Enagás, S.A.

* Main TSO in Spain.
* Technical Manager of Spanish gas system.
* International leader in the management of gas infrastructures
Why to use natural gas network for hydrogen distribution?

- Solve the lack of hydrogen distribution networks.
- Allows integration of power and gas networks.
- Allows to use the high storage and transmission capacity of natural gas networks.
**Injection of hydrogen in natural gas network**

- **Limitation in the amount of hydrogen that could be admixed with natural gas.**
  - Integrity of infrastructures.
  - Safe and efficient utilization.

<table>
<thead>
<tr>
<th>Summary of identified actions for x vol.-% H₂ in the gas grid</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 vol.-% H₂</td>
</tr>
<tr>
<td><strong>Gas turbines</strong> (e.g. performance/durability/legal iss.)</td>
</tr>
<tr>
<td><strong>Underground storages (porous)</strong> (e.g. bacteria growth)</td>
</tr>
<tr>
<td><strong>Gas as feedstock</strong> (e.g. effect on processes regarding performance, efficiency)</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>


Domestic appliances works safely in this range.

- **Before injection, each operation should be assessed in a case by case basis.**
Power to Methane

One option to solve hydrogen issues in natural gas network is *Synthetic Natural Gas, SNG*:

- Methane with traces of reagents.
- \( \text{CO}_2 (g) + 4\text{H}_2 (g) \rightarrow \text{CH}_4 (g) + 2\text{H}_2\text{O} (g) \).

SNG is fully interchangeable with natural gas.

- No problems in transmission and utilisation.

Injection only limited by the capacity of natural gas grid.

If \( \text{CO}_2 \) is from a renewable source \( \rightarrow \text{RENEWABLE GAS} \).

- \( \text{CO}_2 \) from biogas to produce renewable biomethane.
The aim was to develop a technology for production of Synthetic Natural Gas, SNG, from renewable sources.

Funded by Spanish Ministry of Economy and Competitiveness (MINECO) within the framework of the National Programme for Research Aimed at the Challenges of Society.

Budget 2.16 M€ (1.19 M€ funded by MINECO).

Duration: 30 months, December 2014 to May 2017.

Lead by Enagás.

It is foreseen a escalation of the technology in two future phases.
RENOVAGAS
The consortium
**RENOVAGAS Objectives**

- **To develop and construct a 15 kWe Power to Gas plant (SNG),** using H$_2$ from water electrolysis and CO$_2$ from a biogas stream.
- To optimise H$_2$ production from renewable energies by means of an optimised control.
- To develop a new catalyst.
- To develop a new reactor.
- To test the pilot plant in real condition.
- Detailed engineering for a larger plant, phase 2: 250 kWe.
- To estimate future renewable power and biogas availability in Spain.
- Economical study to show the feasibility of this technology.

*The SNG should have a quality fulfilling Spanish specifications.*
Electrolizer

- Alkaline electrolyzer, based on anionic exchange membranes (AMWE).
- New control system to improve integration with RES.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Alkaline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum $H_2$ production</td>
<td>$2 \text{ m}^3(\text{n})/\text{h}$</td>
</tr>
<tr>
<td>$H_2$ Outlet pressure</td>
<td>$35 \text{ bar}$</td>
</tr>
<tr>
<td>$H_2$ Purity</td>
<td>$99,94 %$</td>
</tr>
<tr>
<td>Efficiency at nominal point</td>
<td>$4.8 \text{ kWh/m}^3(\text{n})$</td>
</tr>
<tr>
<td>Maximum power consumption</td>
<td>$15 \text{ kW}$</td>
</tr>
</tbody>
</table>
Catalyst

- Based on nickel & ruthenium.
- Allows direct conversion of biogas to SNG.
  - Biogas: 65 % CH\textsubscript{4} + 35 % CO\textsubscript{2}
- High selectivity to methane formation.
- High carbon dioxide conversion.
  - Higher than the nickel based commercial catalyst.
  - *Allows a reduction in reactor size.*

![Graph showing CO\textsubscript{2} conversion over TOS (h)]

**RENOVAGAS catalyst:**  ᵇ 25000 h\textsuperscript{-1}

**Nickel based commercial catalyst:**
- 25000 h\textsuperscript{-1},  ▲ 15000 h\textsuperscript{-1},  × 4000 h\textsuperscript{-1}
**Methanation Reactor**

\[ CO_2(g) + 4H_2(g) \rightarrow CH_4(g) + 2H_2O(g) \]
\[ \Delta H^0_R = -165 \text{kJ/mol} \]

- Multi channel technology:
  - 388 channels.
  - Few millimetres diameter.
  - Allows reaction in one step.
  - Good management of temperature control.
- Thermal oil used for temperature control.
  - No heat recovery in this project phase.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>GHSV</td>
<td>2000 – 20000 h(^{-1})</td>
</tr>
<tr>
<td>Temperature</td>
<td>275 – 325 ºC</td>
</tr>
<tr>
<td>Pressure</td>
<td>≥ 25 bar</td>
</tr>
<tr>
<td>Ratio (H_2/CO_2)</td>
<td>≥ 4 mol/mol</td>
</tr>
</tbody>
</table>
Plant integration

- All equipment installed in a 6 m container:
  - Electrolyzer.
  - Biogas booster.
  - Reactor.
  - Auxiliary systems
- Development of a fully automatic control.
Test on real condition

- Jerez de la Frontera, Spain.
- Installation in WWTP.
- Connected to a biogas plant.
  - Biogas cleaning needed (critical issue with a catalytic reaction).
Methanation results

- Good CO₂ conversion.
- High selectivity to CH₄.
- Stability of reaction.

<table>
<thead>
<tr>
<th>Nº</th>
<th>Test</th>
<th>CH₄</th>
<th>N₂</th>
<th>CO₂</th>
<th>H₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>80-100% nominal load</td>
<td>95,5</td>
<td>280</td>
<td>1,68</td>
<td>2,75</td>
</tr>
<tr>
<td>2</td>
<td>60% nominal load</td>
<td>95,5</td>
<td>690</td>
<td>2,96</td>
<td>1,41</td>
</tr>
<tr>
<td>3</td>
<td>100% nominal load</td>
<td>95,9</td>
<td>600</td>
<td>0,085</td>
<td>3,88</td>
</tr>
</tbody>
</table>
Scale up to 250 kW
Detailed engineering

H₂ production (electrolysis)

H₂ storage and supply system

Biogas treatment and supply system

SNG production

SNG treatment prior to delivery

Heat recovery
Spanish potential
Power and CO₂ availability

- *Projection to 2020 and 2030.*
- Future surplus of RES according to different scenarios.
- *High uncertainty for 2030.*
- CO₂ availability from biogas according to future development.
- *Best location according to electricity and gas grid.*
- *Main finding:* it is possible to store 10000-12000 GWh of power as SNG (0.6 bcm) in 2030.
**Economical study**

- Based on LCOE as indicator.
- Main inputs:
  - Two size plant: 250 kWe & 5000 kWe.
  - 3000 h/y utilisation.
- Sensitivity study of main inputs.
- Main finding:
  - Influence of working time, hour/year.
  - Size: intensive in capital expenditure.
  - Electricity price, main operational cost.

Base case. Electricity price 50 €/MWh
Economical study
Sensitivity study to main inputs / Comparison

(1) All the scenarios simulated.
(2) Only scenarios with 3000 h/y working time.
Conclusions/Results

- Design and integration of a 15 kWe PtG installation.
- Development of a new catalyst for the methanation reaction between H₂ and CO₂, in a biogas stream, with better properties than commercial ones.
- Design and assembly of a multi-channel reactor which improves methanation reaction due to gas contact maximization and heat management.
- Good quality of SNG obtained.
- Basic and detailed engineering of a 250 kWe PtG plant.
- Identification of Spanish SNG generation potential according to different RES and biogas forecasts.
- Economic study showing the conditions that must be fulfilled in order to achieve this technology be profitable without subsidies.
- **Phase 2 in preparation.**
Thank you for your attention

Any question?