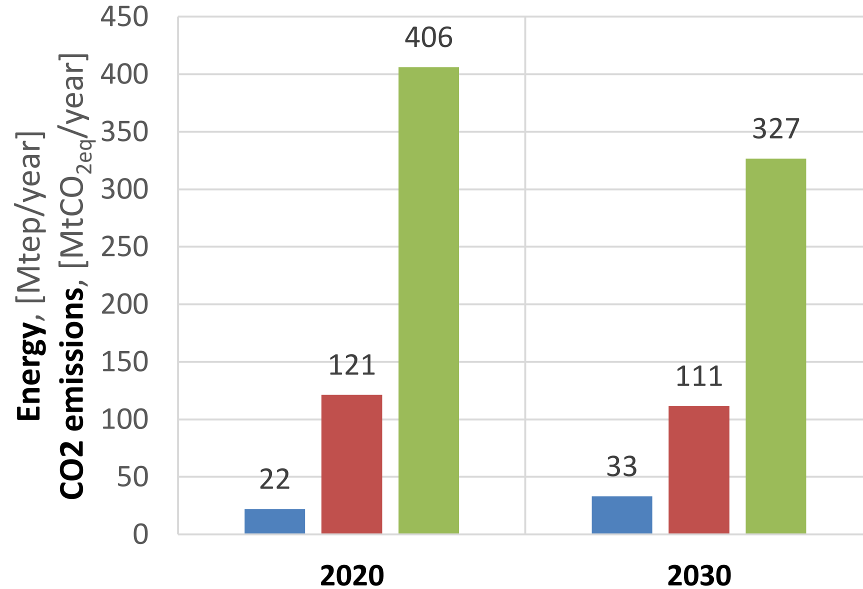
In 2019, the Energy and Climate Plan was proposed to define Italian energy strategy within 2030

Three main pillars are identified:

1. *Increase of renewables in final energy consumption*
2. *Increase of efficiency in energy utilisation*
3. *Carbon Dioxide emissions reduction*

ENERGIA CLIMA 2030





Italian Energy and Climate Plan

1. *Increase of renewable in final energy consumption*

Target = 33 Mtep/year

- **Electricity production from renewables**: 55,4% (+6580 ktep)
- **Thermal energy production**: 33,0% (+4150 ktep)
- **Transport**: 21,6% (-3900 ktep)

Target of the Authority

<u>*Energy balance*</u>:

$$\alpha \int_0^{365} \int_0^{24} P(t)dt\,dy = \int_0^{365} \int_{t_1}^{t_2} P_{ren}(t)dt\,dy \longrightarrow \uparrow\alpha\ (=55{,}4\%) \Rightarrow \uparrow\uparrow P_{ren}$$

<u>*Power balance*</u>:

$$P(t) + P_{storage}(t) = P_{ren}(t) + P_{fossil}(t) \Rightarrow$$ **issues of control and stability of the electric grid**

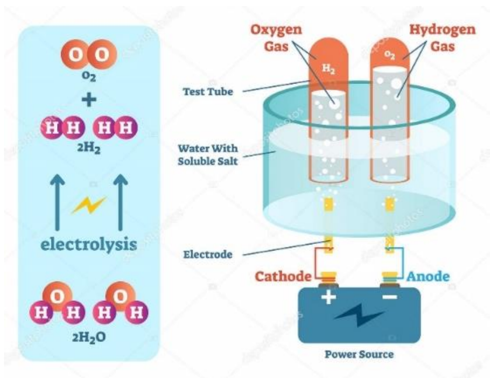
The future energy systems should allow generation flexibility of renewables.

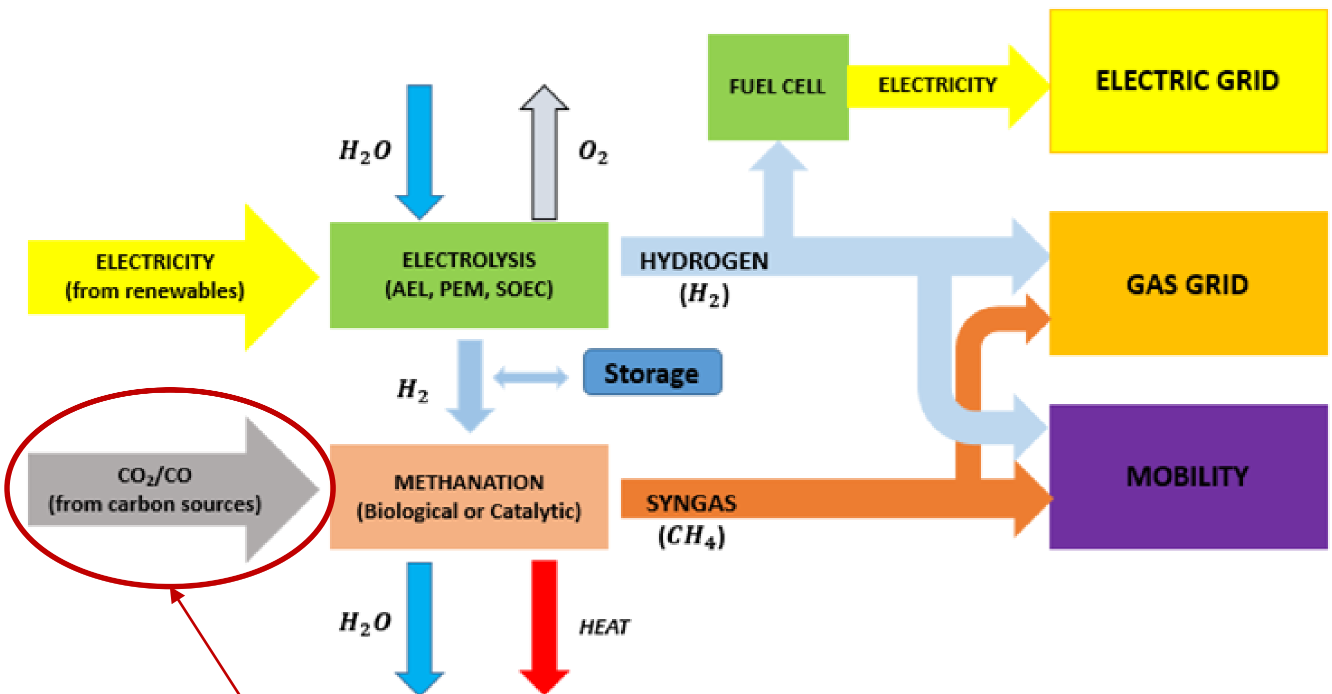
⇓⇓

<u>A mix of conventional and innovative solutions</u> should be introduced for the transition to **smart grids** and to the implementation of **energy storage plants** (86 ktep/day)

Power to Gas

Power to Gas process ensures the **connection between electrons and molecules**, converting the surplus electric power in gaseous fuel, such as hydrogen through **water electrolysis**.





Hydrogen from water electrolysis:

$$2H_2O + Electricity \rightarrow 2H_2 + O_2$$

Synthetic methane:

$$Air + Electricity/Heat \rightarrow CO_2$$

$$H_2 + CO_2 \rightarrow CH_4(Syngas) + 2H_2O + \text{Heat}$$

We also reduce carbon footprint!

AEM: Anion Exchange Membrane
PEM: Proton Exchange Membrane
SOEC: Solid Oxide Electrolyzer Cell

Power to Gas: H_2 demand

Furthermore, **a great demand of hydrogen is currently present in the world** (IEA, 2019):

- **Hydrogen (H_2) global demand**: 70 million tonnes per year.

Environmental impact:

- 48% from methane steam reforming (205 x 10^9 m^3 of gas) → 10 tCO_2/tH_2
- 30% from oil → 12 tCO_2/tH_2
- 18% from coal → 19 tCO_2/tH_2
- 3,9% from **water electrolysis** → **0 tCO_2/tH_2** if renewable electrical energy is used
- 0,1% is produced from other sources

TOT:
830 Mton/y of CO_2

Energetic impact:

- **275 Mtoe/y** totally required for production (2% of global total primary energy demand)
- Total production efficiency ≈ 73,0%

What if all is produced by P2G?

- **E_{el}: 3600 TWh** (> Annual European energy consumption) **and 617 million m^3 of water**

Therefore, **Power to Gas can only in part contribute to produce H_2 global demand reducing carbon footprint**

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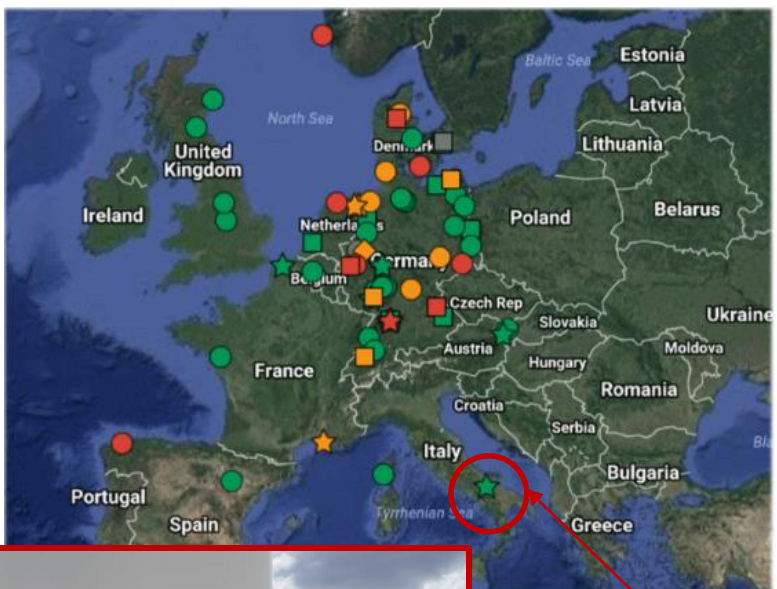
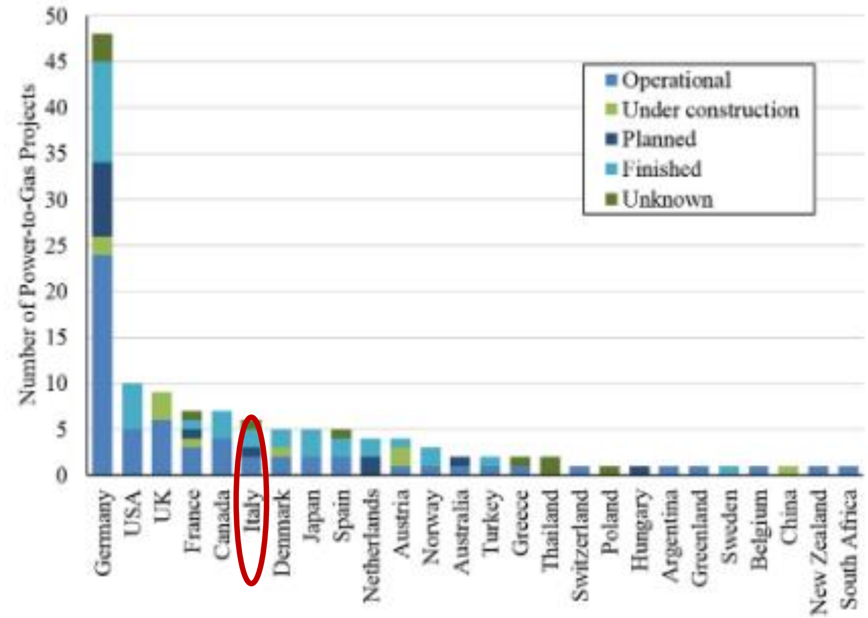
Power to Gas: plants in the world

- < 50 plants fully operational at 2018
- Installed capacity of ≈ 150 MW (Quarton and Samsatli, 2018).

Barriers must be analyzed to solve this gap!





Locations of Power to Gas projects. (Quarton and Samasatli, 2018)

Interactive map
www.europeanpowertogas.com/demonstrations

Store&Go demonstration plant

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The proposed solutions

Project started….

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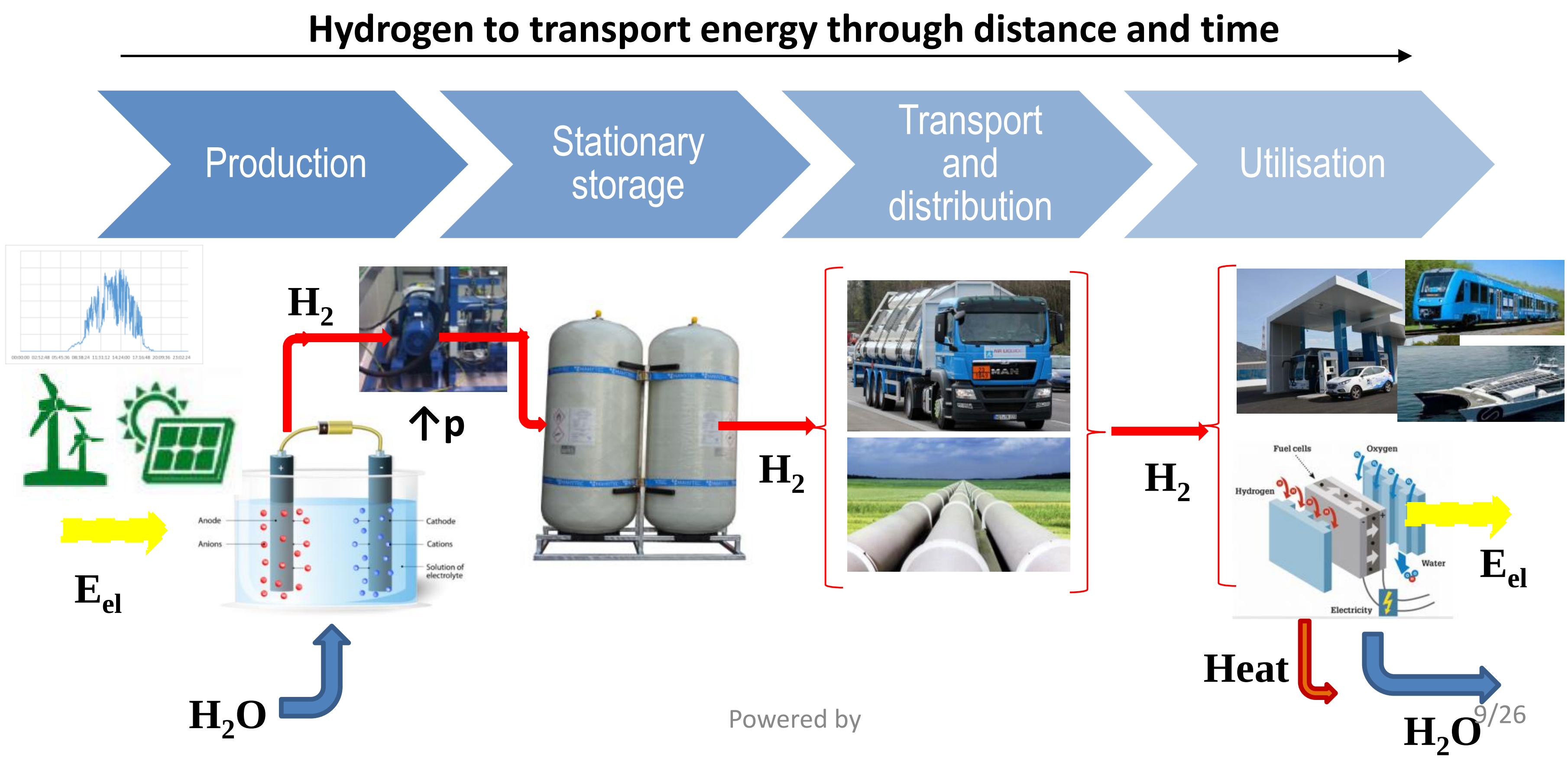
Analysis of the barriers

Several barriers have to be solved in order **to ensure the deep penetration of the Power to Gas into the market**.

To analyze them and to propose possible solutions, a preliminary and simplified hydrogen supply chain has to be introduced:



Analysis of the barriers

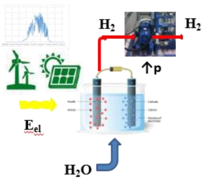
Through a careful analysis of literature, existing projects, standards and other documents the following **barriers classification** was considered:

1. **Economic barriers**: negatively influence project economic feasibility
2. **Technical barriers**: obstacle technology development but can be solved through an intensive and dedicated R&D activity

In accordance to the **HyLaw project** also the following were reported:

3. **Structural barriers**: a non adapted regulation which prevents or seriously hinders the development of Power to Gas projects
4. **Operational barriers**: obstacle Power to Gas projects but can be solved during execution of the specific activity
5. **Regulatory barriers**: due to the complete absence of regulation respect to a specific topic, create great uncertainty about the end result of the project.

Analysis of the barriers



1. Production of hydrogen through Power to Gas

Identified barrier	Type	Reasons
Definition of Power to Gas (P2G)	Regulatory	No clear and unequivocal legal position is present in Italy
Land use plan	Structural	Hydrogen production is considered as an industrial activity → authorization and construction constraints
Permitting processes	Operational	Very complex, long and uncertain permitting process is required for authorization
Permitting requirements	Operational Regulatory	Unclear and complex interpretation of procedures → overprotection measures
Technology CAPEX and OPEX	Economic	High investments (450 – 5000 $/kWel) and operative costs → Levelized Cost of Energy (LCOE) greater than traditional fuels
Electrolyser power supply	Economic Regulatory	No regulatory framework is present about the utilisation of electrolyser as a electricity load balancing device
Technology efficiency	Technical	Low efficiency [60%; 85%] → high energy losses

Analysis of the barriers

2. Stationary storage of hydrogen

Identified barrier	Type	Reasons
Land use plan	Structural	Hydrogen production is considered as an industrial activity → authorization and construction constraints
Permitting processes	Operational	Very complex, long and uncertain permitting process is required for authorization
Permitting requirements	Operational Regulatory	Unclear and complex interpretation of procedures → overprotection measures
Storage characteristics	Economic Technical	Because of low density (0,0899 kg/Nm3) high volumes or pressure are required to store H_2. To store the daily production from a 1 MW_{el} plant (8 h/day at full load with an efficiency of 60% (i.e. 240 kgH_2/day)): **V = 2670 m^3 at nominal conditions** (p = 1atm, T = 0°C) → size↑ (€↑↑) **V = 7,6 m^3 at 350 bar and T = 0°C** → high cost expected for components. Furthermore, electrical consumption of compressor has to be added to production cost → E_{el} = 116659 kJ/kg → **+ 1,53 €/kg**. Liquid Hydrogen. Despite the lower size, very high costs are required to liquefy and maintain liquid H_2

Analysis of the barriers

3. Transportation and distribution of hydrogen: road transportation

Identified barrier	Type	Reasons
Permitting framework	**No barrier**	No barrier are present. (ADR 2017 and D.M. 12/5/17) are valid even if some insights are still required about risk assessment
Quantity and pressure indication	Technical Structural	Limitation in the quantity of product to be transported due to: • Existing rules • Components stress limits
Transport cost	Economic	As shown in (EIA, 2019), road transportation cost has an important impact on the final cost of H_2. **Transport cost [€/kg H_2] = 0,0031 [€/km] x L [km] + 0,07** Production and utilization locations shall be the nearest as possible → geographic constraint

Analysis of the barriers

3. Transportation and distribution of hydrogen: pipe transportation

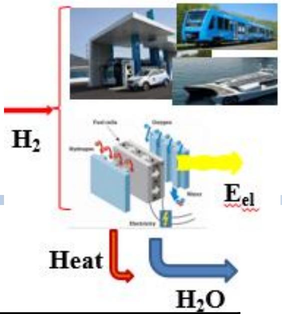
Identified barrier	Type	Reasons
Permission requirements	Regulatory	No clear rule for H_2 injection in existing gas grid (more than 290,000 km, i.e. 15,6 km/km^2). An experimental activity was started by SNAM (main Italian gas TSO) at Contursi Terme to inject up to 5% of H_2 in the grid last 1st of April. **What if?** Italian gas consumption: 29 x 10^9 Nm^3/y Hydrogen to be injected: 1,5 x 10^9 Nm3/y = 1,35 x 10^8 kg/y = 4,5 x 106 MWh/y Consumed electrical energy: 7,5 x 10^6 MWhel/y (5% of the expected renewable production at 2030)
Payment issue	Regulatory	No payment framework is present → very difficult relationship between H_2 producers and grid operators
Gas quality requirements cost	Technical Structural	Existing framework does not define how to measure and to monitor gas mixture characteristics → Wobbe index, calorif value, risk of flame spreading, interaction with materials, and other ones should be defined in standards **What if 5% in volume?** Natural gas LHV: 39163 kJ/Nm^3 Hydrogen LHV: 10788 kJ/Nm^3 Gas mixture LHV: 37744 kJ/Nm^3 (-3,6%) → **Higher volumes to ensure a specific energy need (billing issues).**

Analysis of the barriers

3. Transportation and distribution of hydrogen: pipe transportation

Identified barrier	Type	Reasons
Safety requirements at the grid operator	Structural Technical	Existing technical standards and framework does not account hydrogen injection in national gas transportation and distribution grids. Existing plants and BoP are not certified for the use with H_2.
Safety requirements at the end users	Technical Economic Structural	Existing appliances are not certified for H_2. Possible requirements to substitute devices to guarantee safety performances. Existing technical standards and framework does not account hydrogen.
New skilled required	Technical	Currently no experiences, know how and procedures are available for mixture of natural gas and hydrogen. Existing risk assessments and preventive solutions could be not valid.

Analysis of the barriers



4. Final utilization

Identified barrier	Type	Reasons
Type of approval	Operational	Several devices supplied by hydrogen are not contained in legislative framework, i.e. H_2 fueled vehicle
Service and maintenance	Regulatory	No rules are usually present for services, maintenance and technical inspections
CAPEX, OPEX and incentives	Economic Regulatory	High CAPEX and OPEX costs discourage mass market approach (H_2 cars costs 2,5 times traditional cars) No stimulating measures are also present due to the regulatory lacks
Easy to be used	Technical Structural Operational	Low confidence of possible customers in H_2 products. In fact, many gaps in legislative/regulatory framework and technical issues creates doubts in possible customers.

Analysed barriers

			PRODUCTION		
Barrier	*Economic*	*Technical*	*Structural*	*Operational*	*Regulatory Gap*
Land use plan					
Permitting processes					
Permitting requirements					
Technology CAPEX&OPEX					
Technology efficiency					
			STATIONARY STORAGE		
Barrier	*Economic*	*Technical*	*Structural*	*Operational*	*Regulatory Gap*
Land use plan					
Permitting processes					
Permitting requirements					
Size					
			TRANSPORTATION AND DISTRIBUTION		
			Road transportation		
Barrier	*Economic*	*Technical*	*Structural*	*Operational*	*Regulatory Gap*
Quantity and pressure indication					
Distance vs Cost					
			Pipe transportation - distribution		
Permission and restriction					
Payment issues					
Quality requirements					
Safety requirements at the operators					
Safety requirements at the end users					
New skilled required					
			UTILIZATION		
Barrier	*Economic*	*Technical*	*Structural*	*Operational*	*Regulatory Gap*
Type of approval					
Incentives					
Services and maintenance					
Investment cost					
Number of refueling station					

Dedicated solutions have to be identified for:

Economic barriers

Technical barriers

Regulatory, legislative barriers

This qualitative assessment will be compared with the formulation of a dedicated questionnaires survey.

LOW MEDIUM HIGH

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Conclusions

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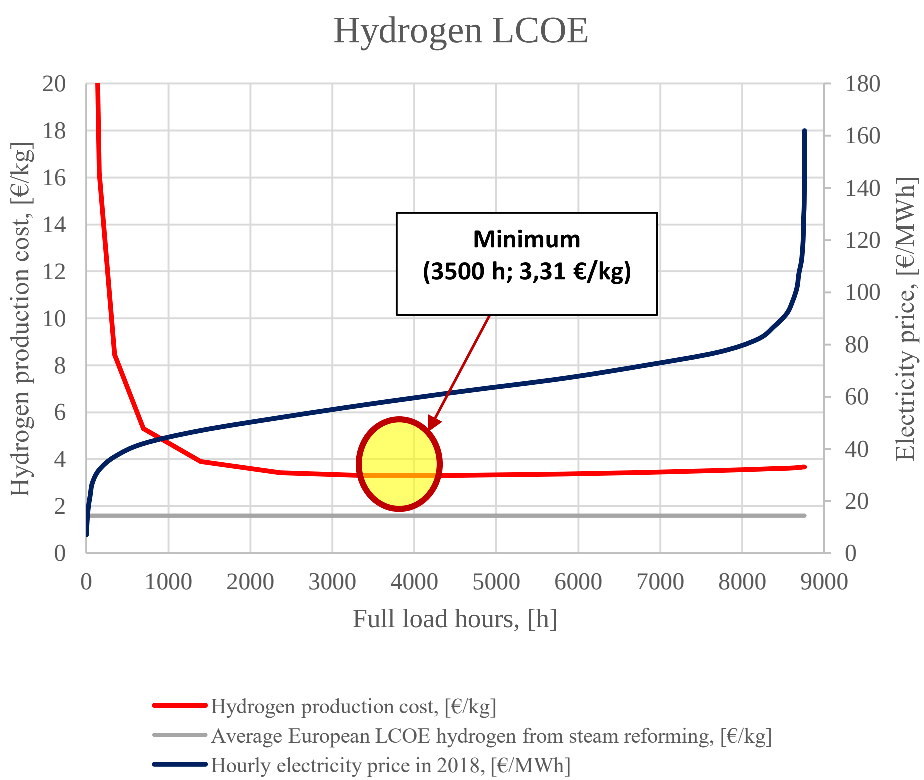
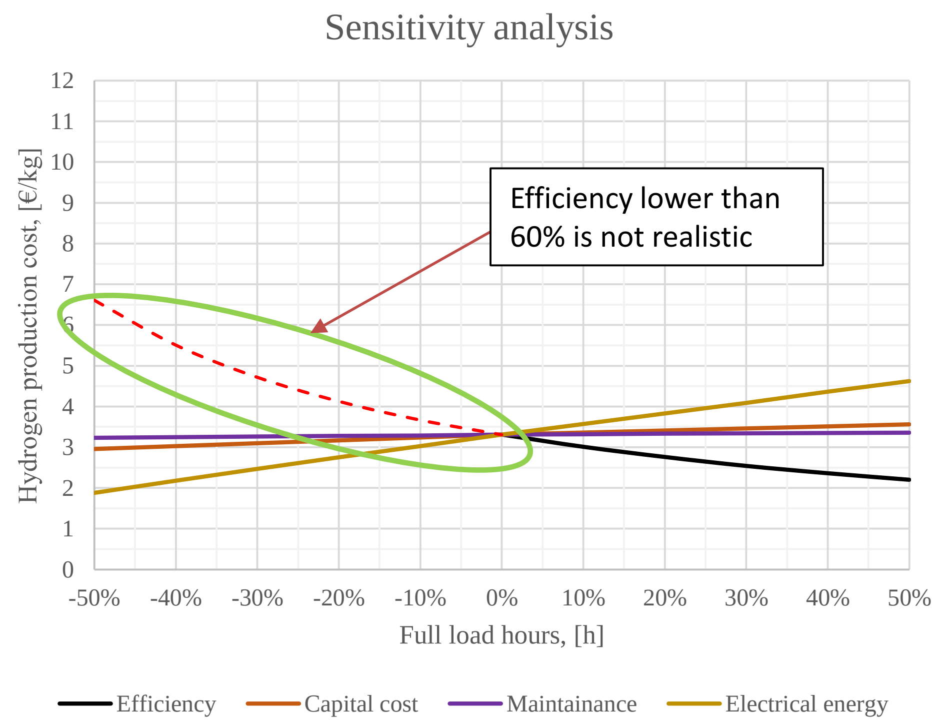
Economic barriers. An example: LCOE for hydrogen production in Italy





Assumptions:

1. CAPEX: 450 €/kW – Alkaline electrolyser
2. η=0,64
3. Maintanance cost: 2% of initial investment
4. Discount rate: 4%
5. Analysed period: 20 years

LCOE is mainly influenced by system efficiency and electrical energy cost.

Dedicated tariffs, incentives and technology improvements are so necessary to stimulate the market

The proposed solutions

Technical barriers

1. **A review of the relevant technical issues** and several surveys should be performed to ensure "easy to be used" solutions

2. **A careful analysis of components** (instrumentation, piping, equipment, appliances, etc.) **and of their integration is necessary to ensure the best performance in terms of total efficiency and safety**

2. **An improvement of water electrolysis efficiency** is required → experimental activities of Universities, R&D centers and companies is required

3. New materials, high efficient compressors and/or integrated solutions should be investigated.

4. **Dedicated courses and risk assessments** should be performed **to improve know-how of H2 gas mixtures**

↓↓

Projects about P2G should be encouraged involving all of the supply chain stakeholders

The proposed solutions

Regulatory, legislative barriers

1. First of all, Power to Gas (P2G) should be included in the definition of "storage systems". Because of the evolution of energy systems, all possible energy forms should be included.
2. To delete the presence of uncertain, long and complicated permission processes:
   - Power to Gas should be considered differently respect to an industrial activity
   - Simplified process should be defined for experimental and demonstrators
   - Dedicated and clear framework should be established for Power to Gas in Italy avoiding over constrained permission procedures
3. Italian energy Authority (ARERA) should establish an operational basis and legal framework regarding the access to the gas grid, the identification of payments, tariffs or incentives but also the minimum performances in terms of safety (HyLaw, 2019)
4. A clear definition of hydrogen devices should be given by Italian policy makers ensuring:
   - The definition of rules to be applied
   - The identification of incentives and of other support measures

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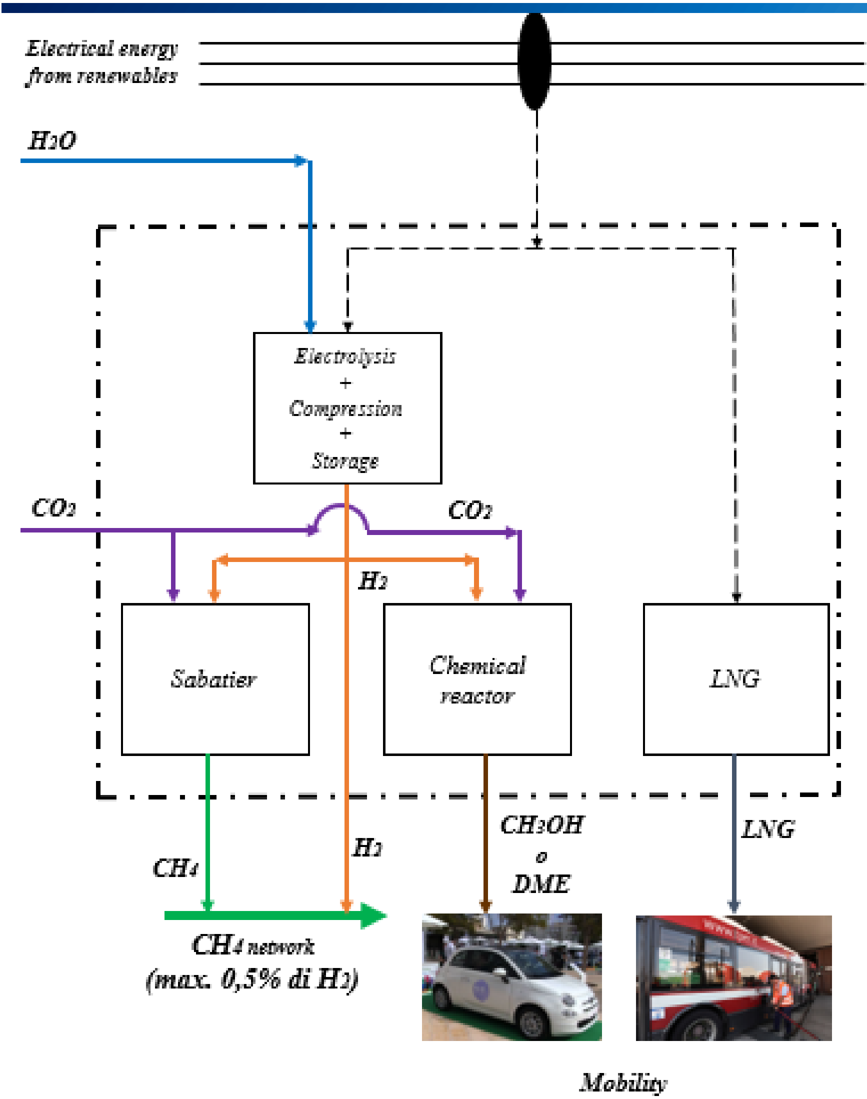
Conclusions

E-CO2



National founded project

Aims of the project:

- To provide an estimation, on a regional scale, of the potential production of CO_2 to be used for syngas production
- To experimentally characterize all the involved devices in the P2G chains
- To technically and economically demonstrate the potential use of synthetic fuels
- To identify models able to simulate all the involved technologies and processes based on experimental data

Duration: 2019 – 2020 (24 months)

Total funding: 768 k€ (from Emilia Romagna region)

Involved partners: 4 Universities/Research centre.
4 industrial partners are also involved: a cement plant operator, a gas DSO, a bus company, an equipment producer

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Conclusion

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1. **Power to Gas (P2G) represents a very interesting and necessary solution to ensure the transition to the new renewable and low carbon expected scenario**

2. **The annual demand of hydrogen, 70 Mton/y, is mainly supplied by conventional processes being responsible for high CO_2 emission. P2G, instead, could contribute being a zero carbon hydrogen source**

3. **Several barriers are currently present in Italy resulting very difficult to operate P2G plants. In particular, technical, economic, operational, structural and economic gaps were identified in all the Italian P2G supply chain**

4. **Dedicated and very complex solutions are required to solve the barriers. Because of the number, an AHP approach should be considered for prioritization**

5. **Projects should be however encouraged to increase P2G public acceptability**

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