Power-to-Gas concept through biological CO_2 hydrogenation process

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Energy in many forms can be transformed, transmitted, and consumed with high efficiency and flexibility in the form of electricity. Electricity suffers, however, from one main disadvantage compared to other energy carriers: it cannot be stored economically, which means that electricity must be consumed the same second it is produced to keep up a functional transmission system and transmission loss (compared to for example the transmission of gas). Additionally, another problem is that supply and demand must always be precisely balanced in the electricity grid, and overload must be avoided. Sometimes, in cases of excess electricity supply, generating companies must pay the managers of the grid to take their electricity (negative prices). The grid operators worry that the growth of solar and wind power could destabilise the grid leading to brownouts or blackouts. This is a real concern since the supply of solar or wind power cannot be controlled. The excess or surplus electricity produced from solar or wind plants at peak periods must be consumed, otherwise this energy will be lost or will cause grid instability. Although short-term electricity surpluses are often observed in some EU countries, they are not yet common but may become so in future, since many countries are supporting the installation of renewable supplies as part of their energy policies. Moreover, with increasing use of renewables it is anticipated that smart grid approaches will have to be adopted and effective solutions for storage and utilisation of surplus electricity need to be developed. Consequently, there has been a surge in interest and pre-commercial development of power-to-gas as a potential means of providing storage for this excess energy.

Among the technologies facilitating power-to-gas concepts is the hydrogenation of CO_2 into biomethane. The process can both be done by thermocatalytical and biological routes. Biological CO_2 hydrogenation has the advantage that it can be performed at mild temperature and ambient pressure, thus with a low energy cost. Moreover, the process is conducted with a variety of exogenous CO_2 sources, such as biogas (CO_2 content ~35-50%) or exhaust/flue gas (5-17% CO_2) offering great flexibility and replicability. It must be underlined that apart from generation of biofuel as end-product, this technology serves as an exemplary method for seasonal on-site energy storage.

The concept relies to the fact that surplus off-peak electricity can be exploited for electrolytically-produced hydrogen (Figure 1). Subsequently, the H_2 is coupled with carbon dioxide from power plants or CO_2-intensive industries. The methane produced is 95% pure and directly compatible with CNG, feeding into an expanding transport fuel market. It can also be directly injected into the gas grid after only minimal cleaning, allowing distribution and use for power generation and direct heat applications throughout the existing European infrastructure. The innovation is that biomethanisation is carried out by naturally occurring mixed cultures of hydrogenotrophic methanogens, which can be adapted to work with non-refined sources of CO_2. The current work will present the outline of a pilot methanation unit that is currently designed and will be constructed within the implementation of the LIFE CO2toCH4 project.

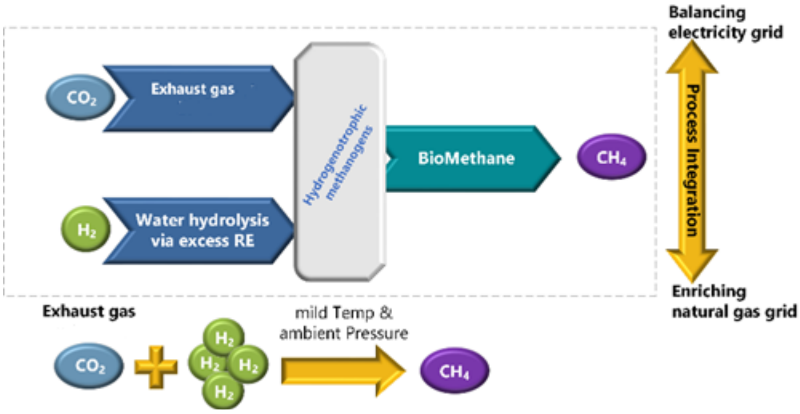

Figure 1. Biological CO2 hydrogenation concept

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References
Angelidaki, I., Treu, L., Tsapekos, P., Luo, G., Campanaro, S., Wenzel, H. and Kougias, P.G., 2018. Biogas upgrading and utilization: Current status and perspectives. *Biotechnology advances*, 36(2), pp.452-466.
Sieborg, M.U., Jensen, M.B., Jensen, B. and Kofoed, M.V.W., 2021. Effect of minimizing carrier irrigation on H_2 conversion in trickle bed reactors during ex situ biomethanation. *Bioresource Technology Reports*, 16, p.100876.
Tsapekos, P., Treu, L., Campanaro, S., Centurion, V.B., Zhu, X., Peprah, M., Zhang, Z., Kougias, P.G. and Angelidaki, I., 2021. Pilot-scale biomethanation in a trickle bed reactor: Process performance and microbiome functional reconstruction. *Energy Conversion and Management*, 244, p.114491.