Techno-economic analysis of electrified turquoise hydrogen production processes

Alessandro de Cataldo*, Paolo Colbertaldo, Stefano Campanari, Alessandra Beretta, Matteo Carmelo Romano

[1]*Politecnico di Milano, Department of Energy, via Lambruschini 4, 20156 Milano, Italy*

**Corresponding author: alessandro.decataldo@polimi.it*

Highlights

- Two technologies based on methane pyrolysis with two products are being investigated from a techno-economic perspective.
- Hydrogen conversion efficiencies of 58% to 63% are reached for electrically heated technologies.
- With carbon capture ratios of 89-96%, the outlet solid carbon accounts for 45-49% of the total LHV energy input from natural gas (NG).
- Economic analysis is performed for all technologies.

1. Introduction

The objective of this work is to develop a techno-economic analysis of full-scale methane pyrolysis (MP) plants to produce either a H_2-rich low-carbon fuel (pyrogas) or high-purity H_2. The study considers two different options for heat supply: (i) through electric heating and (ii) by burning part of the produced pyrogas in a furnace. The advantages with respect to conventional hydrogen production via Steam Methane Reformer lie in allowing a decarbonized production of H_2 with contextual storage of solid carbon that may be transported and sent to disposal or sold as a valuable product.

2. Methods

The methane pyrolysis reactor is composed of a fluidized bed, operating around 800-850°C and at nearly atmospheric pressure. Alumina-supported metal-based catalysts are considered in the analysis [1]. The proposed plants are described in Figure 1. The process involves the presence of solid filters for both catalyst separation from carbon and solid separation from the gaseous stream. The produced pyrogas from the reactor is cooled down and may be either directly exported or, when high-purity hydrogen is produced, sent to a compressor and a hydrogen purification section (composed by Pressure Swing Adsorbers). The unconverted methane and the other inert gases (N_2 and CO_x due to CO_2 in the NG feed) are recirculated back to the pyrolysis reactor to increase global methane conversion. When a furnace is adopted, part of the produced pyrogas is burned to feed the reaction and heat can be recovered from flue gases cooling. The process and components are simulated in Aspen Plus, assuming equilibrium conditions for the pyrolysis reactor. A techno-economic analysis is conducted to determine the most competitive configuration.

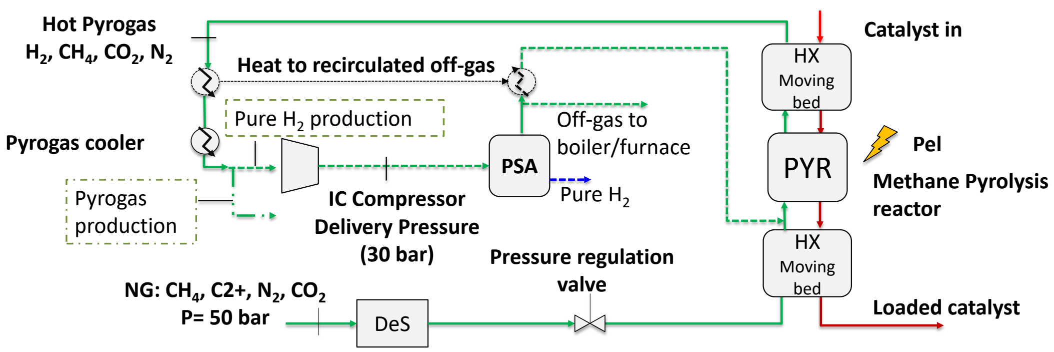

Figure 1. Block flow diagram of a pyrolysis-based plant (dashed lines represent streams and components only present in H_2 production case).

3. Results and discussion

The heat and mass balances for the electrified cases and for the two different considered products are evaluated and presented in Figure 2. Compared to the pyrogas production case, when high purity hydrogen is produced the electricity consumed increases due to (i) the increased methane conversion, (ii) the inert species recirculation, and (iii) the compressor electric consumption up to delivery pressure. In all cases solid carbon accounts for a large share of the total LHV energy leaving the system.

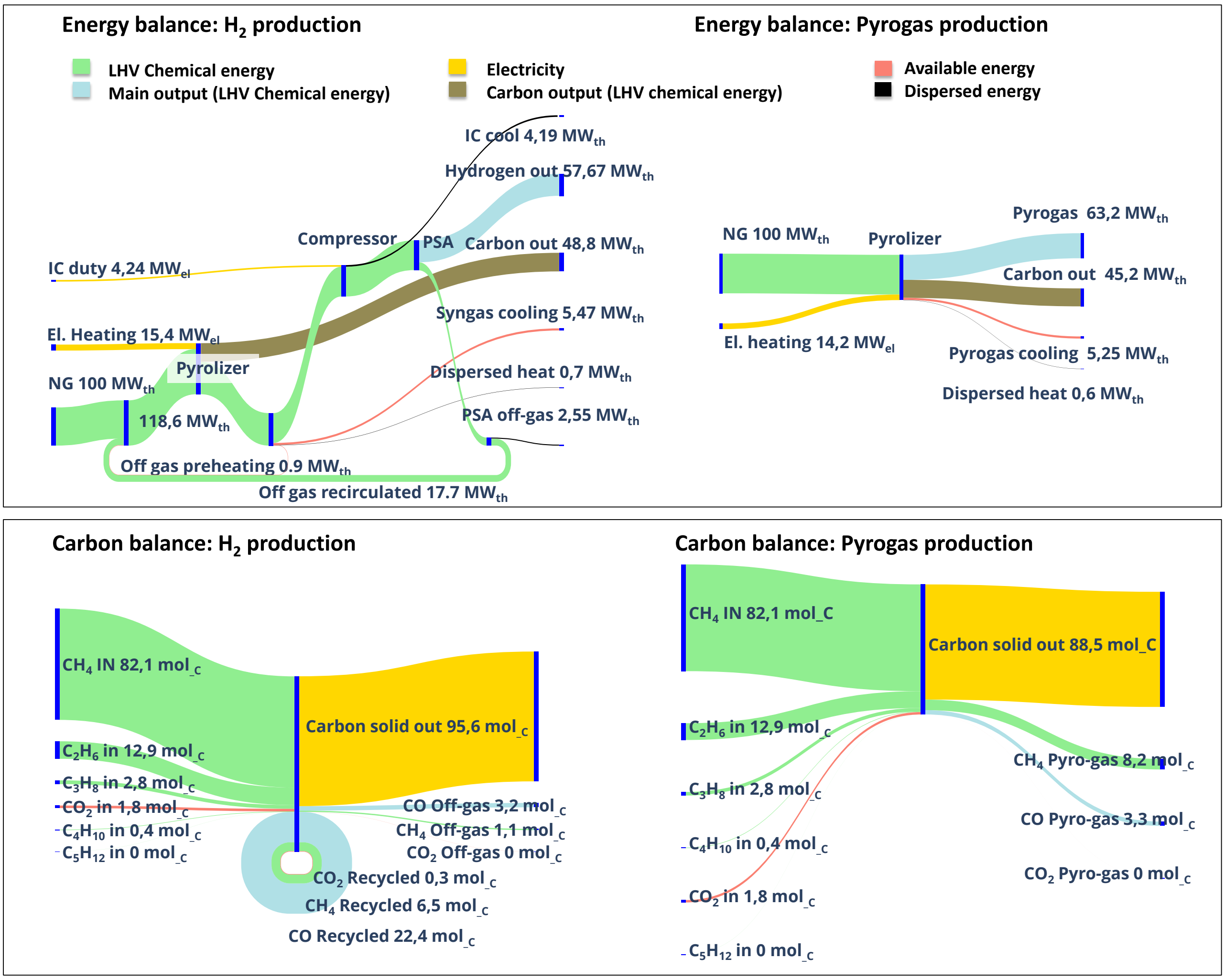

Figure 2. Sankey diagrams for heat (top) & carbon (bottom) balances for the electrified cases in the options of H_2 (left) and Pyrogas (right) production.

4. Conclusions

Electrified Methane Pyrolysis-based plants for the production of pyrogas or hydrogen obtain cold gas efficiencies of 63.2% and 57.7% and Carbon Capture Ratios of 88.5% and 95.8%, respectively. Different scenarios are analyzed to determine: (i) the main drivers for technology development and utilization, and (ii) the economic frameworks under which the selected technologies may represent a feasible way for hydrogen production or industrial plants decarbonization.

References

[1] J.L. Pinilla, R. Utrilla, R.K. Karn, I. Suelves, M.J. Lázaro, R. Moliner, A.B. García, J.N. Rouzaud, Int. J. Hydrogen Energy 36 (2011) 7832-7843

Keywords

Natural gas, turquoise hydrogen, fluidized bed, catalytic decomposition.