Improvement and cost analysis of Power-to-Gas technology through process simulation

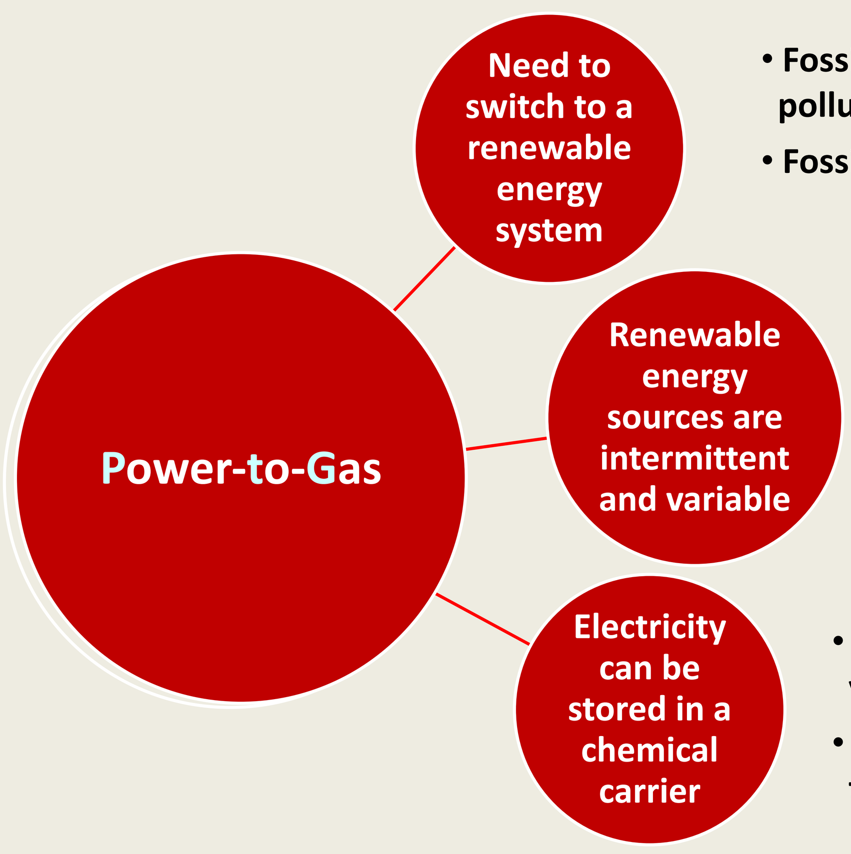
I. García-García[1], J.F. Cambra[1], J.R. Arraibi[2], A.M. Gutiérrez[2], V.L. Barrio[2]

naturgas energia

[1] Faculty of Engineering (UVP/EHU), Dept. of Chemical and Environmental Engineering, Bilbao, Spain
[2] Nortegas Energía Distribución S.A.U., Bilbao, Spain

Universidad del País Vasco / Euskal Herriko Unibertsitatea — Faculty of Engineering Bilbao, University of the Basque Country

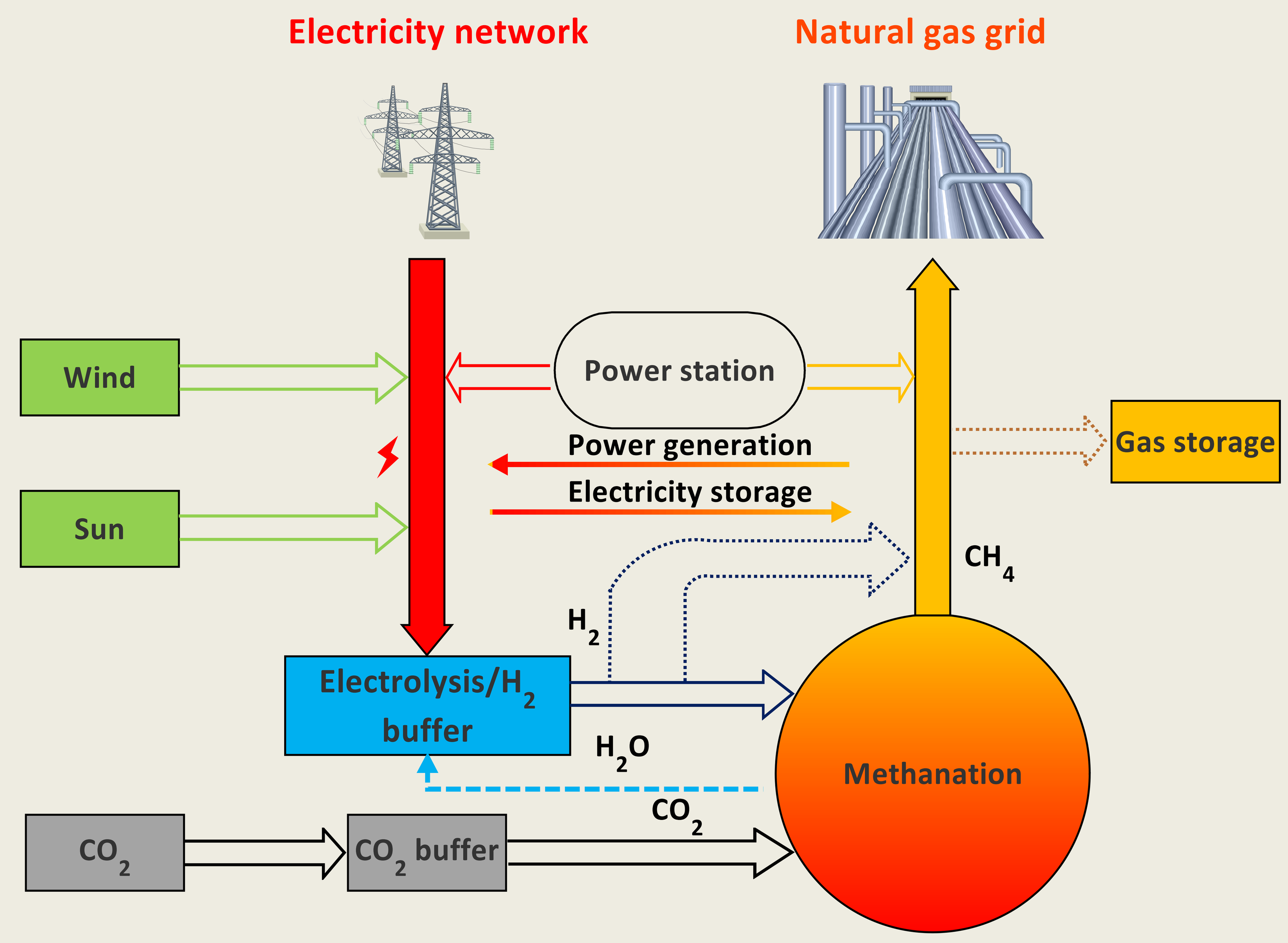
Introduction



- Fossil fuels are the main responsible of pollution.
- Fossil fuel reserves will be exhausted.

- Storage is needed in order to have a flexible system based on renewable energy sources.

- Producing hydrogen results in a higher overall yield.
- Methane is a well-known energy carrier and the infrastructure is ready for its use.



Methodology

Aspen Plus v9 (Aspentech) software was employed for the simulation of the process and the sizing of the different equipments.

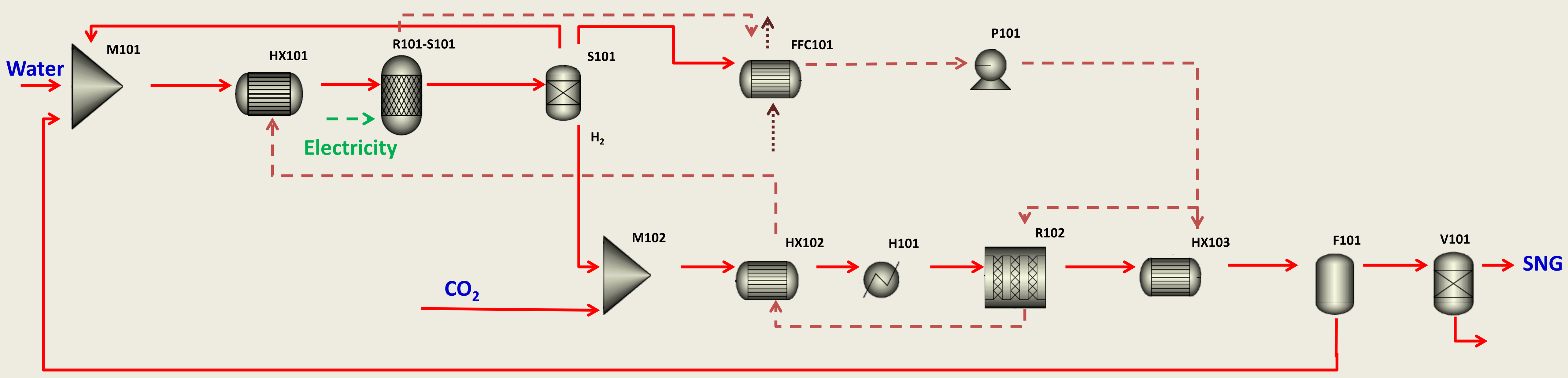
The industrial plant design should be separated in three different areas: i) water electrolysis process, ii) carbon dioxide methanation process and iii) condensation of the produced gas stream, with the gas product being injected into the natural gas grid, taken into account the NG requirements; and the liquid product, mainly water, being recycled in the electrolysis process. The design also should present different heat exchangers in order to optimize the heat efficiency of the process.

Initial assumptions
- Power: 20 MW (average Spanish wind power plant)
- Pure carbon dioxide as feed
- Kinetic model from literature

Model design
- AspenPlus process simulation
- Heat integration
- Economic analysis

Model validation
- Product requirements according to Spanish gas regulation
- Feasibility of the proposed industrial plant

Results



Equipment list:

- M101 and M102: mixer
- R101-S101: electrolyser stack
- HX101, HX102 and HX103: heat exchanger
- H101: heater
- R102: methanation reactor
- F101: flash condenser
- V101: membrane
- FFC101: fin fan cooler
- P101: pump

Electrolyser stack

Design based on commercially available technology obtained from the literature [1].

The stack is composed by 14 electrolysers of 1.25 MW each, able to process 3,150 m^3/h of water. PEM technology was selected in order to operate at variable rates [2] with a expected cost of 486 €/kW by 2020 [3].

Reactor

A fixed bed multitubular reactor was selected as the configuration for the proposed design.

This reactor was selected due to the fact that carbon dioxide methanation reaction is highly exothermic and this design allows an efficient cooling. The reactor was sized using a kinetic model from the literature [4]. The reactor was composed by 16 tubes (2 m length, DN100, Sch 5/5S) filled with a total amount of 332 kg of catalyst.

Obtained products

- High purity synthetic natural gas (SNG). CH_4 content higher than 95 %.
- Composition of the injected product according to the Spanish gas regulation.
- Pure oxygen as main byproduct of the electrolysis.
- Heat released and equipment cost were taken into account for process optimization.

Conclusions

High purity SNG is obtained with the proposed design.

Optimized heat exchanger network allows the use of the heat generated in the reactor. This heat can be used to preheat other currents, minimizing the need of an external energy input.

The proposed design can be feasible as long as renewable electricity is free and available.

Acknowledgements

This research was supported by the University of the Basque Country (UPV/EHU), Spanish Ministry of Economy and Competitiveness (ENE2014-53566-P), European Union through the European Regional Development Fund (FEDER) and Naturgas Energía company. This work has been done in collaboration with *Sener Engineering and Construction* company.

References

[1] M. Paidar, V. Fateev, K. Bouzek. Membrane electrolysis—History, current status and perspective. Electrochim. Acta 209 (2016) 737–756.
[2] Schiebahn S, Grube T, Robinius M, Tietze V, Kumar B, Stolten D. Power to gas: Technological overview, systems analysis and economic assessment for a case study in Germany. Int. J. Hydrogen Energy 2015; 40:4285–94.
[3] FP7 project, FCH JU, 2013. MEGASTACK: Stack Design for a Megawatt Scale PEM Electrolyser.
[4] Koschany F., Schlereth D., Hinrichsen O. On the kinetics of the methanation of carbon dioxide on coprecipitated $NiAl(O)_x$. Appli.Catal., B 2016; 181:504–16.