RENOVAGAS Project

ELYntegration Workshop
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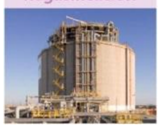
Regasificación



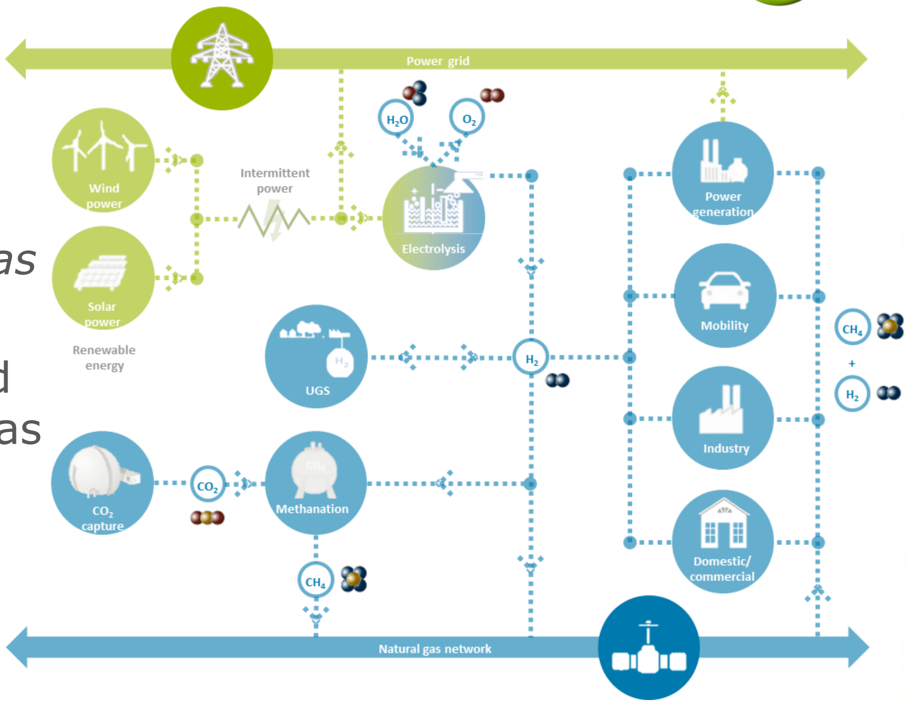
Transporte

Almacenamiento

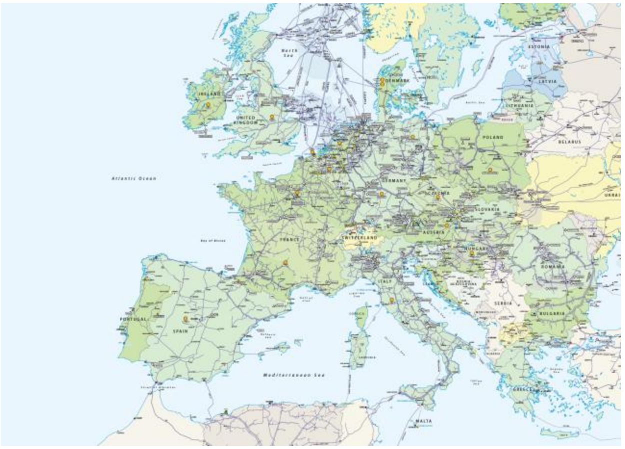
- Main TSO in Spain.
- Technical Manager of Spanish gas system.
- International leader in the management of gas infrastructures

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.



Fuente: Enagas.



Fuente: ENTSOG

Injection of hydrogen in natural gas network

RenovaGas

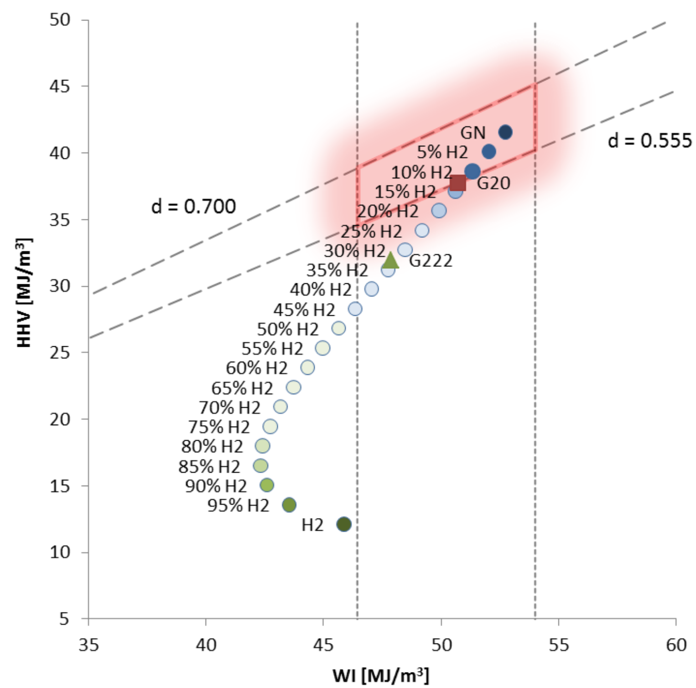
- *Limitation in the amount of hydrogen that could be admixtured with natural gas.*
  - Integrity of infrastructures.
  - Safe and efficient utilization.

Summary of identified actions for x vol.-% H_2 in the gas grid

2 vol.-% H2	5 vol.-% H2	10 vol.-% H2
Gas turbines (e.g. performance/durability/legal iss.)	Same as for 2 vol.-% H2 plus:	Same as for 2 and 5vol.-% H2 plus:
Underground storages (porous) (e.g. bacteria growth)	**CNG on board tanks** Fatigue induced failure /vehicle regulation and standardisation	**Compressors** (e.g. performance)
Gas as feedstock (e.g. effect on processes regarding performance, efficiency)		**Underground storages (caverns)** Installations and bacteria growth in underground cavern storages
		Safety and grid integrity
		Industrial/residential burners and engines (e.g. performance)

Fuente: G. Müller-Syring & J. Dubost, CEN/TC 234 Workshop on Hydrogen in Natural Gas (H2NG), 29th March 2017, Brussels.

Domestic appliances works safely in this range.



Fuente: Enagas. Reference condition 0/0

Red area: CBP natural gas specification limits, as reference

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

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Power to Methane

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

- Methane with traces of reagents.
- CO_2 (g) + $4H_2$ (g) → CH_4 (g) + $2H_2O$ (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 CO_2 is from a renewable source → ***RENEWABLE GAS***.

- CO_2 from biogas to produce renewable biomethane.

RENOVAGAS

Spanish Joint Industrial Project

- 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

Centro Nacional del Hidrógeno

CSIC
Consejo Superior de Investigaciones Científicas

tecnalia Inspiring Business

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ABENGOA HIDROGENO

aqualia

gasNatural fenosa

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Objectives

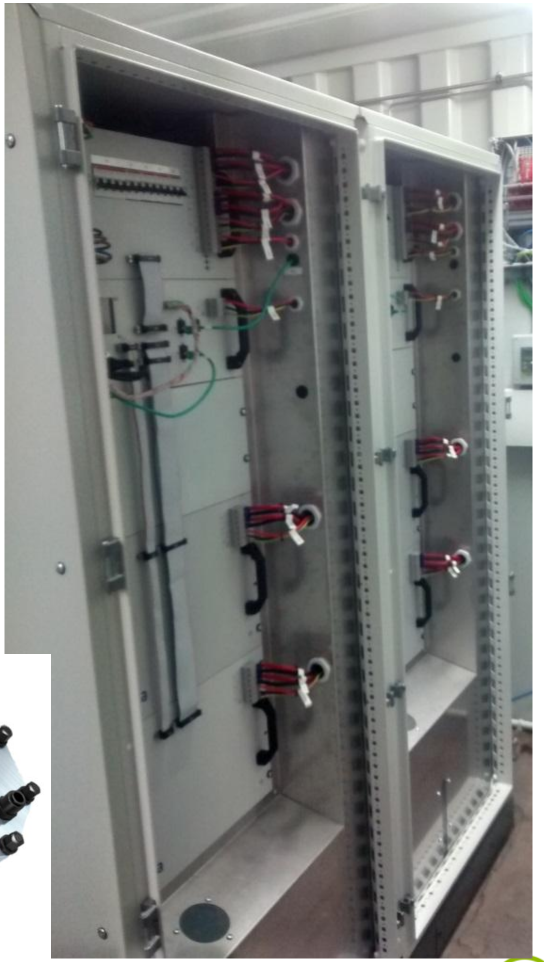
- *To develop and construct a 15 kWe Power to Gas plant (SNG)*, using H_2 from water electrolysis and CO_2 from a biogas stream.
- To optimise H_2 production from renewable energies by means of an optimised control.
- To develop a new catalyst.
- To develop a new reactor.
- To test the pilot plant in 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

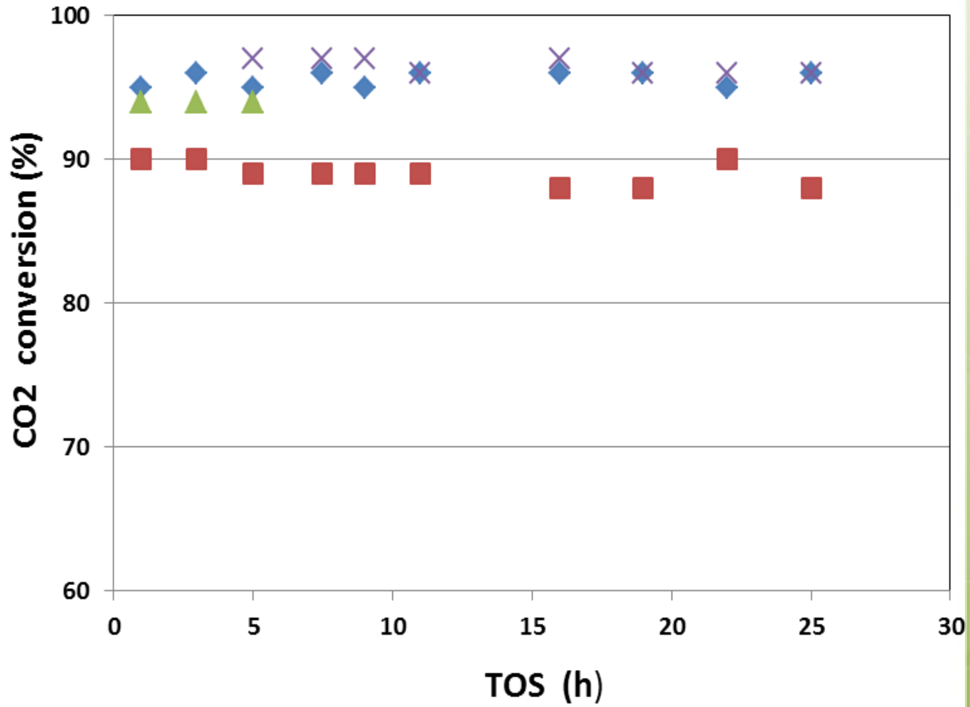
- Alkaline electrolyzer, based on anionic exchange membranes (AMWE).
- New control system to improve integration with RES.

Technology	Alkaline
Maximum H_2 production	2 m^3(n)/h
H_2 Outlet pressure	35 bar
H_2 Purity	99,94 %
Efficiency at nominal point	4.8 kWh/m^3(n)
Maximum power consumption	15 kW



Catalyst

- Based on nickel & ruthenium.
- *Allows direct conversion of biogas to SNG.*
  - Biogas: 65 % CH_4 + 35 % CO_2
- High selectivity to methane formation.
- High carbon dioxide conversion.
  - Higher than the nickel based commercial catalyst.
  - ***Allows a reduction in reactor size.***



RENOVAGAS catalyst: ♦ 25000 h^{-1}

Nickel based commercial catalyst:

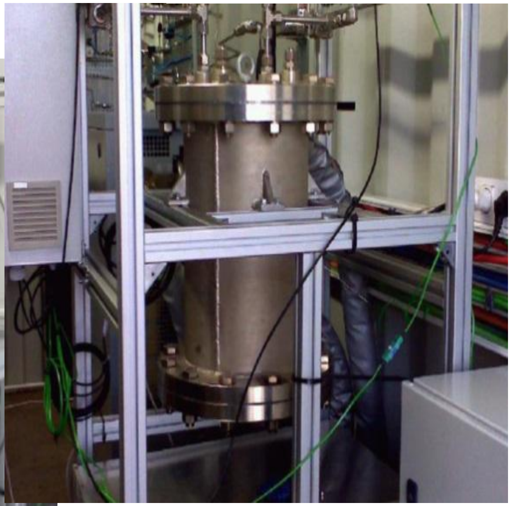
■ 25000 h^{-1}, ▲ 15000 h^{-1}, x 4000 h^{-1}

Methanation Reactor

$$CO_{2(g)} + 4H_{2(g)} \rightarrow CH_{4(g)} + 2H_2O_{(g)}$$

$$\Delta H_R^0 = -165 kJ/mol$$

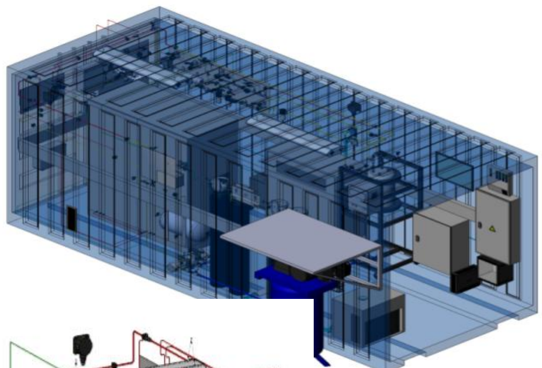
- Multi channel technology:
  - 388 channels.
  - Few millimetres diameter.
  - Allows reaction in one step.
  - Good management of temperature control.
- Thermal oil used for temperature control.
  - No heat recovery in this project phase.

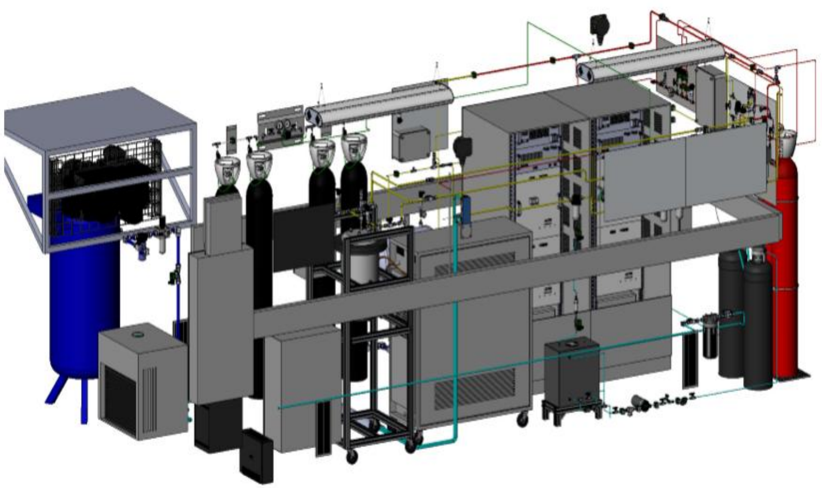


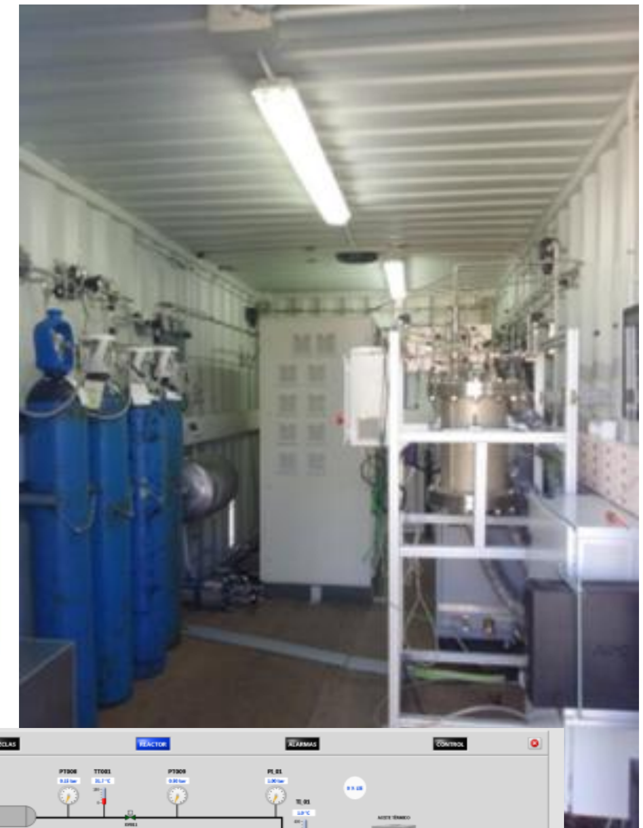
GHSV	2000 – 20000 h^{-1}
Temperature	275 – 325 ºC
Pressure	≥ 25 bar
Ratio H_2/CO_2	≥ 4 mol/mol

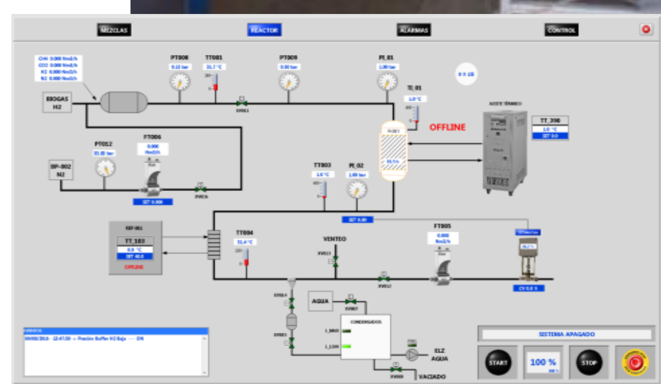
Plant integration

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







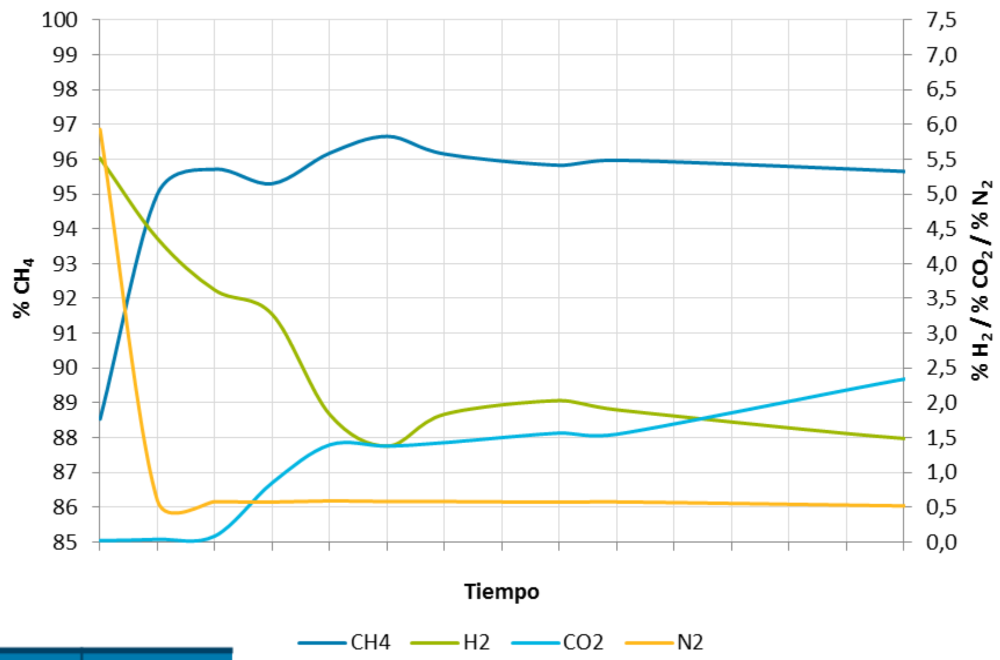


Test on real condition

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

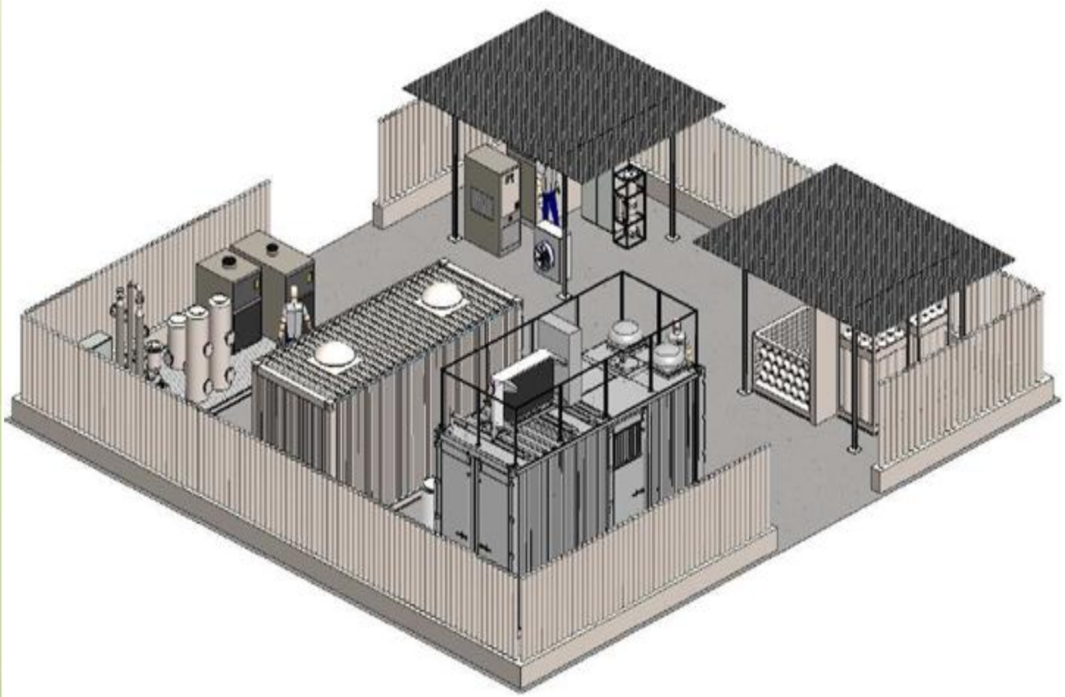
Methanation results

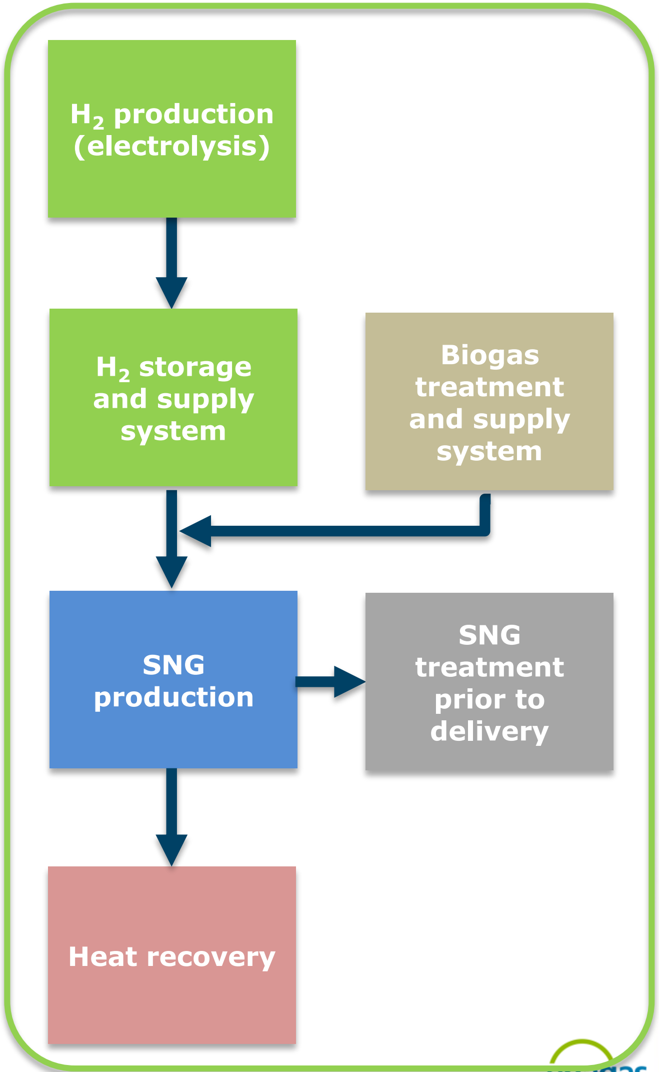
- Good CO_2 conversion.
- High selectivity to CH_4.
- Stability of reaction.



Nº	Test	CH_4 %-mol	N_2 ppm	CO_2 %-mol	H_2 %-mol
1	80-100% nominal load	95,5	280	1,68	2,75
2	60% nominal load	95,5	690	2,96	1,41
3	100% nominal load	95,9	600	0,085	3,88

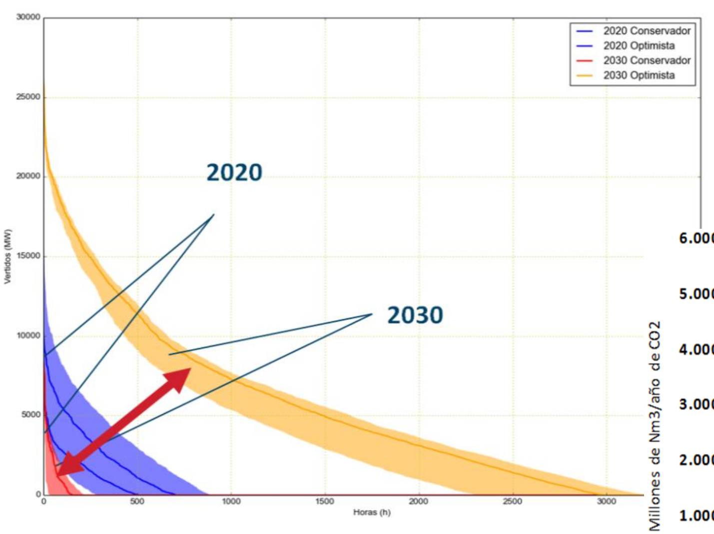
Scale up to 250 kW
Detailed engineering

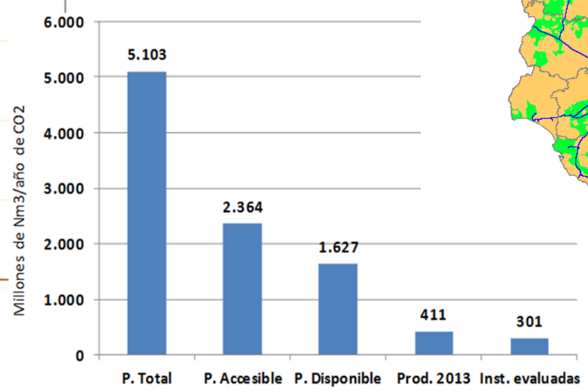


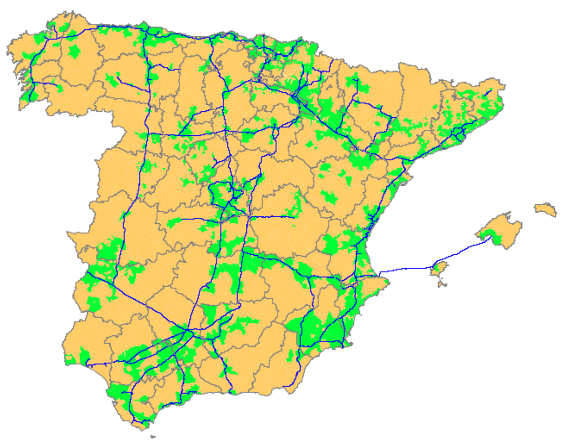


Spanish potential
Power and CO_2 availability

- *Projection to 2020 and 2030.*
- Future surplus of RES according to different scenarios.
- *High uncertainty for 2030.*
- CO_2 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.



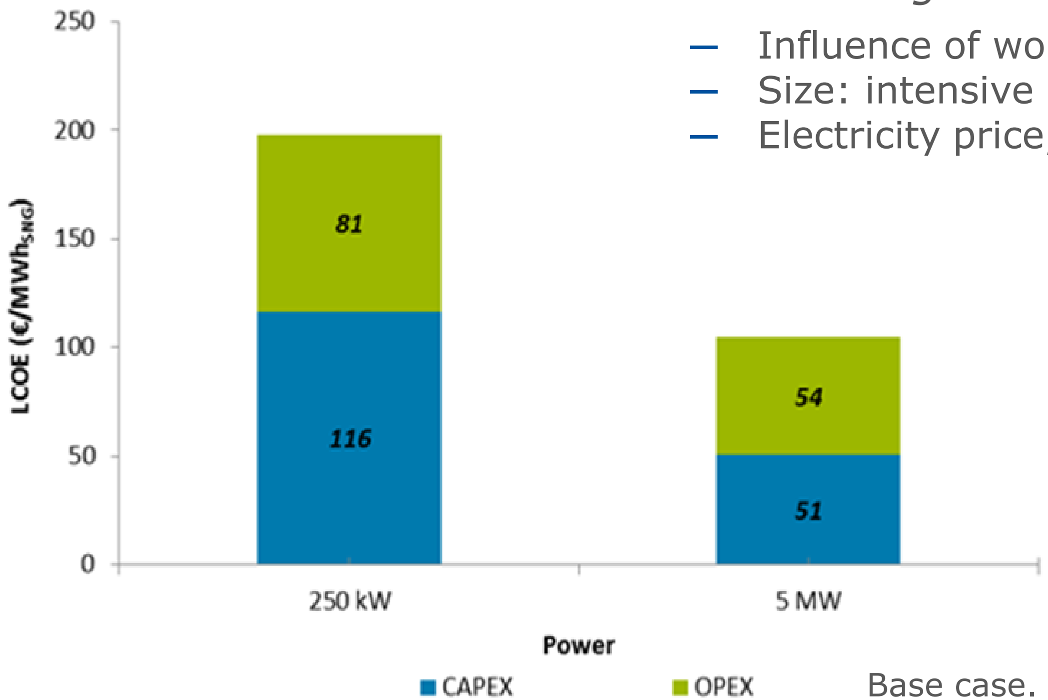




Economical study

RenovaGas

- *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. Electricty price 50 €/MWh

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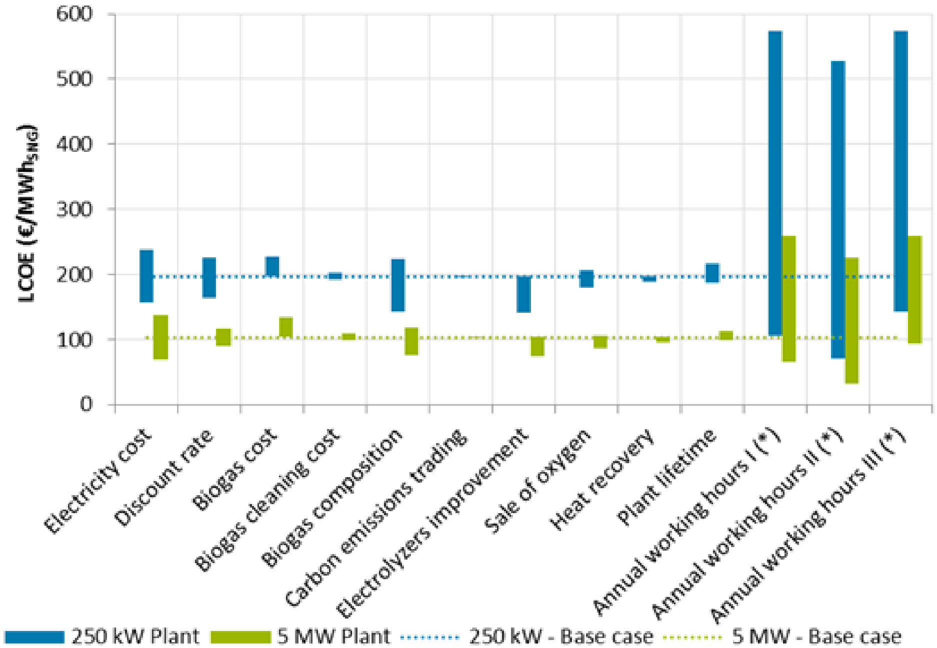
Economical study
Sensitivity study to main inputs / Comparison



Author	Estimated cost of SNG (€/MWh)
RENOVAGAS, 2016	30 –570 (1)
	70 – 240 (2)
Ritcher, F., 2012	15 – 250
Müller-Syring, G. et al, 2013	32 – 900
Pedersen, A.H., 2013	73 – 645
SBC Energy Institute, 2014	40 – 400
Pedersen, A.H. & Wiersma, K.G., 2015	25 – 350
WEC, 2016	200 – 700

(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 H_2 and CO_2, 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?