POWER TO FUEL: Power2Biomethane Project

John Chamberlain

May 2018

gasNatural fenosa

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Our Company: Gas Natural Fenosa

Natural gas supply

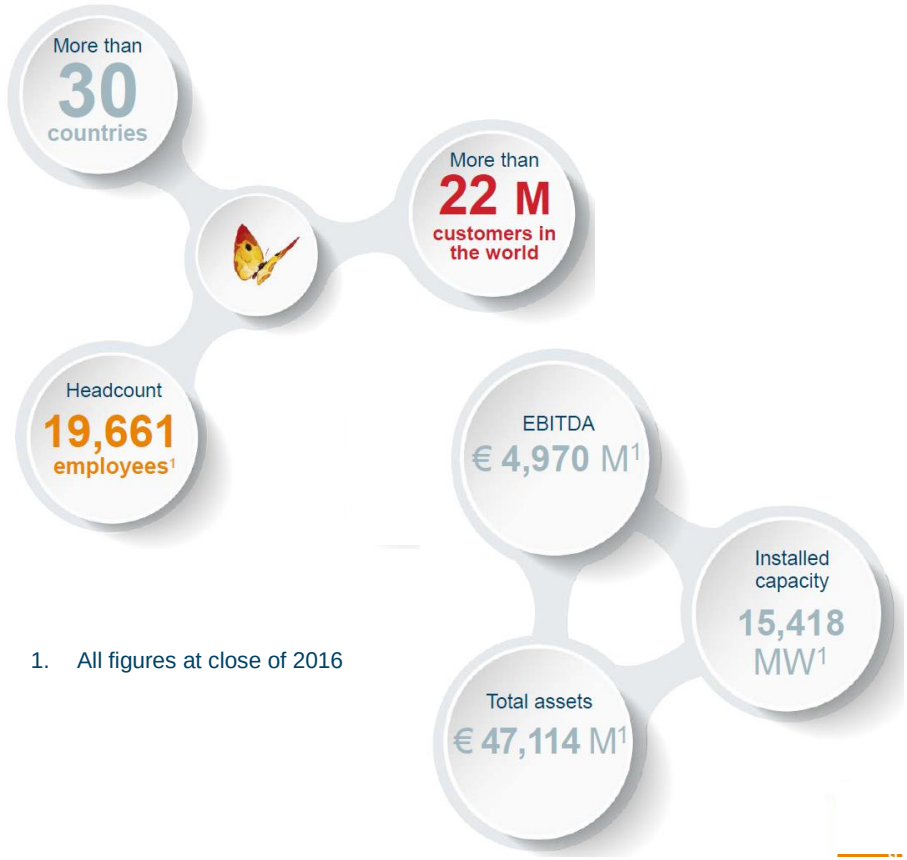
Natural Gas transportation

Power generation

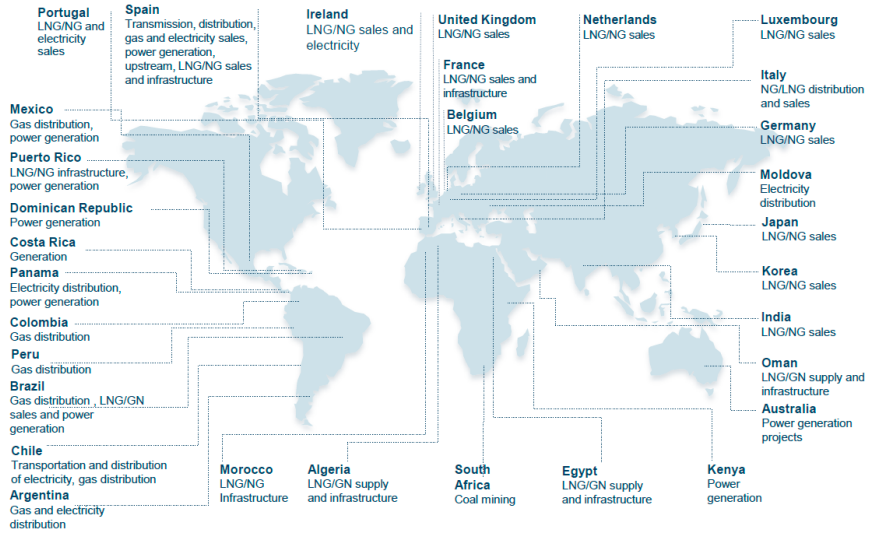
Gas y Elec. Distribution

Marketing

Trading



1. All figures at close of 2016



The largest integrated gas and electricity company in Spain and Latin America

A multinational company, leader in the sector of gas and electricity committed to Innovation

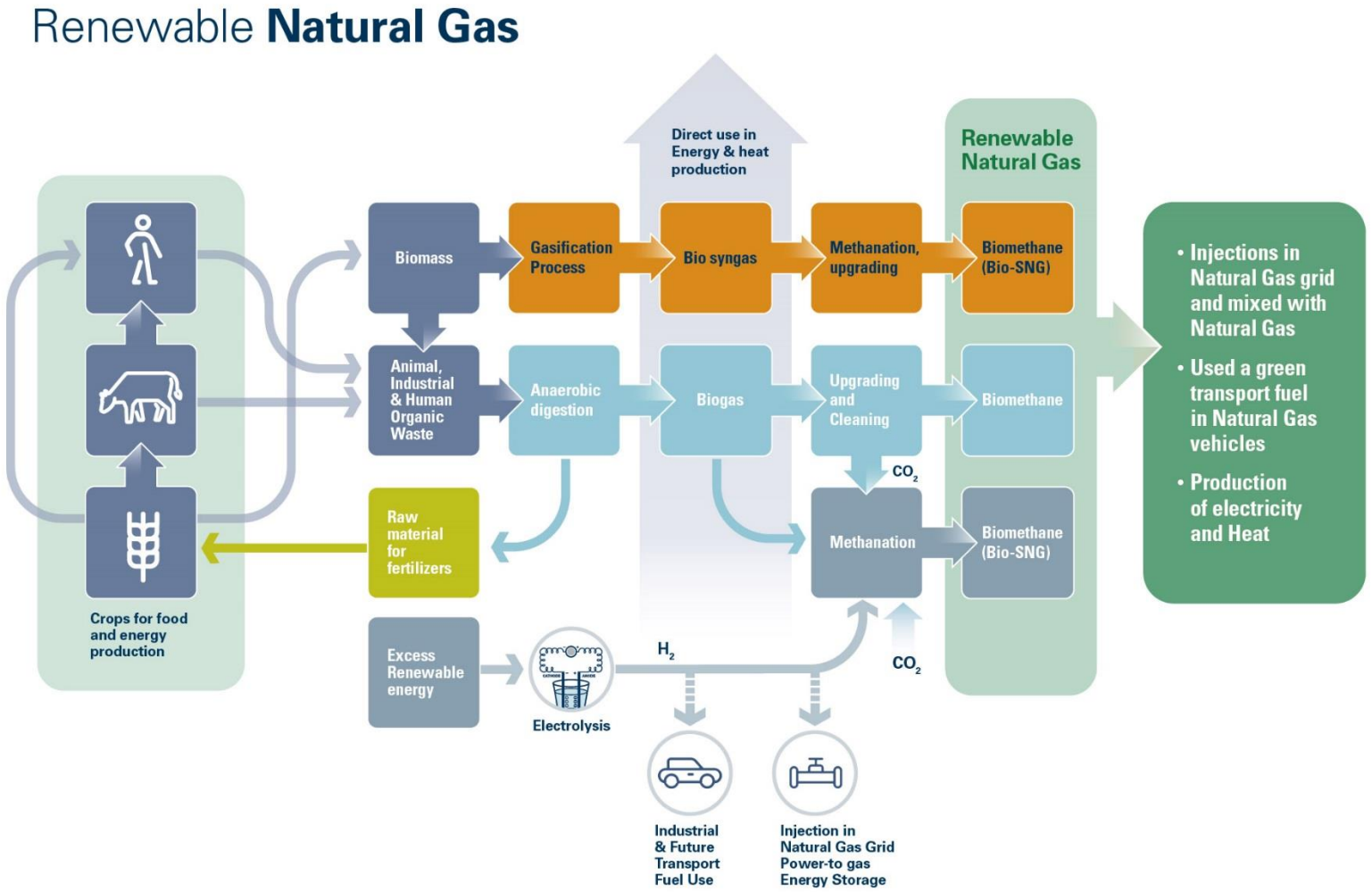
We are the principal supplier of LNG in the Atlantic and Mediterranean basins (30 bcm).

P2G & Renewable Natural Gas

1

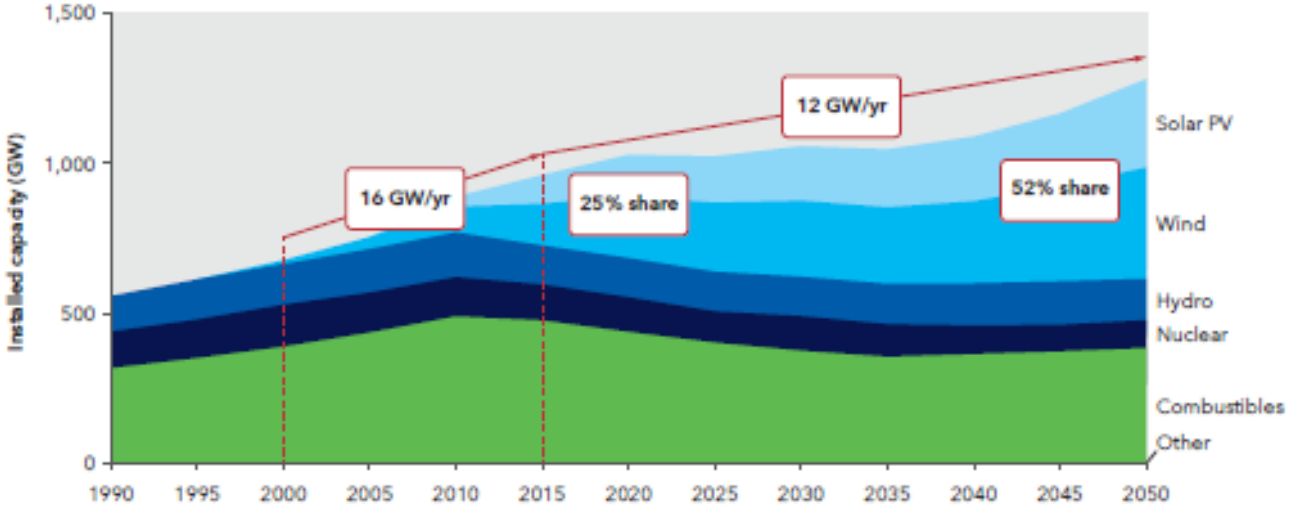
Renewable Natural Gas & P2G

- **Upgrading of Biogas to produce Biomethane:** The initial product, Biogas, is upgraded (Removal off Contaminants and separation of CO_2) to obtain biomethane, a gas with a high concentration of CH_4.
- **Bio-syngas o Bio-SNG:** A gas composed principally of CO & H_2 obtained principally from the gasification of biomass
- **P2G (H_2 o Methane):** Employing excess renewable energy generation



Challenge: High Penetration of Renewable Energy in Electrical Sector

- The large renewable energy penetration predicted in Europe during the coming decades will produce a scenario of difficult management and the need for Energy Storage.



Historic and future growth rates in installed capacity up to 2050 for wind and solar power plants; Source: DNV GL image based on EU Reference Scenario 2016

Source: European Power to gas White Paper

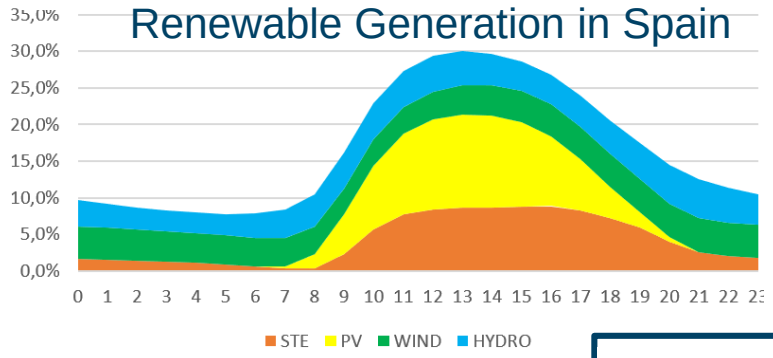
Germany had an installed capacity of 44.5GW of wind turbines and 39.3GW of solar power at the end of 2015. The average load profile in Germany fluctuates between 50 and 80GW on a work day and 40 and 60GW during weekends. When both renewable sources produce electricity at full capacity in periods of a lower load profile, there is surplus electricity generation. This situation occurred various times in 2015 resulting in 4.7 terawatthours (TWh) of electricity being curtailed (93% wind and solar power). The network operators had to pay compensations in total of €315 million (m). This amount is expected to increase in the coming years as grid extensions do not have the necessary velocity.

Curtailment in Germany in relation to the installed capacity of wind and solar power. Based on data from the German Federal Network Agency (Bundesnetzagentur)[5]

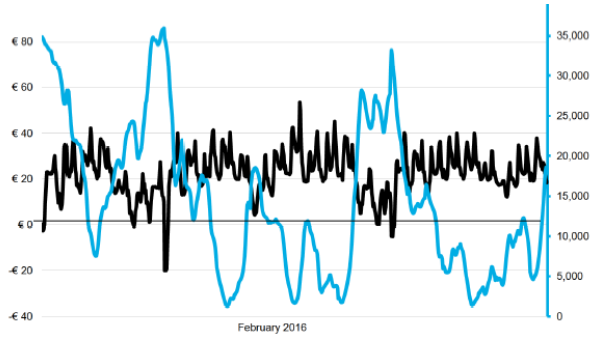
Extract from European Power to gas White Paper

Challenge: Variation in Electricity Generation and Demand

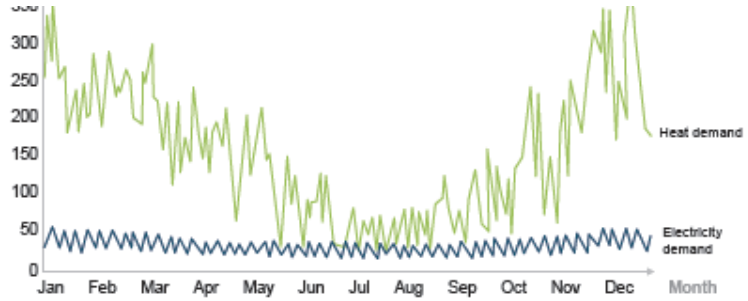
Graph of Protermo Solar based on REE data.



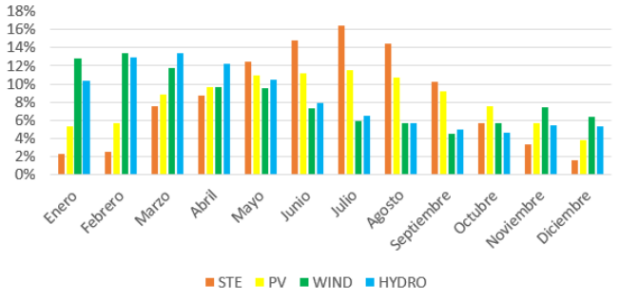
Daily Demand in Germany & EnergyCosts



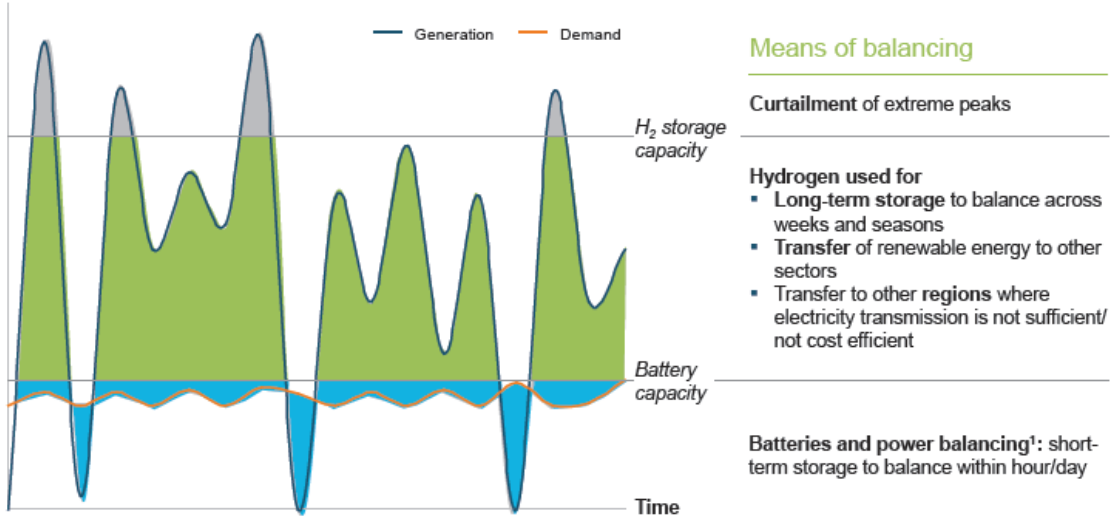
Seasonal Demand in the UK



Graph of Protermo Solar with REE data.



Storage Requirements



Means of balancing

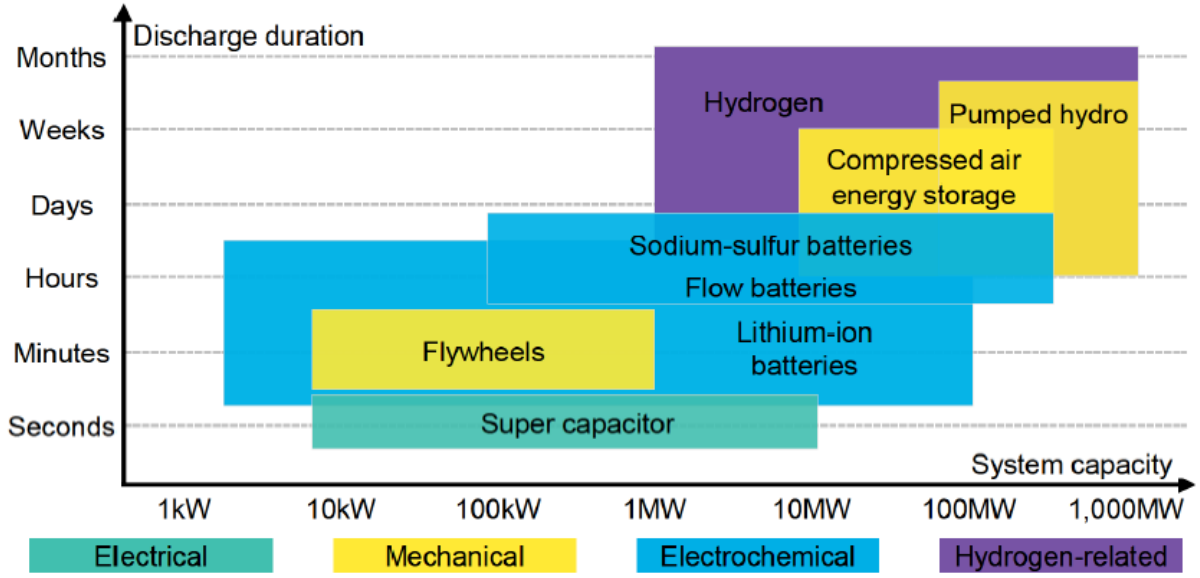
Curtailment of extreme peaks

Hydrogen used for
- **Long-term storage** to balance across weeks and seasons
- **Transfer** of renewable energy to other sectors
- Transfer to other **regions** where electricity transmission is not sufficient/ not cost efficient

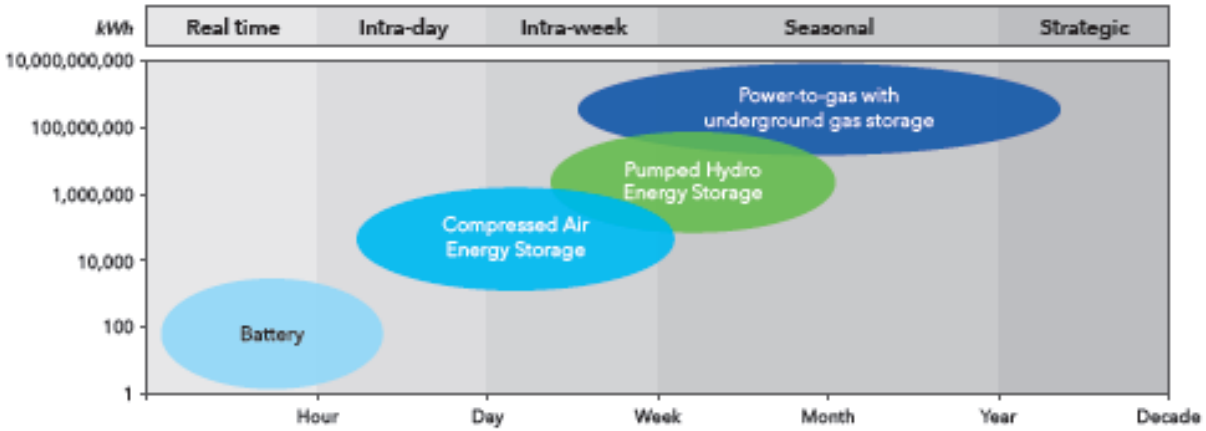
Batteries and power balancing[1]**:** short-term storage to balance within hour/day

Extract from Hydrogen Scaling up (Hydrogen Council)

Key: Large Scale Stationary Storage



Source: Bloomberg New Energy Finance. Note: system capacities and discharge durations are based on general use, rather than technical limitations.

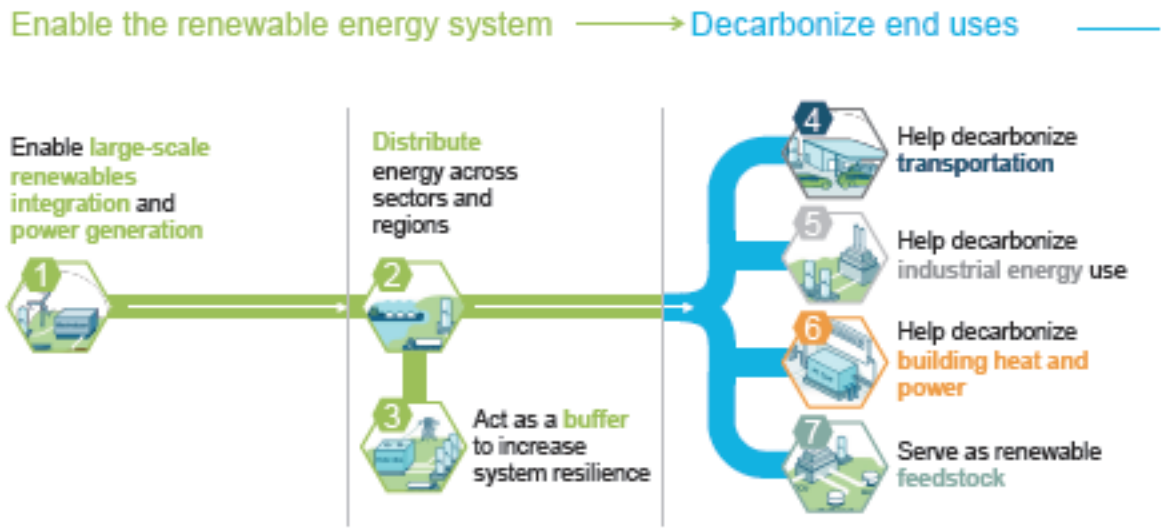


Extract from European Power to gas White Paper

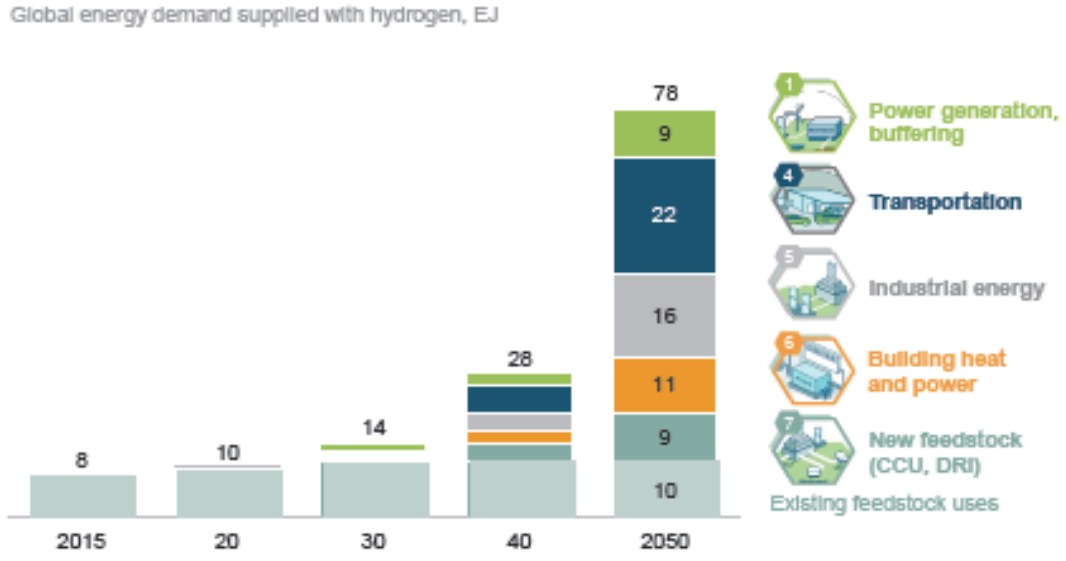
Key: Progressive Integration of the Gas & Electricity Grids

- The integration of the gas and >Electricity Grids will progressively increase with the increase in Renewable Electricity Generation.
- Within a decarbonization scenario, the gas grid will adopt the tendency initiated in the Electricity sector with the quantity of renewable Natural gas progressively increasing.

Engie have announced that their system will be 100% Biomethane and Hydrogen by 2050. http://www.powerengineeringint.com/articles/2017/12/engie-pledges-switch-to-green-gas-by-mid-century.html



SOURCE: Hydrogen Council



SOURCE: Hydrogen Council

Power2Biomethane Project

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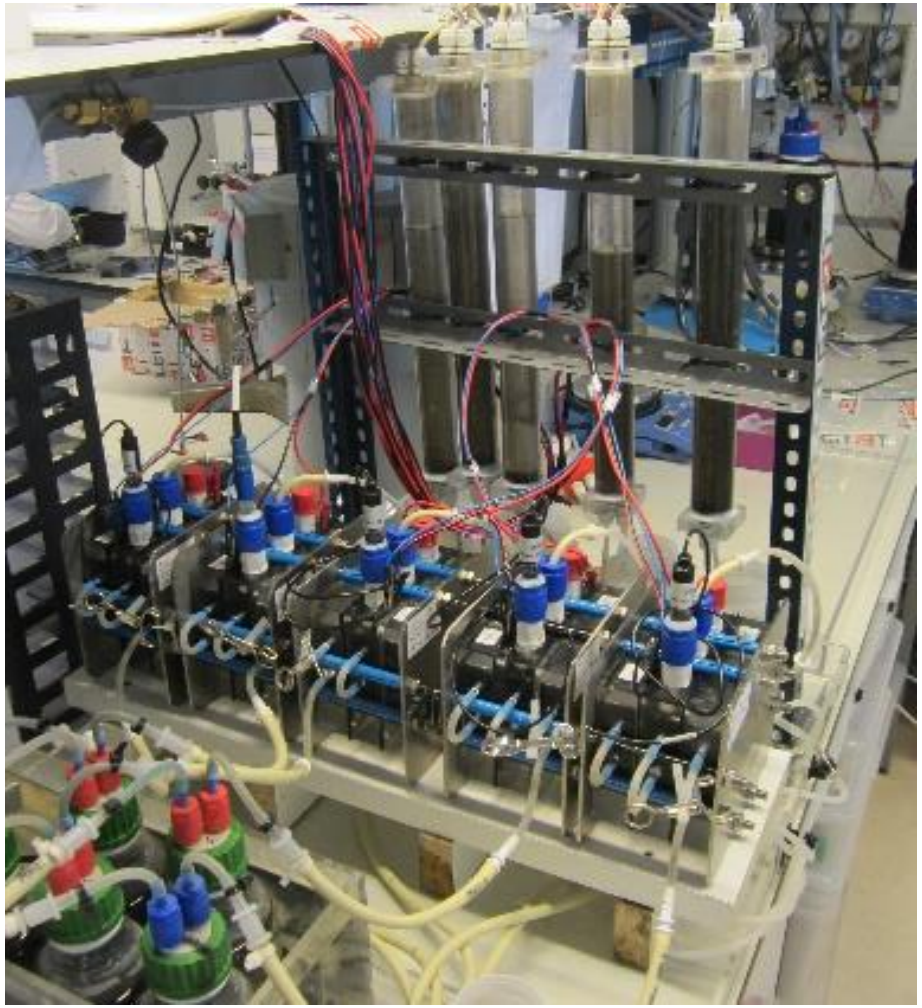
POWER TO FUEL: Power2Biomethane Project

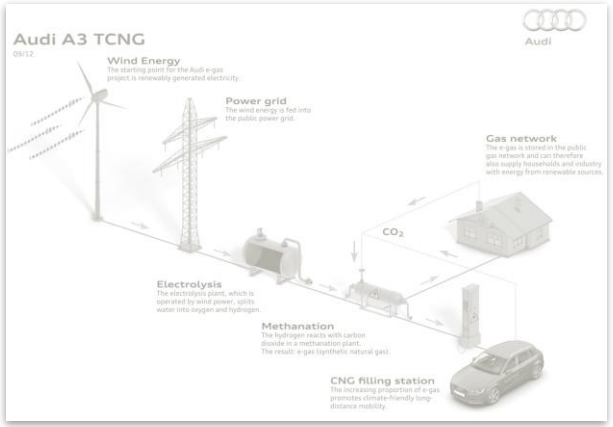


- POWER2BIOMETHANE project of Retos-Colaboración call from Spanish research program (Desarrollo e Innovación Orientada a los Retos de la Sociedad) in the Spanish framework of Scientific and Technical Research and innovation 2013-2016

Power2Biomethane Project: Motivation

- Power-to-fuel technology is a potential solution.
- Currently in EU, there are some pilot plants demonstrating the Sabatier reaction

Is there any solution more energetically competitive?



Parameter	**(A)** laboratory-stage **Electromethanogenesis**	**(B)** pilot-stage **Chemical methanation**	**(C)** pilot-stage **Biological methanation**
CH_4 production rate (m^3 CH_4 m^{-3} reactor d^{-1})	**0.27 – 27**	1500 m^3 CH_4 m^{-3} catalyst d^{-1}	1.2 – 43.2
Conversion efficiency (%)	**65 – 99%**	46-75%	58%
Energy consumption (kWh m^{-3} CH_4)	11 – 19	**26 – 35**	19
CH_4 purity (%)	≥ 95	≥ 96%	98 – 99%
Operating pressure (bar)	**1**	**1-100**	1 – 4
Operating temperature (ºC)	**20-30**	**180-600**	40 – 70
Observations	**On-demand ignition**	**Expensive catalysts**	**On-site need of H_2**

Power2Biomethane Activities of GNF

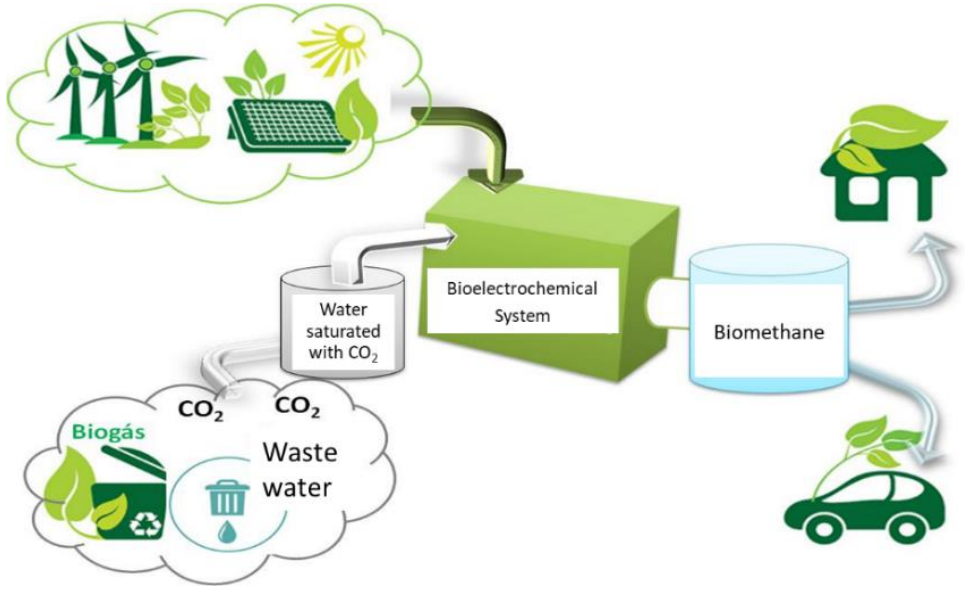
Renovagas

Ris3Cat Cosin

Unidad Mixta Gas Renovable

Power2Biomethane Project: Objective

- To be a storage solution for intermittent renewable energy using methane as the energy carrier
- React CO_2-rich gases with waste water to produce a biofuel (circular economy)
- To develop bioelectrochemical batteries for this conversion of CO2 into biomethane obtaining an adequate quality to inject this biomethane into the natural gas network and also be economically competitive.
- Development of an optimized electric control system suitable for the injection of the surplus of renewable energies into the bioelectrochemical batteries



Power2Biomethane Project: Outline

1. Reuse of CO2 emissions to fuel production

Currently disposed by anaerobic digestion

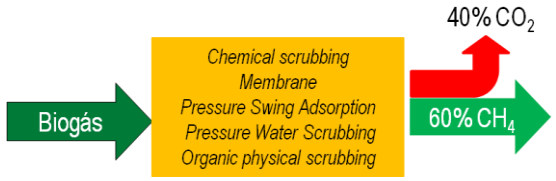
Biological sludges

Biogas composition

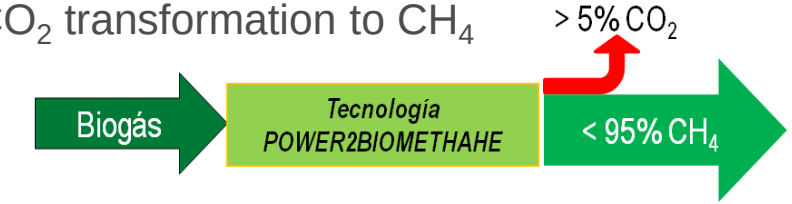
CH_4 = 50 – 65%
CO_2 = 35 – 50%
H_2S < 2500ppm
O_2 + N_2 + other < 0.5%

Currently: Electricity Generartion/Heat and/ or 

Biomethane



CO_2 transformation to CH_4



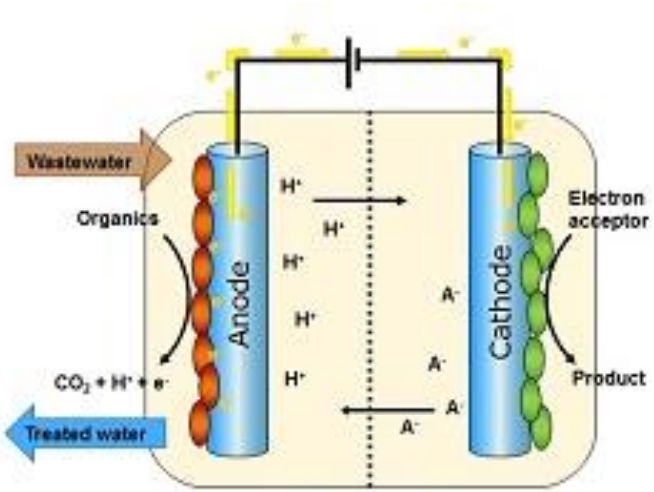
Spanish law ITC/3126/2005

Biomethane composition

CH_4 > 95%
CO_2 < 2%
H_2 < 5%

Power2Biomethane Project: The System

Power2Biomethane project strategy



Bioelectrochemical System (BES)

www.meteorr.ac.uk/science/microbialelectrochemicaltechnology

Electrode	Reaction	$E^{0'}$ (V vs SHE)	Notes
Anode	$2H_2O \rightarrow 4H^+ + O_2 + 4e^-$	+0.82	$\Delta E << 0$
Anode	$CH_3COO^- + 4H_2O \rightarrow 2HCO_3^- + 9H^+ + 8e^-$	-0.28	$\Delta E \leq 0$
Cathode	$HCO_3^- + 9H^+ + 8e^- \rightarrow CH_4 + 3H_2O$	-0.24	DET
Cathode	$2H^+ + 2e^- \rightarrow H_2$ $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$	-0.41	IET

Mild conditions

Low voltage and Low Pressure and Temperature

Direct Biological Conversion of Electrical Current into Methane by Electromethanogenesis

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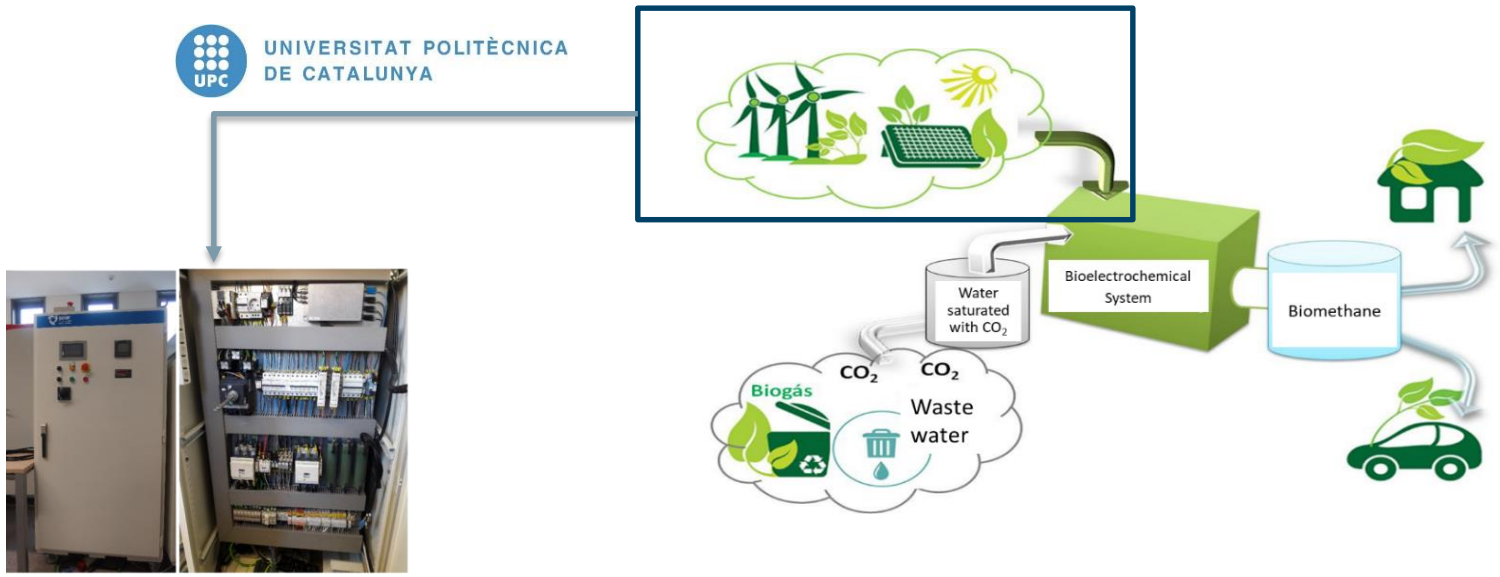
Received December 12, 2008. Revised manuscript received March 5, 2009. Accepted March 6, 2009.

a theoretical potential as high as 1.1 V under neutral pH conditions (*1*). The MEC is a type of modified MFC that has been used to efficiently store electrical energy as a biofuel (hydrogen gas) (*2*). Hydrogen gas evolution from the cathode, however, is not spontaneous (*3*−*5*). The voltage produced by electrogenic bacteria on the anode using a substrate such as acetate ($E_{an} \approx -0.2$ V) is insufficient to evolve hydrogen gas at the cathode ($E_{cat} \approx -0.414$ V, pH=7). By adding a small voltage, hydrogen gas can be produced using MECs at very high energy efficiencies evaluated in terms of just electrical energy alone (200−400%) or both electrical energy and substrate heat of combustion energy (82%) (*3*). One disadvantage of electrically assisted method of hydrogen production (electrohydrogenesis) is that a precious metal catalyst such as platinum is usually used on the cathode. Hydrogen compression is also an energy-intensive process, and hydrogen storage can be problematic (*6*).

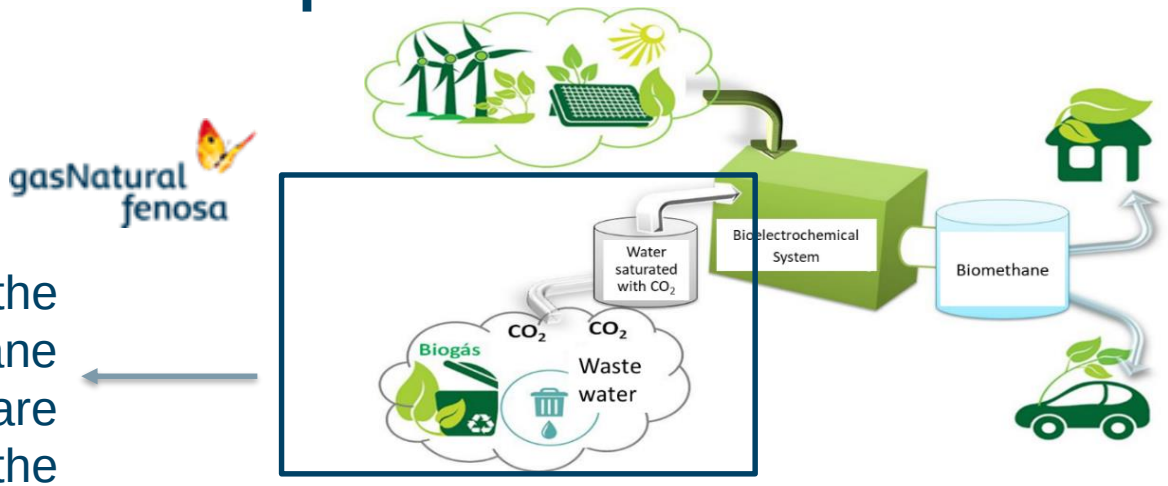
Power2Biomethane Project: Description and results

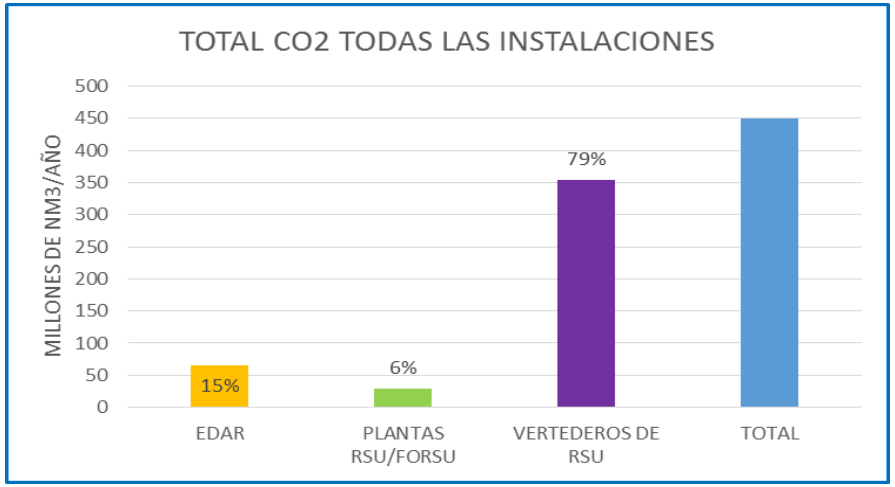


- Modeling the electro-chemical behavior of the BES battery
- Construction of load that simulates battery stack 630kW
- Validation in the laboratory that the batteries have good behavior as a system of energy storage

Power2Biomethane Project: Description and results

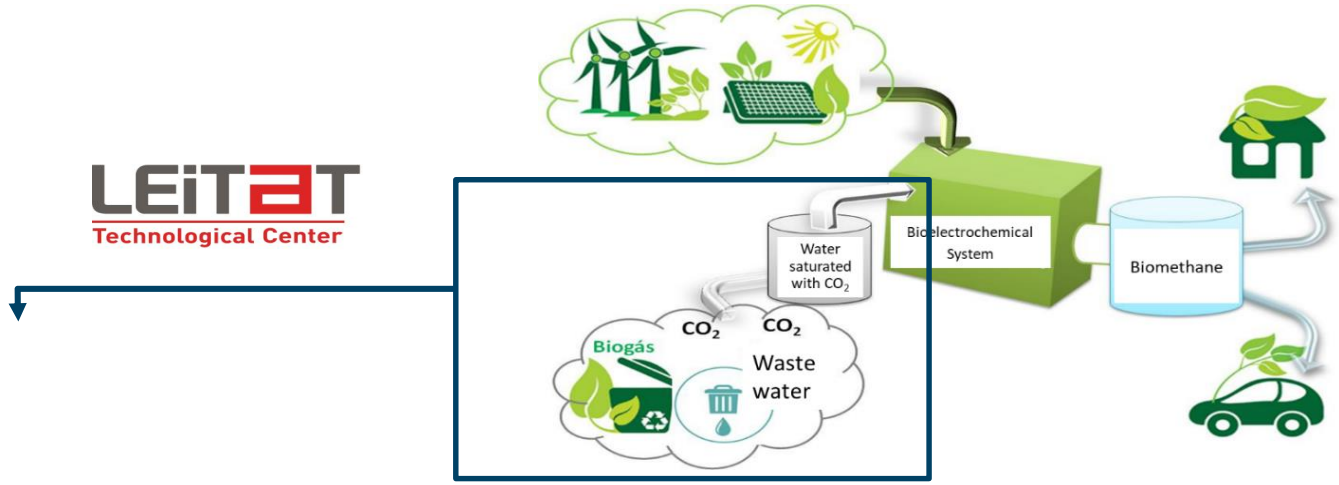
- The optimal installation for the implementation of the P2Biomethane system is a WWTP because there are the two necessary inputs for the process (biogas and wastewater).
- Although the CO_2 produced in WWTP currently only is 15% of the total CO_2 produced in all facilities considered, in absolute terms this percentage represents an emission of 66 million Nm^3 of CO_2 per year, so it is considered that the WWTP have ample potential for the study and implementation of Power2Biomethane technology

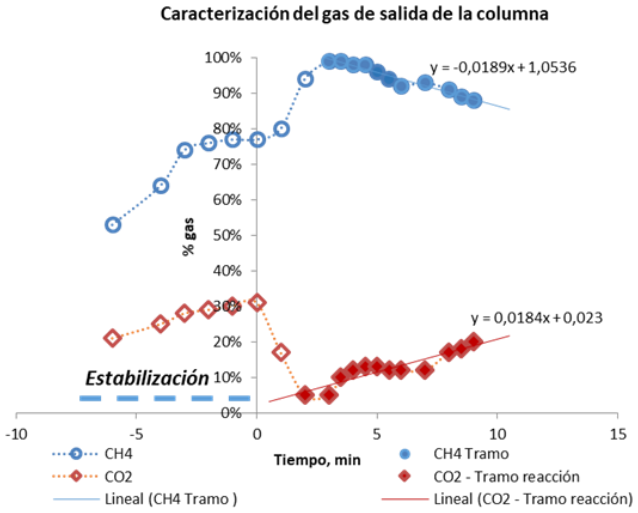


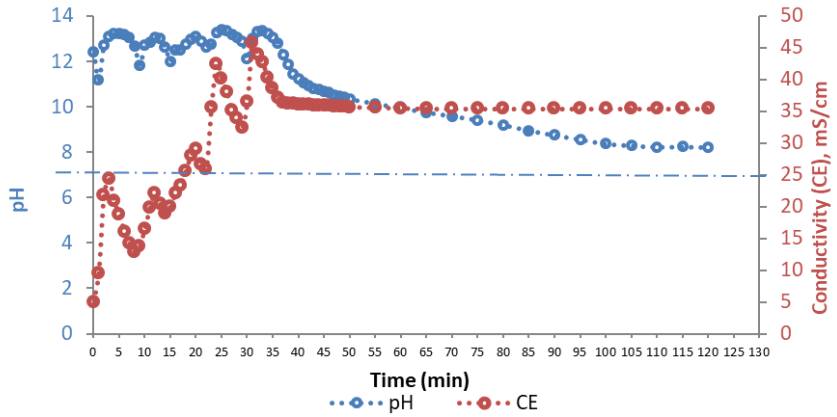


	CO_2 (MILLONES DE NM^3/AÑO)	Porcentaje
EDAR	66	15%
PLANTAS RSU/FORSU	29	6%
VERTEDEROS DE RSU	354	79%
TOTAL	**449**	**100%**

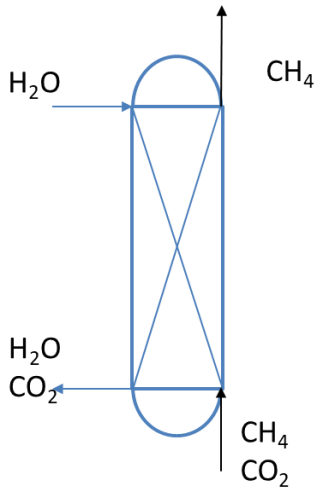
Power2Biomethane Project: Description and results





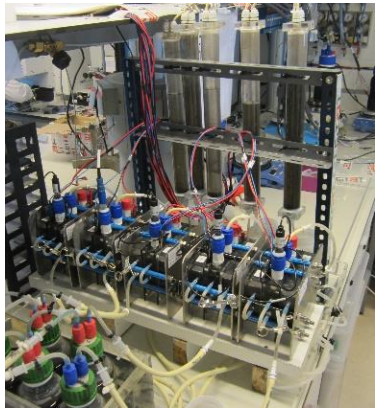


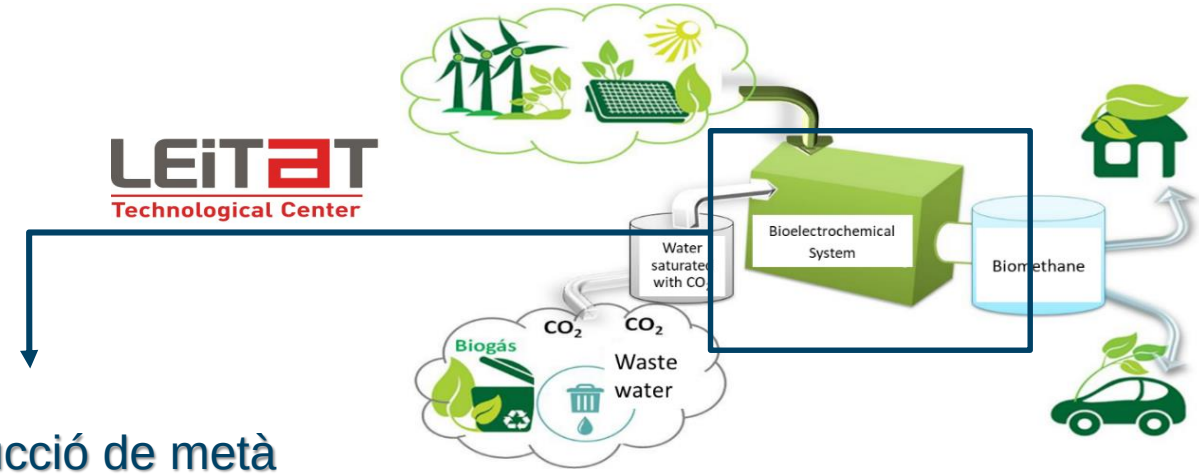
pH and conductivity are adjusted in the feed of BES reactor



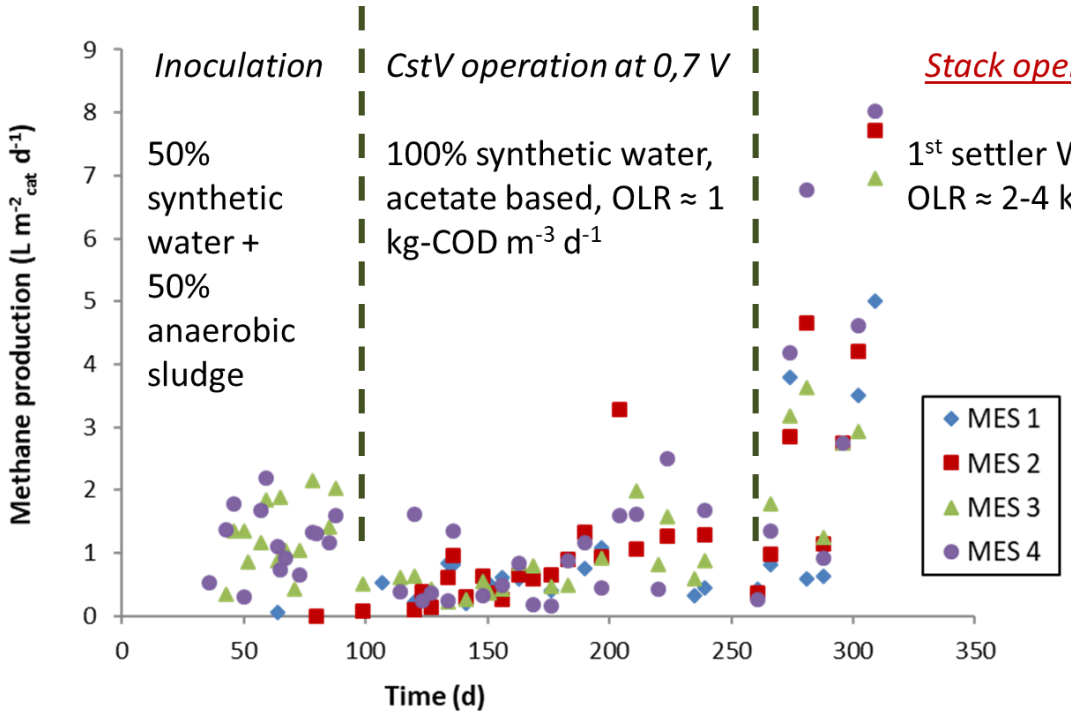
- Confidencial -

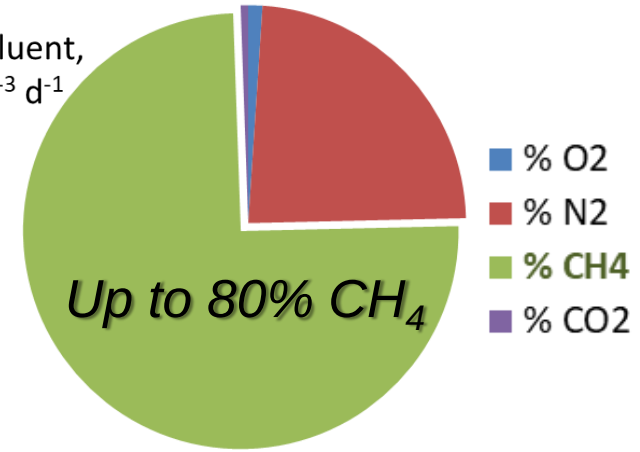
Power2Biomethane Project: Description and results





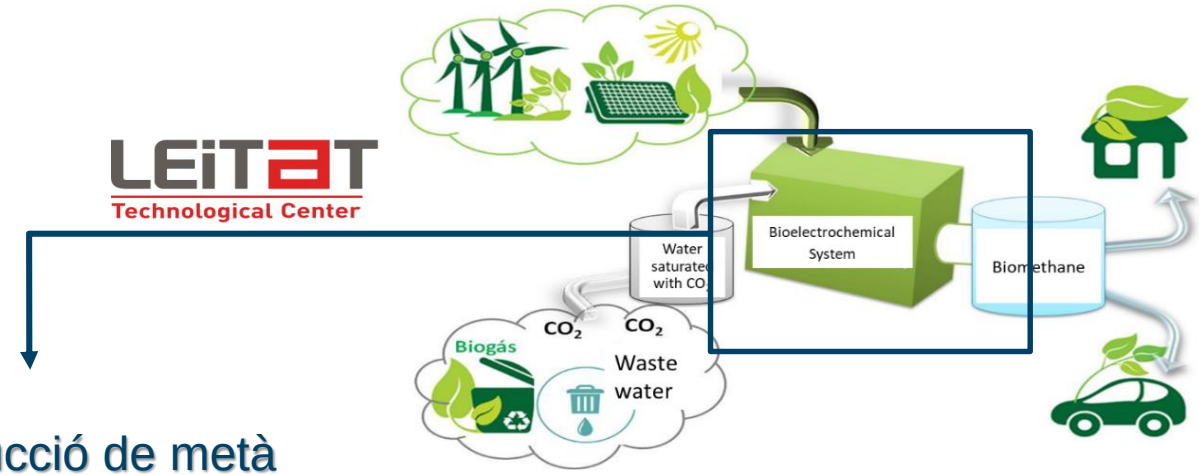
Producció de metà



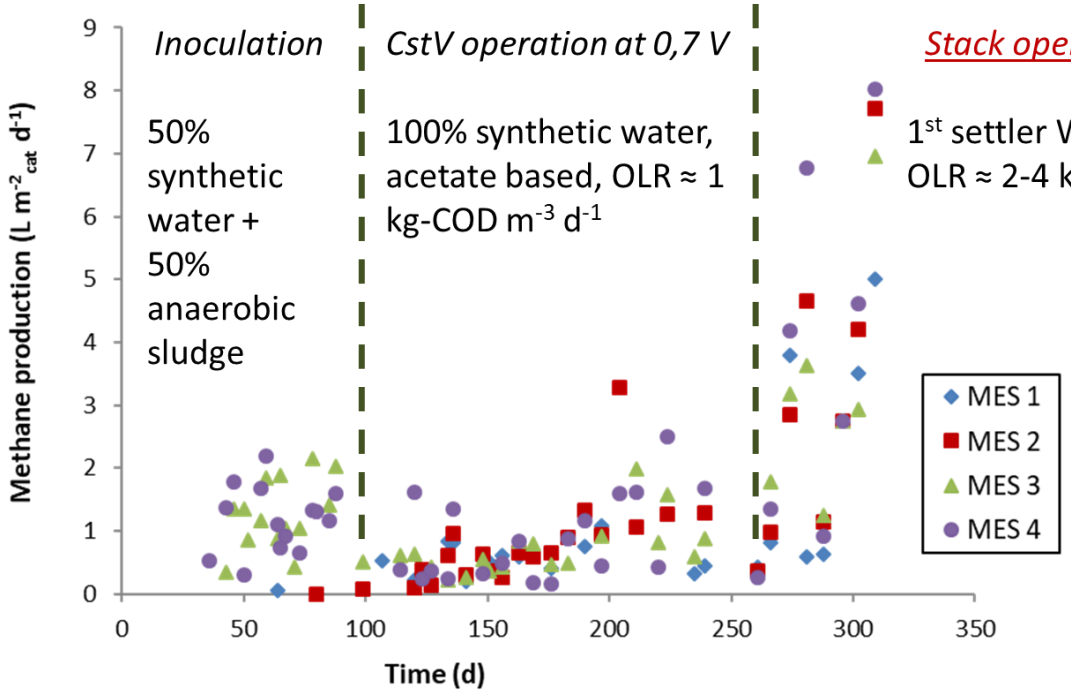


> 95% CH_4/CO_2

Power2Biomethane Project: Description and results

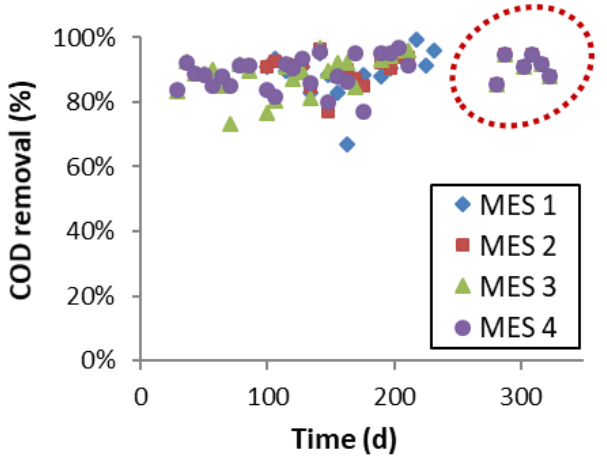


Producció de metà



Tractament WW

90% COD removal



Power2Biomethane Project: Description and results

LEITAT Technological Center

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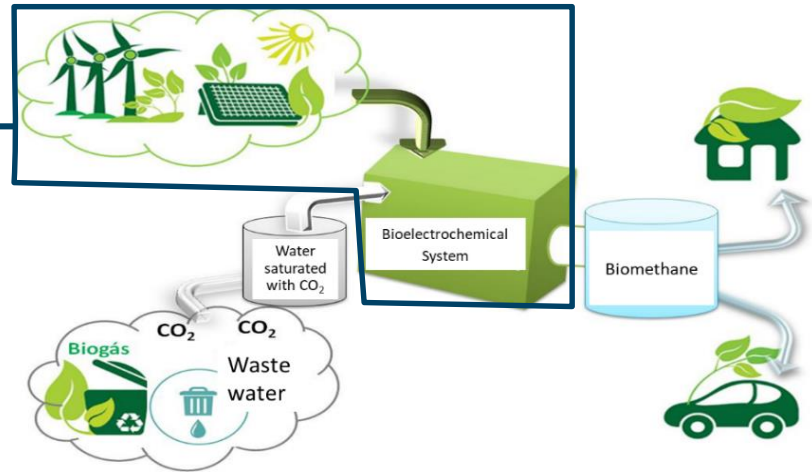
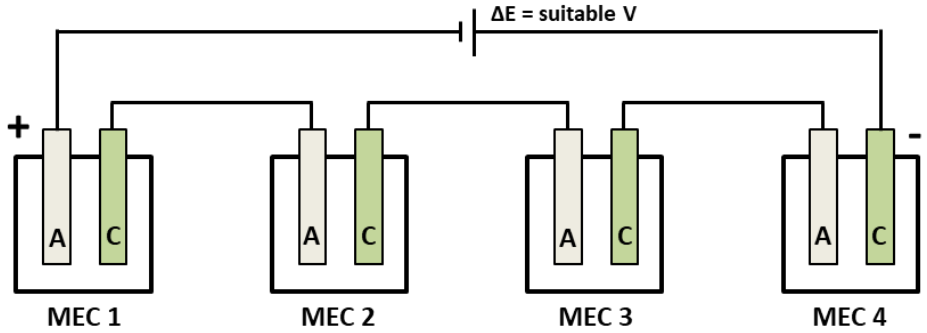
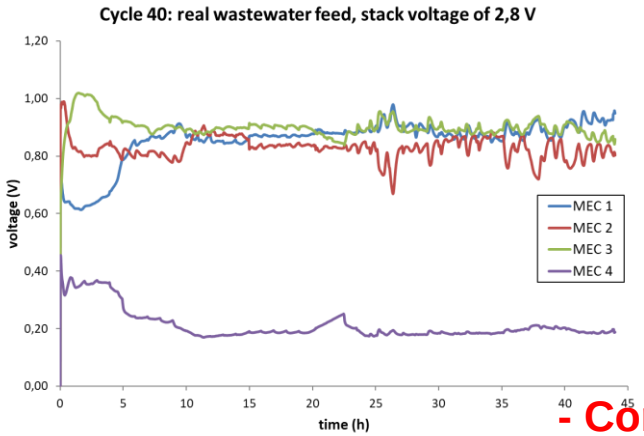




12, 24, 48, … V stack cells is needed to couple a reliable electronic control.

Cell voltage is controlled by passive, low-cost, up-scaling and robust electrical component

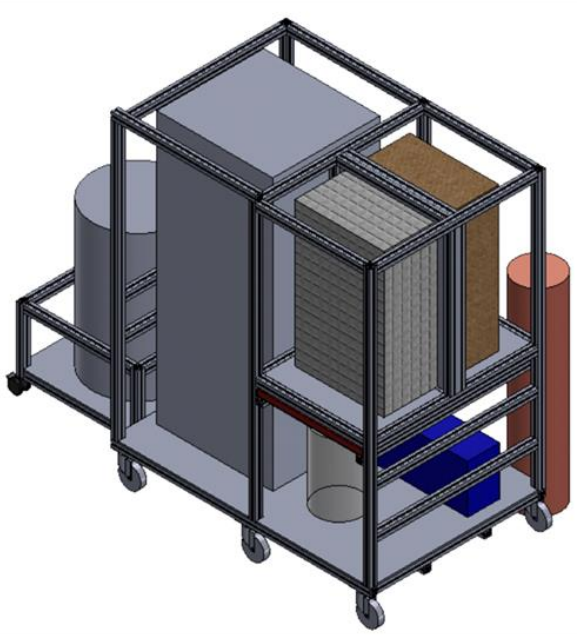


Power2Biomethane Project: Current Work

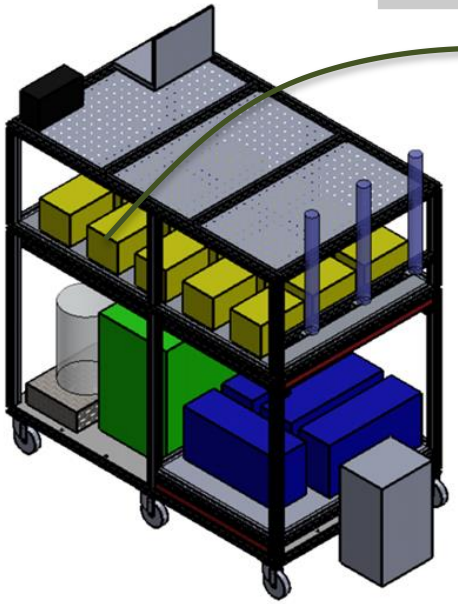
- Upscaling of the technology to TRL 5-6

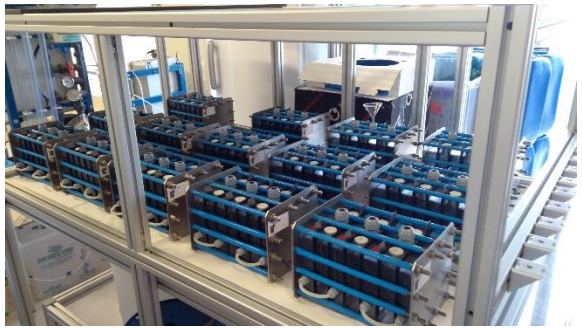
Paràmetre	Pilot TRL5-6
Volum net	27 L
Requeriment elect.	35 V // 20 mA // 1 W // 0,025 kW·d
Cabal aigua tractada	0,5-1.0 L_{ww}/h
Carga DQO	
Producció de biogàs	1-2 L CH_4/d > 95 % puresa

Sistema de dissolució de CO_2



Stack de piles BES





Conclusions

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Conclusions

- Power-2-Gas technology is a large scale storage option for the future management of excess renewable energy systems. The integration of the gas and electricity grids could play a significant role in a future renewable energy scenario.
- BES is an emerging technology with the potential to be a competitive option for power-to-fuel to produce renewable methane. It is potentially a particularly attractive method for biogas upgrading converting the CO_2 in biogas into biomethane.
- It is a potential low P and T solution (lower energy concept solutions).
- At the laboratory stage, good performance has been demonstrated.
- It is a low-cost, robust and scalable system.
- Power-to-Biomethane prototype based on BES is currently under construction for future evaluation.

Muchas gracias