Power to Gas Technologies and Innovative Use of Existing Energy Infrastructures to meet long term CO$_2$ Neutrality Goal

LCS-Rnet  11° Annual Meeting  Rome 18 October 2019

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Outline

• Introduction

• Energy Storage Technologies and Power to Gas

• Assessment of technologies

• Hydrogen production and CO2 methanation

• Background activities at ENEA

• Conclusions and perspectives
“ENEA is the National Agency for New Technologies, Energy and Sustainable Economic Development, a public body aimed at research, technological innovation and the provision of advanced services to enterprises, public administration and citizens in the sectors of energy, the environment and sustainable economic development”

Its focus sectors are:

- energy technologies (renewable sources, energy storage, smart grids…), nuclear fusion and nuclear safety, energy efficiency, technologies for cultural heritage, seismic protection, food safety, pollution, life sciences, strategic raw materials, climate change…

Other institutional tasks are:

- National Agency for Energy Efficiency
- The National Institute of Ionizing Radiation Metrology
- Integrated Service for the management of non-electronuclear radioactive waste
• Today electricity sector is moving to higher RES penetration but… storage issues & balancing

• On the other hand 240,000 km of meshed gas network all over EU w/ 118 millions of end-users (45%)

• Today gas sector in EU covers 20-25% final energy demand but is traditionally oriented to fossil → NG

• Moreover in 2050 EU forsee a 80% reduction of GHGE on 1990 basis Climate Neutrality of Energy Sector

CLIMATE MITIGATION… ENERGY 75% EMISSIONS BUT SUSTAINABLE, SECURE & COMPETITIVE…

HOW TO MANAGE ALL?

Avoiding emissions replacing fossil fuels with renewables alternatives

Utilizing carbon dioxide in closed loops in industrial activities

Sequestering carbon dioxide in geological permanent storage
Renewable Energy Sources & Energy storage

Broad consensus on scenarios with 60% maximum electrification

2019 PNIEC 55% share of Electricity from RES at 2030 - 34%2017

Energy storage can contribute to peak shaving of vRES (wind & sun) avoiding surplus or deficit in power supply.

Daily production South Italy

PAST

intra week day

TODAY

weekend day

PAST

Higher penetration of RES in electricity market leads to the needed developing of daily and seasonal energy storage systems.
Energy Storage Technologies

1) Differ in capacity:

- Condensers, flywheel, batteries… compressed air energy storage, pumped hydro energy storage systems (BAU) can offer relatively limited capacity (40TWh in EU 5d)

- Power-to-Gas systems have potentially higher capacity with the actual gas storage capacity (1131 TWh not considering available linepack that has to be added)

2) Differ in time scale:

- Short, Medium, Long
- Seasonal
Existing Gas Grid & long term CO2 Neutrality Goal

• Renewable Gas can serve as a seasonal storage of renewable energy

BUT MORE!

• Gas networks can reduce the need for electricity network expansion
• Replacing NG by Renewable Gas enables climate-neutral energy end use!

• RG → Biomethane, Hydrogen, Synthetic Methane
  all coming from RES and biogenic sources - in the transition also blue hydrogen could be used
• Utilization of readily available gas infrastructure requires less investments
• Can speed up the transition to a future energy system also fostering security of supply
• Can ensure cost effectiveness from a societal perspective
Power to Gas Technologies

H₂O → Electrolizer → H₂, O₂ → Methanation → CH₄ → Gas Grid → End Users (Mobility, Heat supply, Storage)

Renewable Energy Sources not Programmable (vRESs)

Source CO₂

DAC, Biogas, Biomethane Plants
Syngas from biomass gasification
Geothermal fields, Soil gas and CO₂ sinks
CO₂ from Energy Intensive Industry (EII)

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Sector Coupling and Innovative Use of Grids

Power & Gas Grids: A new Paradigm…
Efficiency of P2H2 and P2M processes

H₂-Path

Renewable energy

<table>
<thead>
<tr>
<th>Component</th>
<th>Efficiency</th>
<th>Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current transformer and accumulator</td>
<td>94.1%</td>
<td>5.9%</td>
</tr>
<tr>
<td>Electrolyser (including auxiliary plants)</td>
<td>69.2%</td>
<td>30.8%</td>
</tr>
<tr>
<td>Compressor, storage</td>
<td>64.9%</td>
<td>35.1%</td>
</tr>
<tr>
<td>Transport (500 km)</td>
<td>64.9%</td>
<td>35.1%</td>
</tr>
</tbody>
</table>

\[ \eta = 90\% \]

<table>
<thead>
<tr>
<th>Power-to-Gas (Transport and Storage)</th>
<th>64.1%</th>
</tr>
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\[ \eta = 85\% \]

<table>
<thead>
<tr>
<th>CH₄-Path</th>
<th></th>
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<tbody>
<tr>
<td>Current transformer and accumulator</td>
<td>100%</td>
</tr>
<tr>
<td>Electrolyser (including auxiliary plants)</td>
<td>94.1%</td>
</tr>
<tr>
<td>Compressor, storage</td>
<td>65.9%</td>
</tr>
<tr>
<td>Methanation</td>
<td>52.7%</td>
</tr>
<tr>
<td>Transport (500 km)</td>
<td>51.3%</td>
</tr>
</tbody>
</table>

\[ \eta = 77.9\% \]

| Power-to-Gas (Transport and Storage) | 51.3% |

Source: DVGW Research Center at Engler-Bunte-Institut of Karlsruhe Institute of Technology (KIT) Marco Gaz

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P2G Demo Projects in Europe

Demonstration Projects and Plants in EU

Source: http://www.europeanpowertogas.com/demonstrations
Examples of P2G Plants

Audi Pilot Project with 6 MWe plant in Northern Germany (2015)

- **Power input** elect 3 x 2 MW<sub>e</sub>
- **Eff.PtG**: (w/heat) 54% - 70%
- **Max. H<sub>2</sub> out**: 1300 Nm<sup>3</sup>/h
- **Max. H<sub>2</sub> storage time**: 60min
- **Max. CH<sub>4</sub> output**: 325 Nm<sup>3</sup>/h
- **Operation time**: 4,000 h/a

- **BoP and EPC**: ETOGAS
- **Electrolysis**
  - Alkaline Electrolyzer
  - Atmospheric operation with downstream compressor
  - 3rd party technology
- **Methanation**
  - Catalytic Methanation
  - Salt cooled shell and tube reactor
  - 3rd party technology

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Examples of P2G Plants

Jupiter1000

Coordinator GRTgaz French TSO
Site: Fos sur Mer France (2018)
Demostrate practical application of P2G technology
2 technologies for electroliser: PEM and Alcaline
CO₂ delivered from industrial plant
Injection tests of H₂ mixed with CH₄ w/ H₂ < 6 % vol

Power input elect 1 MWₑ (0.5 Alcaline & 0.5 PEM)
Max. H₂ output 200 Nm³/h
Max. CH₄ output 30 Nm³/h

Fundings: 30 M€
40% da GRTgaz (Commission de Régulation de l’Energie)
30% da UE (FEDER), Etat Francaise (Program ADEME)
and Autorità Regional Provence-Alps-Cuite Azur

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Examples of P2G Plants

Power to Gas with biological methanation applications in biogas upgrading
Injection into gas grid since March 2015: Operation time: > 8,000 h / Performance: CH₄> 8%, H₂< 2%
# Research trends and needs in P2G

<table>
<thead>
<tr>
<th><strong>H₂ Production</strong>&lt;br&gt;Electrolysis</th>
<th>Test e developing of different processes in P2G application (Alcaline, PEM, SOEC…)&lt;br&gt;Flexibility in terms of variable power supply&lt;br&gt;Fast load variations keeping high efficiencies, rangeability, stand by&lt;br&gt;Benchmarking of technologies&lt;br&gt;High temperature, high pressure</th>
</tr>
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<tbody>
<tr>
<td><strong>Methanation</strong></td>
<td>Adaptability to various carbon sources (dac, biogas, syngas, effluents from EIi…)&lt;br&gt;Catalysts: different basis Ni, Ru…, different concepts (bulk, monolite, foams, structured…)&lt;br&gt;New concepts for reactors: compactness, flexibility, rangeability&lt;br&gt;Methanation “in situ” and “ex situ” for biological reactors</td>
</tr>
<tr>
<td><strong>CH₄ as a fuel</strong></td>
<td>Injection into national gas grids&lt;br&gt;Refuelling stations for mobility&lt;br&gt;LNG as a fuel for heavy duty transport and shipping</td>
</tr>
<tr>
<td><strong>Heating</strong></td>
<td>Buildings, process, power generation…</td>
</tr>
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Background on P2G

• Systems and component testing at pilot scale (electrolysis, methanation…)
• Commercial and Adhoc Catalyst test on lab and pilot plants
• Modelling, system and economic analysis
• Coordination of R&I activities, collaboration w/ Industries and Universities
• Technology transfer, patents, support to P.A. and Policy Makers
Experimental activities

Source: ENEA
Conclusions

• Power-to-Gas (both P2H e P2M) is a promising technology and a possible measure to improve Renewable Gases Use and energy storage (seasonal) w/ injection into Gas Grid based on Coupling of Power and Gas Transmission Infrastructures

• Process integration has to be done taking into account flexibility, costs, efficiencies and environmental advantages

• Different activities/projects are ongoing on different scales (MW) new uses of existing gas grid will be possible

• Production, storage and use/injection of RES gas (H₂ from Electrolyzer, SNG, biomethane…)

• Injection into the grid and heavy duty transport sector can be important drivers

• CO₂ can come from natural sources and/or from industrial processes (biogenic or fossil is NOT the same)

• Development of technologies, industrial applications, business real cases, financial support, rules… are NEEDED!

The role of gas need not to be limited to balancing vRES but it could enable climate neutral energy w/ existing infrastructure and on end-user side with relatively cost efficient way
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