Power to Gas in Aragón

CO_2 CAPTURE-USE AND INDUSTRIAL EMISSIONS MITIGATION GROUP

Mechanical Engineering Department
Escuela de Ingeniería y Arquitectura. Universidad de Zaragoza (Spain)

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ELYNTEGRATION Workshop, November 8th, 2017

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- ✓ 4. POWER TO GAS – CARBON CAPTURE HYBRID SYSTEMS
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CO_2 CAPTURE-USE AND INDUSTRIAL EMISSIONS MITIGATION GROUP

Main lines of research

- ✓ Energy integration and emissions mitigation in industry
- ✓ Energy Storage
- ✓ Carbon capture and utilization
- ✓ **Power-to-Gas**

Relevant recent projects

2018 – 2020 Solar Calcium-looping integration for Thermo-Chemical Energy Storage
Horizon 2020, European Union

2017 – 2019 Methane based on renewable energy and carbon capture and utilization, in residential, industrial and transport sectors
MINECO, Spanish ministry

2016 – 2018 Hydroxycombustion: towards 3rd generation of oxy-fuel combustion plants
MINECO, Spanish ministry

2015 – 2016 Energy storage (Power-to-Gas) and carbon capture integration in chemical industry with hydrogen production
ERCROS S.A., Private project

2013 – 2016 Amine-impregnated Alumina Solid Sorbent for CO_2 Capture
Research Fund for Coal and Steel, European Union

2014 – 2015 Modelling and optimization of CHP plants SAICA-1, SAICA-2, SAICA-3 and SAICA-4
S.A. Industrias Celulosa Aragonesa, Private project

2012 – 2015 Optimisation of oxygen-based CFBC Technology with CO_2 capture (O2GEN)
Seventh Framework Programme, European Union

2014 Innovative Processes: Implementation of Power to Gas technology in the Aragonese Pyrenean region
Ministerio de Industria, Comercio y Turismo, Spanish ministry

FUNDACIÓN PARA EL DESARROLLO DE NUEVAS TECNOLOGÍAS DEL HIDRÓGENO EN ARAGÓN

POWER TO GAS IN ARAGÓN

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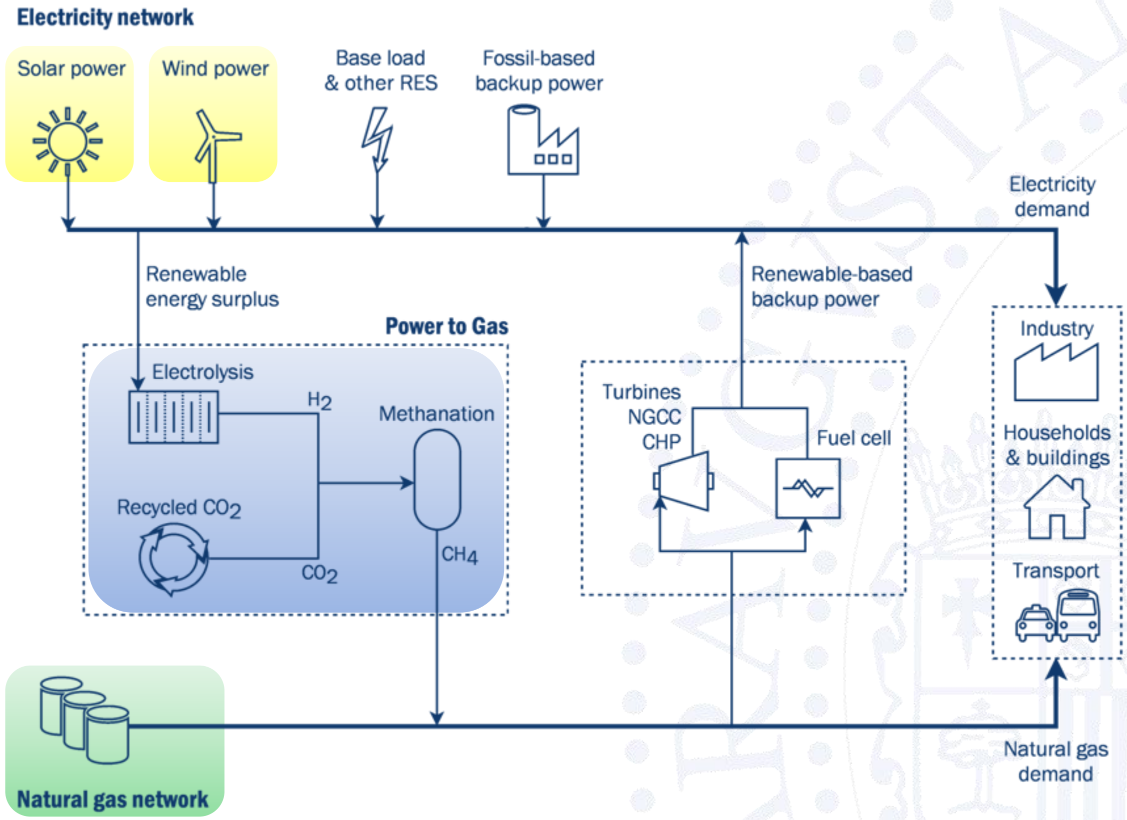
POWER TO GAS AND CO_2 RECYCLE



Energy storage

Surplus electricity from renewable sources is transferred to the natural gas network

Electrolysis

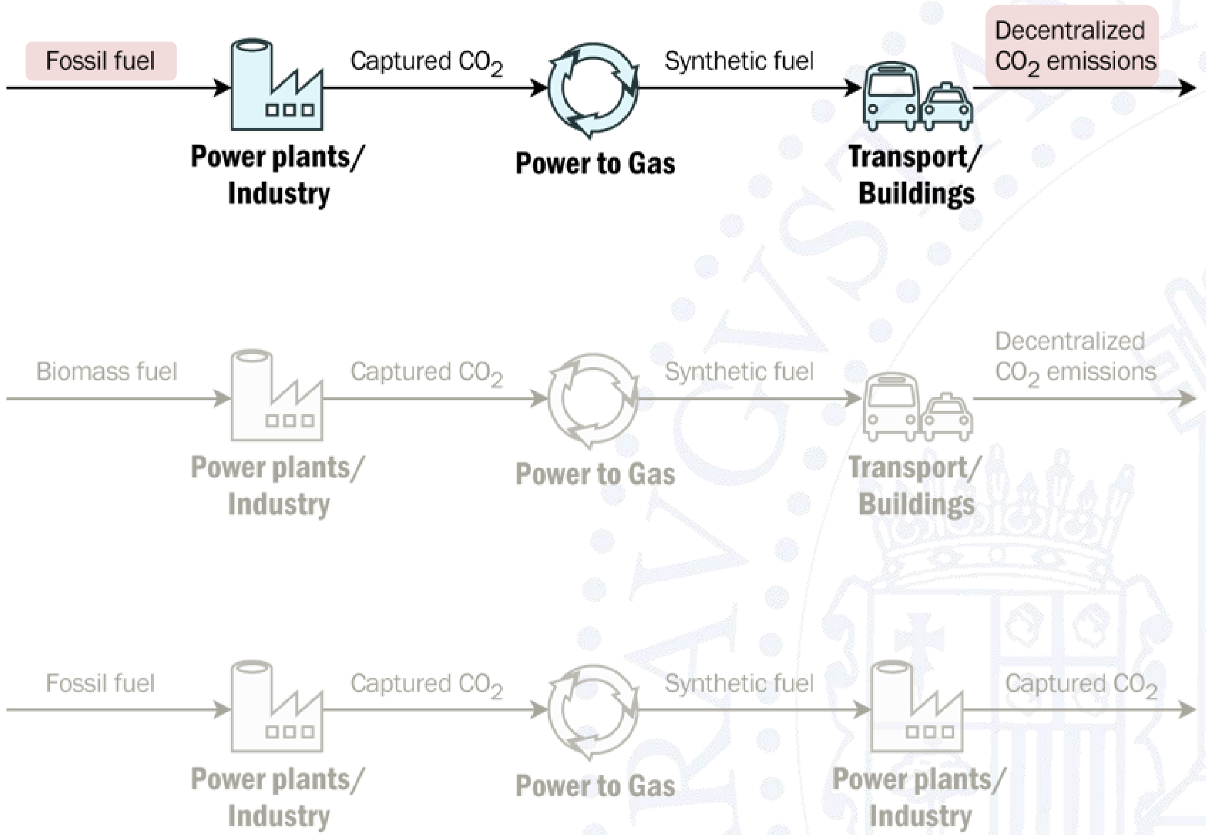
$$H_2O \leftrightarrow H_2 + \frac{1}{2}O_2$$

Methanation

$$CO_2 + 4H_2 \leftrightarrow CH_4 + 2H_2O$$

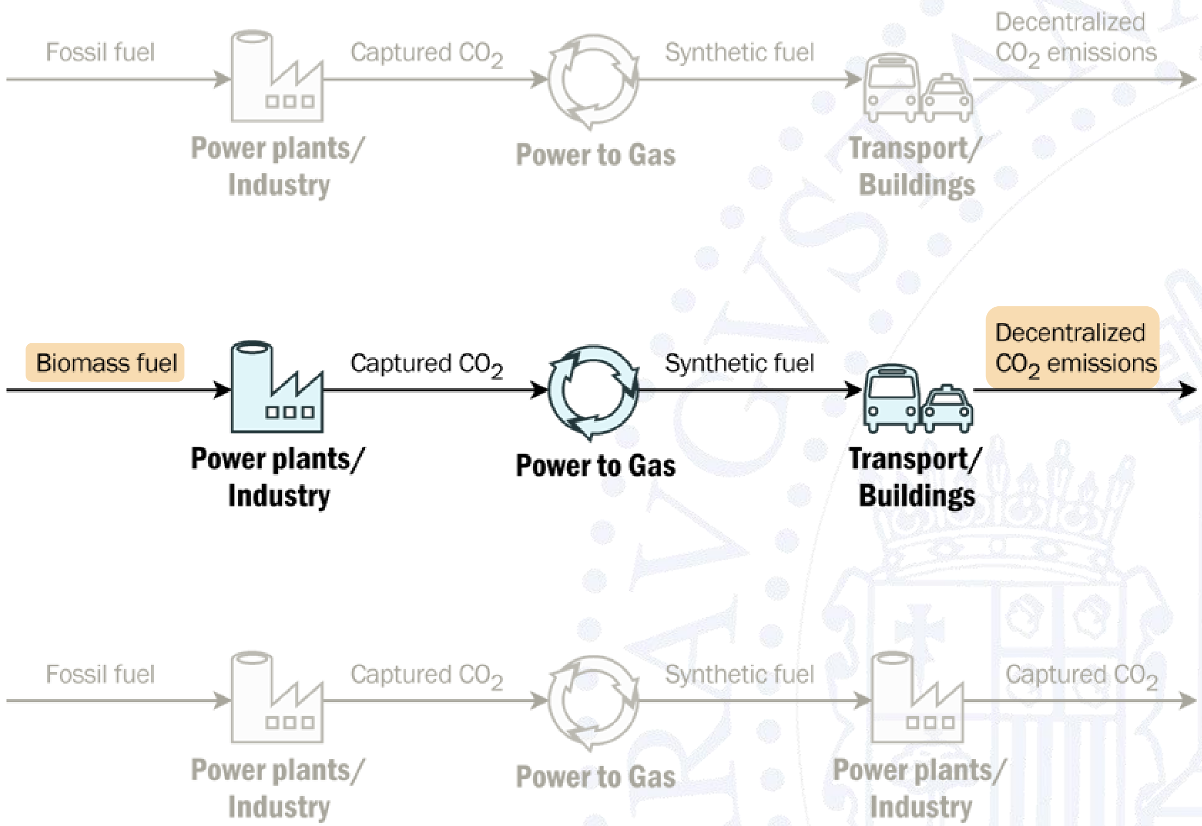
Bailera et al. (2017) Renew. Sust. Energ. Rev., 69, 292-312

POWER TO GAS AND CO_2 RECYCLE



PtG from fossil fuels + decentralized application = **net CO_2 emissions**

POWER TO GAS AND CO_2 RECYCLE



PtG from fossil fuels + decentralized application = **net CO_2 emissions**

PtG from biomass + decentralized application = **neutral CO_2 emissions** **(+dependence on biomass)**

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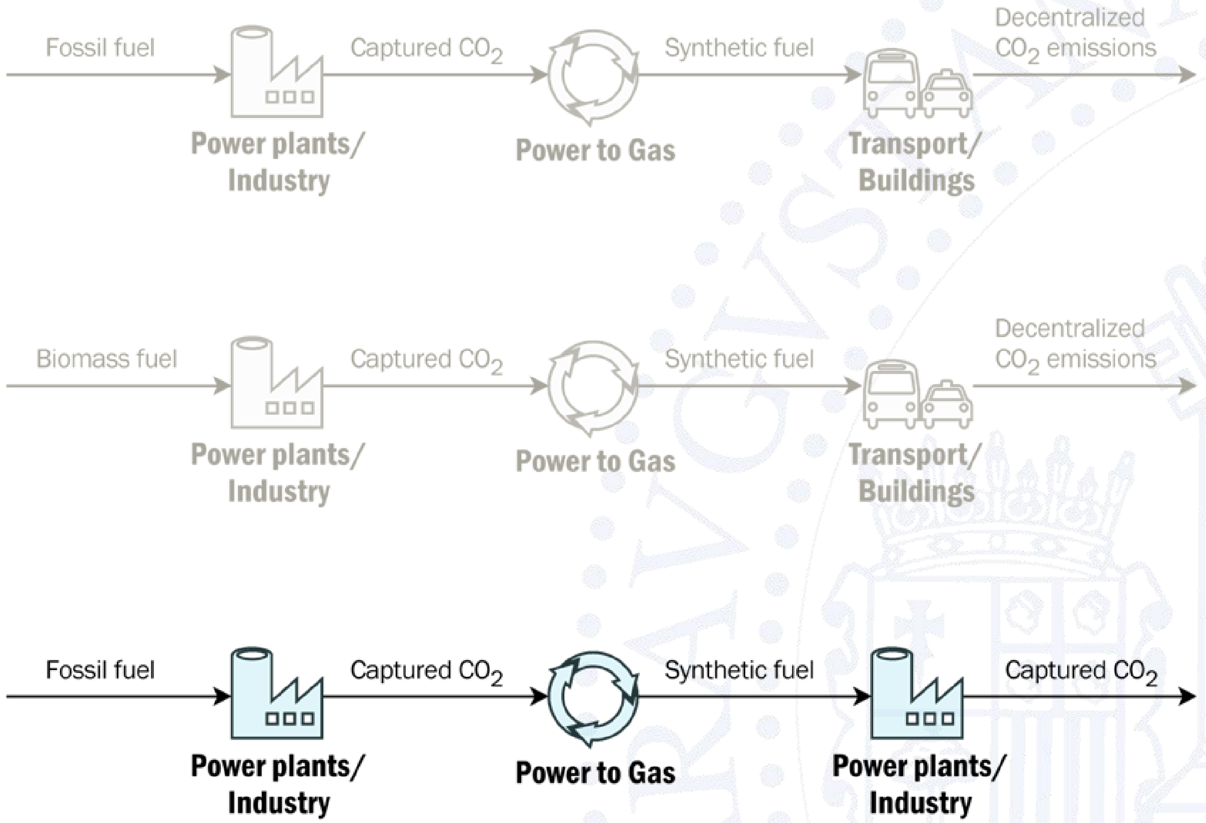


PtG from fossil fuels + decentralized application = **net CO_2 emissions**

PtG from biomass + decentralized application = **neutral CO_2 emissions** **(+dependence on biomass)**

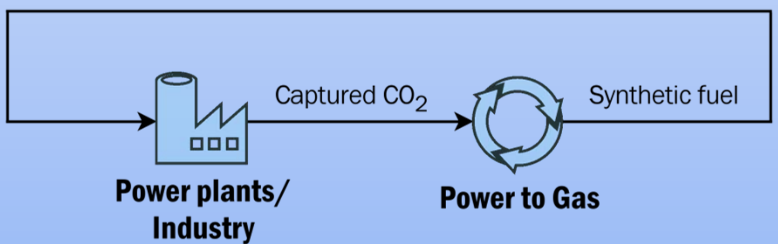
PtG from fossil fuel + centralized application = **CO_2 avoided**

POWER TO GAS AND CO_2 RECYCLE

CO_2 recycling

Industry and power plants can produce the SNG they need by using their own emissions.

- CO_2 avoided
- Fuelled just by renewable energy
- No need to retrofit industry/power plants



PtG from fossil fuels + decentralized application = **net CO_2 emissions**

PtG from biomass + decentralized application = **neutral CO_2 emissions (+dependence on biomass)**

PtG from fossil fuel + centralized application = **CO_2 avoided**

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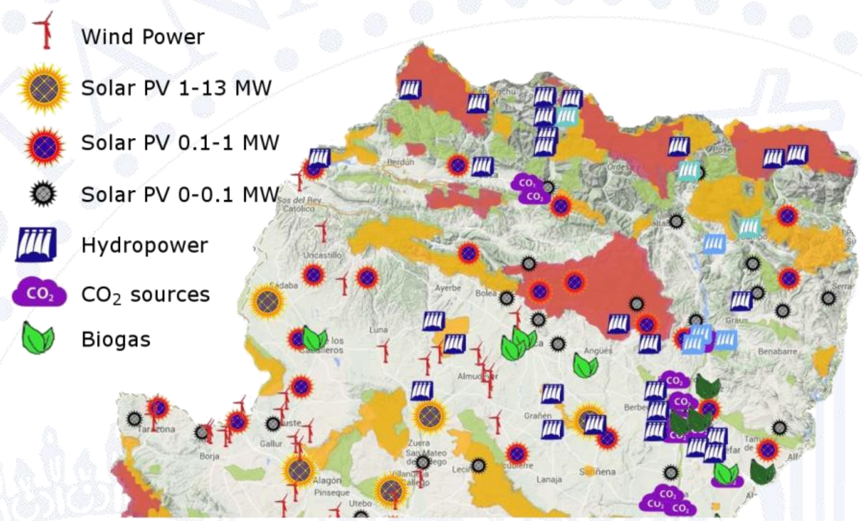
RENEWABLE ENERGY & CO_2 POTENTIAL IN THE PYRENEES

- **FdH_2 collaboration**

FUNDACIÓN PARA EL DESARROLLO DE NUEVAS TECNOLOGÍAS DEL HIDRÓGENO EN ARAGÓN

- **A detailed analysis of the availability of renewable energy resources (wind energy, solar and hydropower) has been carried out to select the most appropriate renewable source**.
  - Wind energy is located far from the Pyrenees region
  - Solar energy is influenced by orientation and not suitable for the reduction of available working hours



- **It has been concluded that hydropower is the best option and most flexible for this kind of projects.**
- There are several important sources of CO_2 in the industrialized area but most of them are far from the renewable sources. One specific case has been selected in the Pyrenees region because the industry has also possibilities of excess hydrogen.

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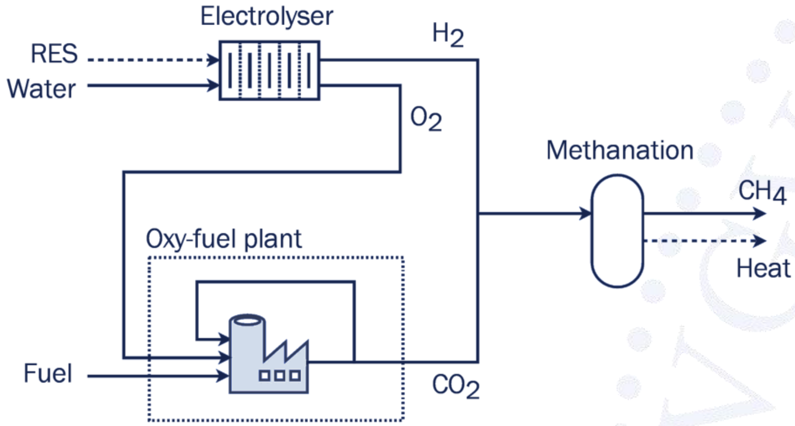
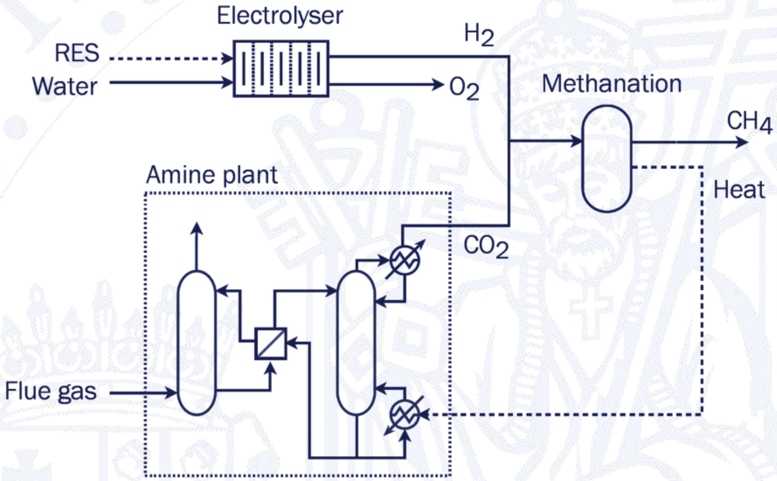
POWER TO GAS – CARBON CAPTURE HYBRID SYSTEMS

1. PtG – OXYFUEL COMBUSTION



- ✓ O_2 from electrolysis replaces ASU
- ✓ Heat from methanation can be integrated in the power cycle of the power plant

2. PtG – AMINE PLANT



- ✓ Heat from methanation is integrated in the reboiler of the stripper column
- ✓ O_2 integration depends on the application

POWER TO GAS – CARBON CAPTURE HYBRID SYSTEMS – OXYFUEL

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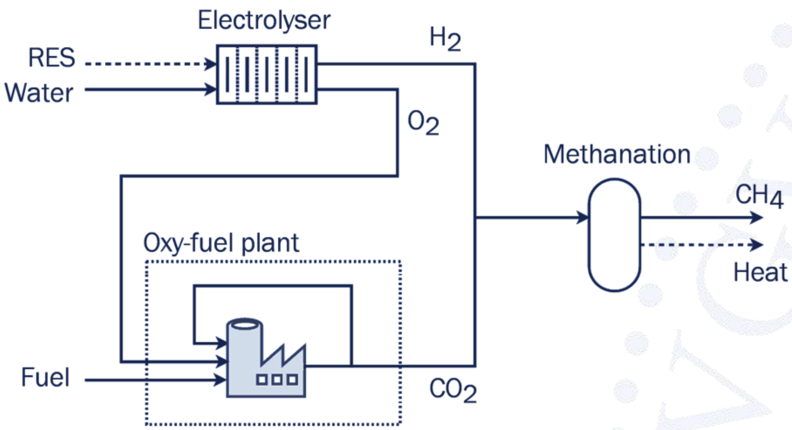

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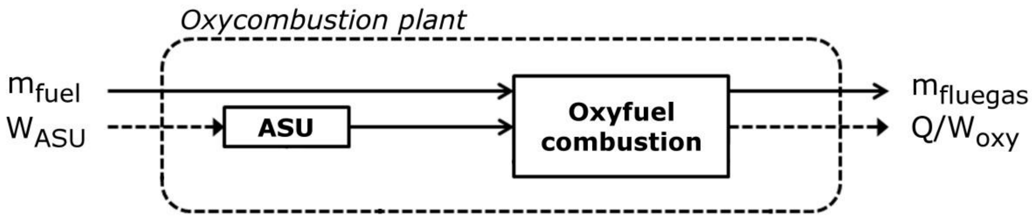

Bailera et al. (2015) Int. J. Hydrog. Energy, 40, 32:10168-10175
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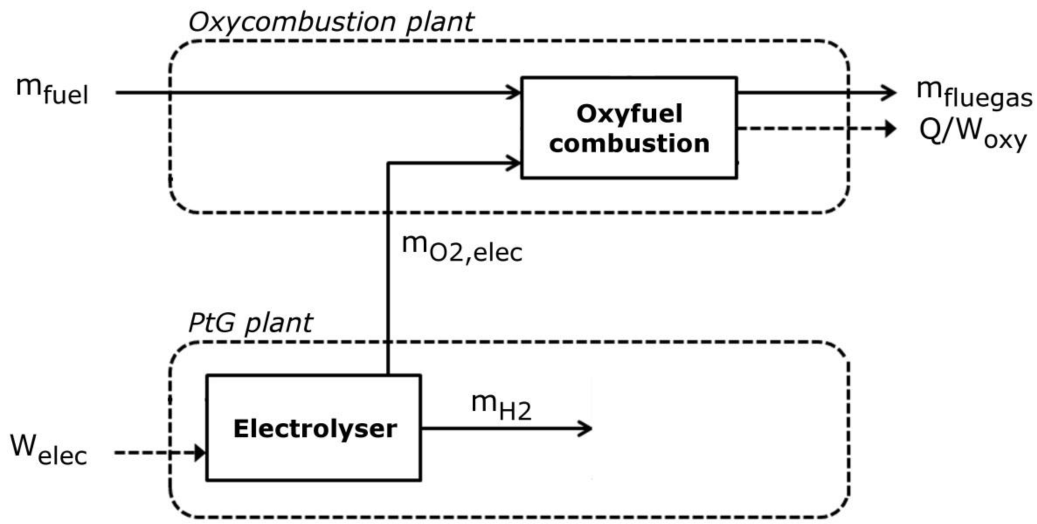
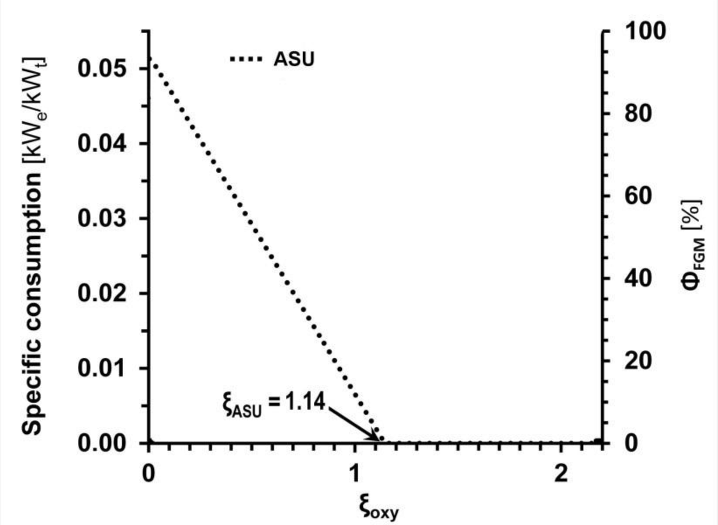


Can **ASU** be avoided?

$$\xi_{oxy} = \frac{LHV_{H2} \cdot \dot{m}_{H2}}{\dot{Q}_{oxy}}$$



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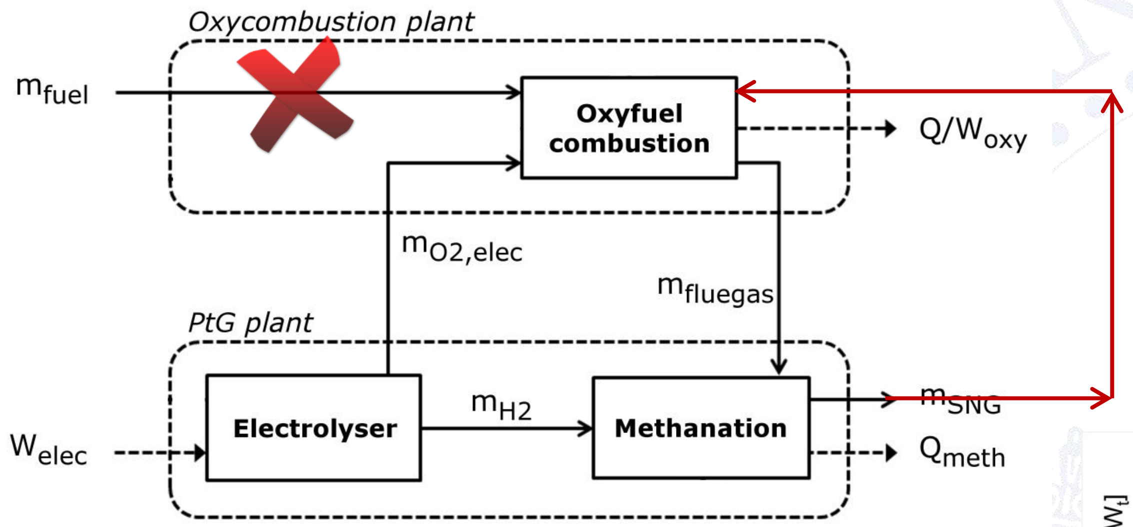
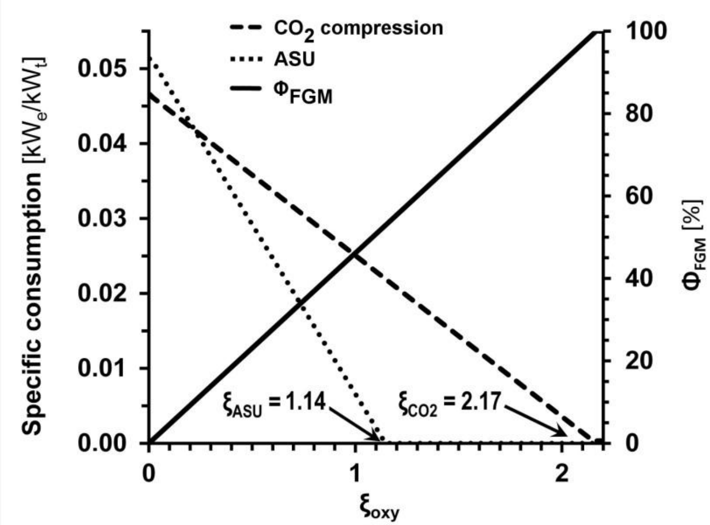


Can **CO_2 storage** be avoided?

$$\xi_{oxy} = \frac{LHV_{H2} \cdot \dot{m}_{H2}}{\dot{Q}_{oxy}}$$



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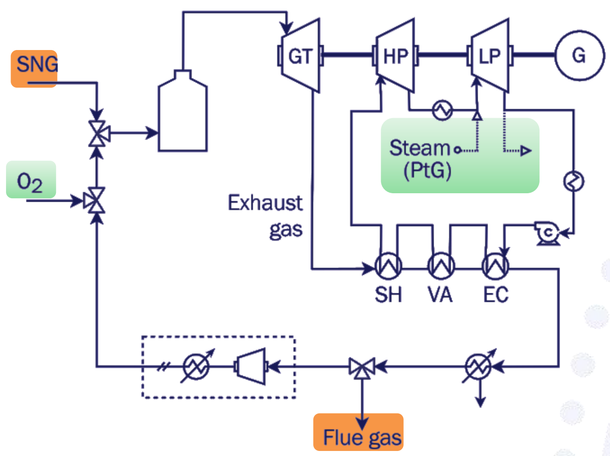
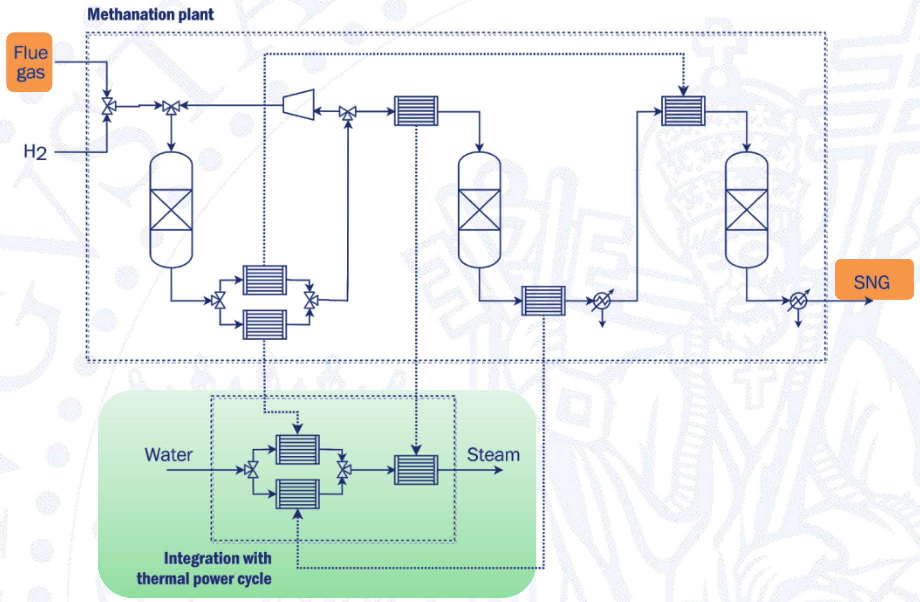
POWER TO GAS – CARBON CAPTURE HYBRID SYSTEMS – OXYFUEL

APPLIED CASE: Power to Gas - Oxyfuel combined cycle (~30 MWe)





CASE: hybrid plant

- ✓ **Net power:** 31.1 MWe → 35.8MWe
- ✓ **ASU consumption:** 3MWe → 0 MWe
- ✓ **Efficiency:** 55.9% → 64.0 %
- ✓ **Fuel input:** 5775.9 m^3 of SNG (95.2% CH_4)
- ✓ **Flue gas output:** 5859.1 m^3 → 0 m^3
- ✓ **SNG production:** 0 m^3 → 5757.0 m^3 (95.2% CH_4)

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POWER TO GAS – CARBON CAPTURE HYBRID SYSTEMS – OXYFUEL

APPLIED CASE: Power to Gas - Oxyfuel combined cycle (~30 MWe)

Electrolysis necessity:

98.2 MWe *(same hours in storage/production mode)*

Efficiency of the plant:

35.8 MW / 98.2 MW = 36.5%

Converting renewables into manageable sources gives similar efficiencies to those presented by power plants with carbon capture

Advantages:

- ✓ No fossil fuel required
- ✓ No CO_2 to be stored
- ✓ PtG-OxyCC can be used to manage renewable surplus

✓ **Efficiency:** 55.9% → 64.0 %

✓ **SNG production:** 0 m^3 → 5757.0 m^3 (NTP) (95.2% CH_4)

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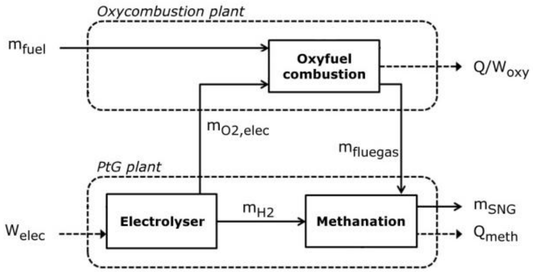
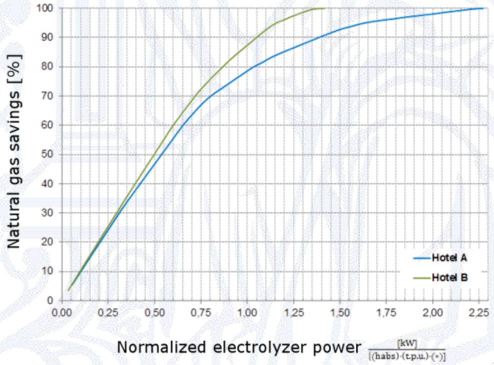
FUNDACIÓN PARA EL DESARROLLO DE NUEVAS TECNOLOGÍAS DEL HIDRÓGENO EN ARAGÓN

APPLIED CASE: Power to Gas - Oxyfuel in small applications

- ✓ **Oxyfuel boiler integrated with an electrolyser and a methanation reactor** applied to supply thermal energy in hotels (medium size, 80 rooms)
- ✓ **Efficiencies higher than 50% and fuel savings up to 60% are obtained**
  - ✓ Option A is dimensioned with a 30 kW electrolyser and able to produce 25% of the natural gas demand
  - ✓ Option B is bigger with a 72 kW electrolyser and able to produce 60 % of the natural gas demand.
- ✓ **The conclusions showed that with actual costs both installations were not feasible without subsidies.**
- ✓ Nevertheless, social and environmental benefits (employment and CO_2 reduction) are relevant for the touristic region if these systems are installed



	Required electrolizer power [kW]	
Natural Gas Savings [%]	Hotel A	Hotel B
20	30,4	48,5
40	62,4	98,1
60	96,3	149,3



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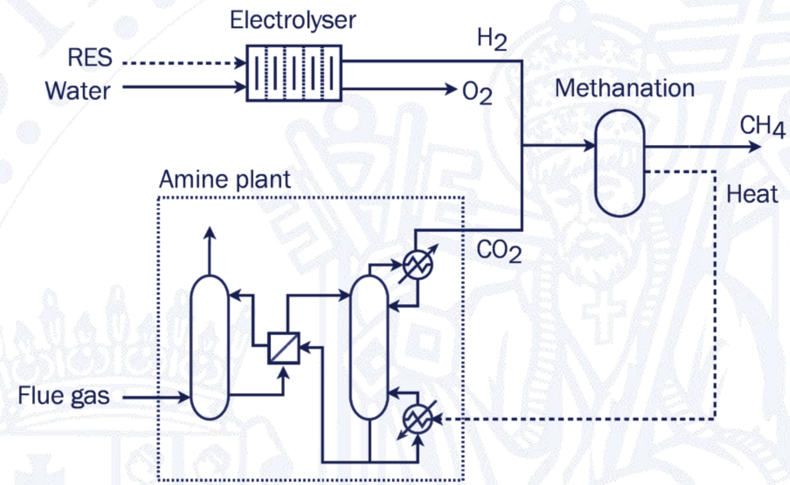

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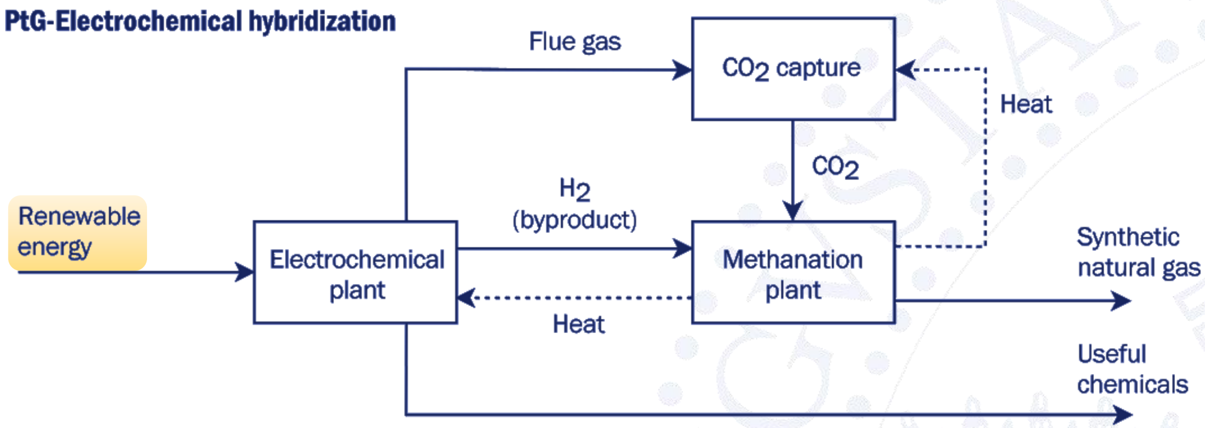
APPLIED CASE: Power to Gas – Electrochemical industry (real case)



Electrochemical plant

The EC plant follows the **low cost** periods of the **electricity** market

Bailera et al. (2017) Appl. Energy, 202, 435-446

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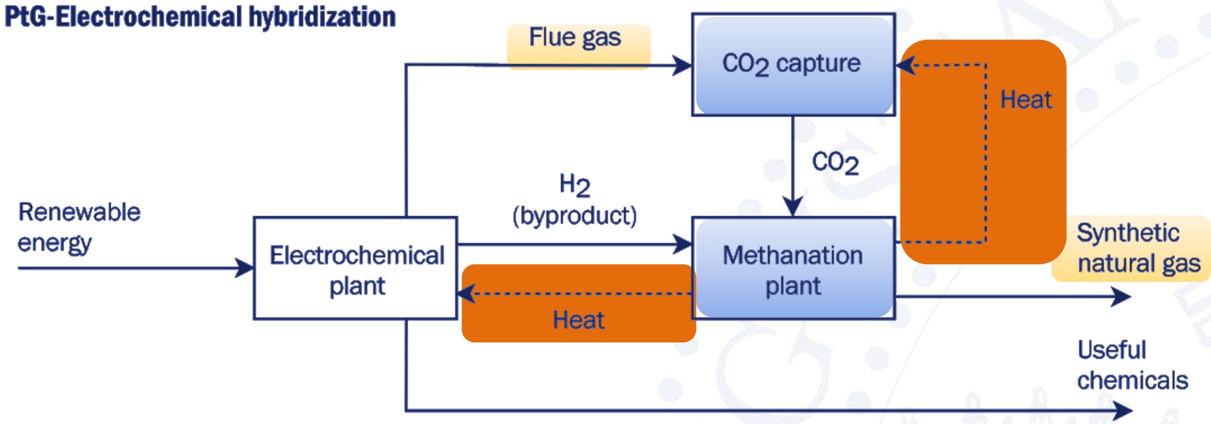

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Electrochemical plant

The EC plant follows the low cost periods of the electricity market

Useful chemical products are obtained by processes of electrolysis that sub-produce H_2

The EC plant needs steam, which is produced in a natural gas boiler.
Flue gas can be recycled to SNG with methanation and amine carbon capture

Heat from methanation can be **integrated** in the amine plant or can be used to produce steam

POWER TO GAS – CARBON CAPTURE HYBRID SYSTEMS – AMINE PLANT

APPLIED CASE: Power to Gas – Electrochemical industry (real case)

Size and economics

Selected methanation plant:

- ✓ 6 MW of H_2 input
- ✓ H_2 buffer of 1000 Nm^3 (criteria: small to reduce costs)
- ✓ 6070 h (criteria: > 6000 h)
- ✓ 85.9% H_2 used (criteria: > 85.0%)
- ✓ 58.2% CO_2 used (amine plant's nominal output: 524 Nm^3/h)

CAPEX (5.1 M€)

- ✓ Amine plant, 523 k€
- ✓ Methanation plant, 2158 M€
- ✓ Heat exchanger network, 180 k€
- ✓ Other (direct costs), 1316 M€
- ✓ Other (indirect costs), 960 k€

OPEX (215 k€/year)

- ✓ MEA, catalyst, electricity, O&M…

INCOMES (1.0 M€/year)

- ✓ Natural gas savings, 978 k€/year
- ✓ Steam savings, 36 k€/year

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POWER TO GAS – CARBON CAPTURE HYBRID SYSTEMS – AMINE PLANT

APPLIED CASE: Power to Gas – Electrochemical industry (real case)

Size and economics

Pay-Back: 8 year

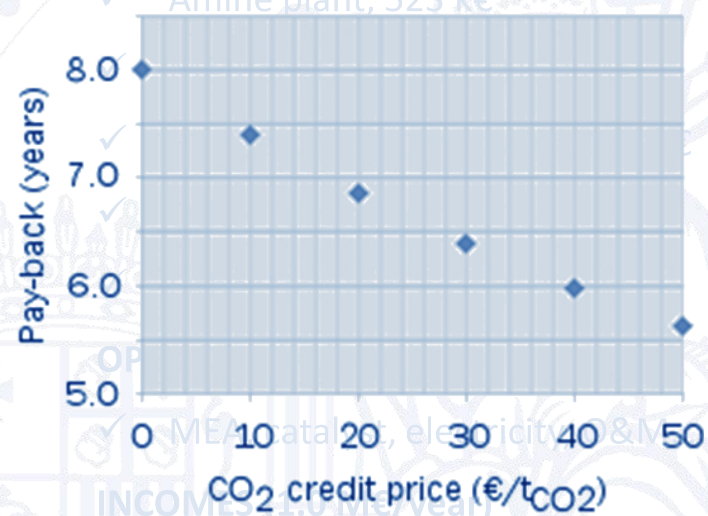
Internal rate of return: 8.96%

Net Present Value: 4.76 M€

NG price: 28.99 €/MWh

CO_2 credit price: **0 €/t_{CO2}**

Project lifetime: 20 years



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CURRENT RESEARCH

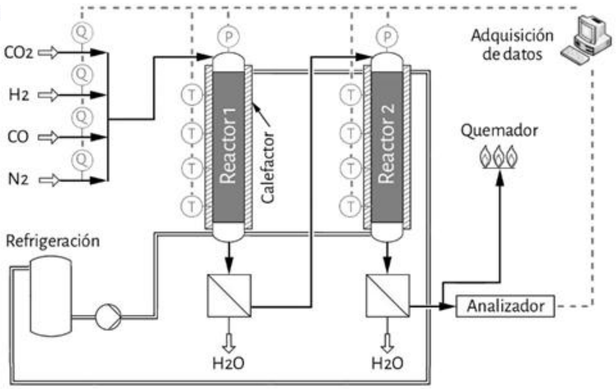
MERCURIA PROJECT

- ✓ Pilot plant installation (equivalent to a 5 kW electrolyser and two atmospheric pressure methanation reactors)

- ✓ Analysis of operational variables as input gas impurities, transient response to temperature changes and heat transfer.

- ✓ Thermographic analysis: On-line monitoring with an infrared camera for the measurement and control of catalyst temperature.

- ✓ Proposals and analysis of configurations of Power to Gas applications in residential, transport and industrial sectors.



POWER TO GAS IN ARAGÓN

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HIGHLIGHTS

- ✓ Based on an analysis of the availability of renewable energy resources, it has been concluded that **hydropower is the best option** to be used jointly with Power to Gas **in the Pyrenees region**

- ✓ **Power to Gas-Carbon capture** hybrid systems allow to **recycle CO_2** in closed loops

  - ✓ **PtG-Oxycombustion** avoids, both CO_2 storage and ASU, energy penalizations in small applications

  - ✓ **PtG-Amine** in chemical industry is economically **FEASIBLE**, and it avoids CO_2 emissions and saves natural gas

- ✓ **Current research** is focused in the **design and operation of a PtG pilot** plant installation and the analysis of **configurations of PtG** applications in residential, transport and industrial sectors

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Thanks for your attention!

Acknowledgements

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