CO_2 recycling based on 'Power to Gas-Carbon capture' hybrid systems

M. Bailera[1], L.M. Romeo[1]*, P. Lisbona[2], S. Espatolero[3], B. Peña[1]
[1]Escuela de Ingeniería y Arquitectura. Departamento de Ingeniería Mecánica. Universidad de Zaragoza, Campus Río Ebro, María de Luna 3, 50018, Zaragoza, Spain
[2]Escuela Universitaria de Ingenierías Agrarias de Soria, Universidad de Valladolid, Campus Universitario Duques de Soria, 42004 Soria, Spain
[3]Fundación CIRCE. Mariano Esquillor Gómez, 15, 50018, Zaragoza, Spain
*luismi@unizar.es

Keywords Oxycombustion; Power-to-Gas; CO_2 recycling; methanation

ABSTRACT

Beyond the development and implementation of the CO_2 capture technologies required to separate this gaseous compound from flue gases and avoid its emission to the atmosphere, there exists the need of recycling and valorize this stream which, otherwise, must be compressed and stored with the consequent associated energy and economic cost.

On the other hand, the constant penetration of renewable energy sources in electricity production has brought to light the necessity of deploying energy storage systems. The management of the intermittency of renewable energy sources and the variable excess power derived from a highly renewable energy scenario is one of the largest future challenges for developing a sustainable power sector. Power-to-gas (PtG) has been proposed in the last years as one of the promising technologies to overcome these problems.

In general terms, PtG converts the surplus of electricity into synthetic natural gas by combining water electrolysis and CO_2 methanation. This technology valorizes captured CO_2 to produce a 'CO_2 neutral' natural gas while facilitate the use of hydrogen in the current energy system. Thus, the interconnection of the electric and gas network increases the flexibility of the energy supply. Several combinations may lead to a better integration of energy and mass flows in the PtG plant.

Two hybridization proposals are presented in this study: (i) PtG-Oxyfuel system and (ii) PtG-Amine based capture system. To take advantage of the oxygen generated by electrolysis, **PtG is integrated with oxyfuel combustion** (O_2/CO_2 as comburent) that provides thermal energy and generates flue gases mainly composed by CO_2 (Figure 1). CO_2 is introduced together with hydrogen in a methanation reactor to produce natural gas.

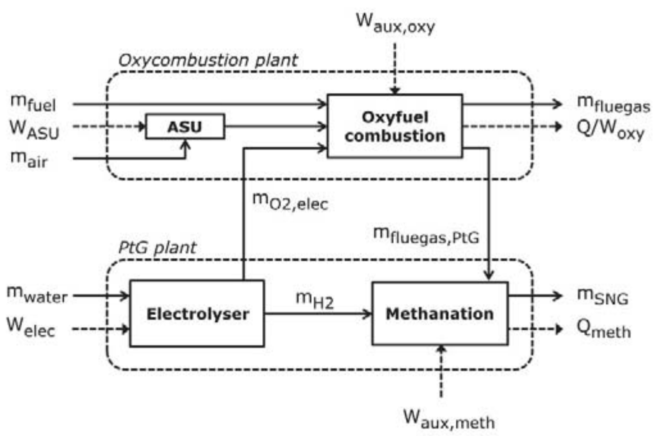

Figure 1. Hybrid Power to Gas-Oxyfuel system

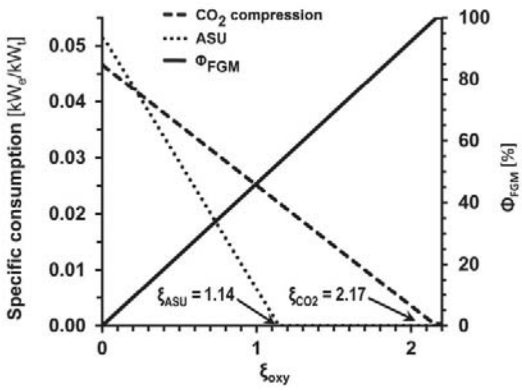

Figure 3. Specific consumptions and methanised flue gas vs ξ_{oxy}, for biomass fuel

The variable which defines this kind of systems is the size ratio ξ_{oxy}, which relates the energy contained in hydrogen produced by electrolysis and the thermal output of the oxyfuel boiler.

$$\xi_{oxy} = \frac{LHV_{H2} \cdot \dot{m}_{H2}}{\dot{Q}_b} \left[\frac{kW_{H2}}{kW_t}\right]$$

The value of the size ratio between boiler and electrolyser, ξ_{oxy}, will determine the strategy to operate the PtG–oxycombustion hybridized plant (Figure 3): (i) ASU removal when the oxygen produced in the electrolysers is enough to completely fed the oxyfuel boiler (ξ_{ASU}); and (ii) CO_2 stream removal when flue gas flow produced in the oxyfuel combustion is completely reused and converted to SNG thanks to the hydrogen generated (ξ_{CO2}). This work also presents how ξ_{oxy} varies depending on the used fuel. For example, the use of biomass in the boiler, instead of coal, allows reducing the size ratio requirement for avoiding the need of ASU, ξ_{ASU}, since oxygen content in biomass is much greater.

The combined system of **PtG with an amine-based capture** process does not make use of the sub-produced oxygen. However, the heat released in the methanation reactors may be integrated in the regeneration step of the amine and reduce the energy penalty (Figure 2).

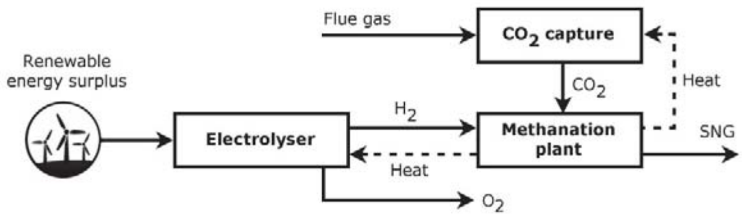

Figure 2. Hybrid Power to Gas-Amine CO_2 capture system

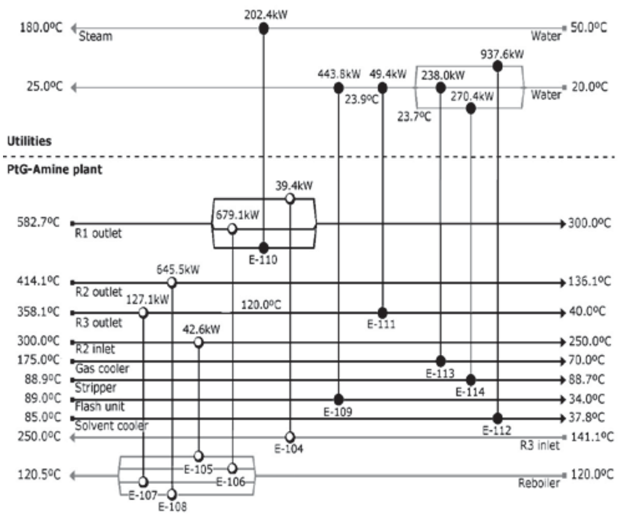

Figure 4. Optimized heat exchanger network of a PtG-Amine hybrid system

A case study of an electrochemical plant which subproduces H_2 is analysed after the inclusion of an amine capture plant to treat its flue gas flow. In this kind of systems, the grater heat requirement comes from the CO_2 desorption process in the amine plant. This requirement may be provided by the streams of both systems what, in our specific case study, diminishes the cooling needs down to 2141.6 kW. Moreover, part of the remaining cooling necessity takes place at high temperature, so it allows the production of 238.8 kg/h of steam at 180 ºC which may be use in the electrochemical plant; the rest can be cooled with water since the temperatures to reach are not lower than 34 ºC.