**Biogas to Methanol: comparison between CHP and different CHCP plant configuration**

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**Highlights**

* Biogas is used in CHP plant for electricity production causing net CO2 emissions.
* CHCP plant can use Biogas for bio-methanol production avoiding CO2 emissions.
* CHCP plant is economically feasible considering actual incentives.

**1. Introduction**

Biogas is a mixture of methane (CH4) and carbon dioxide (CO2), produced by anaerobic digestion of organic matter (sewage, manure, organic/agricultural waste, etc.). It is currently considered an important resource by the European Union, since many claims that it allows production of heat and electric energy at zero carbon emissions [1]. Therefore, biogas is usually converted into heat and/or electricity as is, using a Combined Heat & Power (CHP) plant, and/or upgraded to bio-methane, via removal of CO2 and other impurities, and then injected into the natural gas distribution grid. Although these two techniques for energy production (thermal and/or electrical) may be considered greener than those currently in use, they still have a non-zero carbon footprint. The latter is comprised of the CO2 emissions of all the processing steps needed to produce the feedstocks, synthesize biogas and use it. Thus, it is important to consider alternative uses of biogas, associated with no carbon emissions, e.g. the novel concept of Combined Heat, Power and Chemical (CHCP) plant. A CHCP plant converts biogas into bio-methanol (MeOH) such that part of the carbon of the biogas feedstock is not released back into the atmosphere as CO2 (bio-methanol is a solvent and a building-block that can be utilized to produce other chemicals, e.g. dimethyl ether, acetic acid and formaldehyde). This chemical conversion process takes place in two principal unit operations, namely a reformer and a methanol synthesis reactor, of which the first converts biogas into syngas while the second transforms syngas into methanol [2]. Compared to most conventional biogas conversion processes, CHCP plants offer a lower environmental impact and generate valuable chemicals. CHCP plant was studied analyzing 2 different configurations for syngas production: steam reforming (SRtoM) and tri-reforming (TRtoM) [3]. The aim of this work was the comparison between CHP and different CHCP configurations.

**2. Methods**

We hypothesized three different biogas composition (30%, 40% and 50% of CO2) and three different flowrates (100, 200, and 500 kg/h). In CHP plant all biogas is burnt to maximize the electricity production, instead of CHCP process, where biogas is partially used for the methanol synthesis and partially burn to supply the duty necessary to reforming section. Only in this way the CHCP process can be considered energetically self-sustainable. Operative conditions of reformer and methanol synthesis reactor were optimized in order to maximize the methanol productivity. Profits depend on electricity production in case of CHP plant, and on methanol production in case of CHCP. Methanol and electricity prices have been studied evaluating the importance of government incentives. The different processes were simulated using PRO/II® 10.0, a steady-state simulation software. The economic evaluation was performed using the model costing technique [4].

**3. Results and discussion**

SRtoM and TRtoM process are both technically feasible. The latter can produce more syngas but nitrogen, added as air, acts as inert increasing the dimension of the methanol synthesis section. The economic profitability of CHP and CHCP processes is strictly related to CO2 content and process configuration. Generally, higher the scale (500 kg/h of biogas) lower is the payback time and higher is the methane content lower is the profitability. Biogas with a high CO2 content (50%) increases the payback time at over 10 years and makes CHPC process economically unfeasible while CHP could be interesting since the payback time is slightly lower, 7 years. In all the simulation and considering incentives, the lower payback time is obtained with SRtoM process due to the high value of methanol. TRtoM is less competitive than SRtoM since the methanol synthesis section is bigger, and so more expensive.

**4. Conclusions**

The aim of the work was the comparison of different process for biogas use. Results show that government incentives and CO2 content are the main limits for economic feasibility. With actual government incentives the CHCP process has the lower payback time. CHP can be considered a better option with high CO2 concentration. Considering also the lower carbon emissions CHPC plant could be an interesting alternative to CHP.

**References [Calibri 10]**

1. EurObserv’ER Report, 2016, The State of Renewable Energies in Europe.
2. Manenti, Processo di conversione del biogas, 2015, patent: “102017000073797, 2017”.
3. Vita A., Italiano C., Previtali D., Fabiano C., Palella A., Freni F., Bozzano G., Pino L., Manenti F., Renewable Energy (2018), 673-684
4. Turton R.C., Bailie R.C., Whiting W.B., Shaeiwitz J.A., Bhattacharyya D., (2012), Analysis synthesis, and design of chemical processes fourth ed.