A BIOMETHANE PLANT AND GREEN HYDROGEN

The energy transition to be effective requires not only renewable energy, typically produced by wind, solar, biomass and hydropower, but also transmission and storage systems, mainly because solar and wind are discontinuous sources. The solar energy is linked to the seasons (more in summer and less in winter) and to the day-night cycle while the wind energy is linked to the presence or less of winds.

To correlate these productions with energy consumption, electrical and thermal, we need a system that allows us to accumulate energy when it is produced, for instance in the warmer months for solar energy, and release it when we need it most: hydrogen fulfils this function. A key feature of hydrogen is its ability to act as both a source of clean energy and an energy carrier for storage. Hydrogen, in fact, can be transported through existing gas pipelines, in mixture with natural gas and in perspective in dedicated gas pipelines, and it can offer a solution to store energy at a cost ten times lower than batteries (about 20 dollars per megawatt/hour versus 200 $/Mwh).

Currently, hydrogen is produced mainly from fossil methane and used as a raw material in the fertilizer industry and in fuel refining. In this case, the starting material from which hydrogen is obtained is methane (CH_4) through a specific treatment in which hydrogen atoms (H) are separated from carbon atoms (C). This separation process produces two types of emission: a hydrogen flux (also known as “gray hydrogen”) and a carbon dioxide flux (CO_2) with climate altering effects.
An alternative system to produce hydrogen in a sustainable and not climate altering way (“**green hydrogen**”) is one that uses water (H_2O) and renewable electricity to separate hydrogen (H) from oxygen (O), without causing CO_2 emissions. The purpose of this case study is to consider a third way of producing hydrogen using biomethane as raw material. Biomethane consists of methane atoms that were produced by bacteria through the digestion of biomass (for instance organic waste or agricultural and agro-industrial by-products) and that, due to their origin, do not produce climate altering effects.
Also in this case, when biomethane is used for combustion, CO_2 is produced but at the same time it is reabsorbed through the photosynthesis of biomass that allowed the production of biomethane itself.

On this hypothesis we can think of being able to produce hydrogen using as a raw material the biomethane and as a technology the one currently used to produce hydrogen from fossil methane, called **Steam Reforming**. Therefore, based on previous assumptions we ask you to:

1. Calculate **the carbon footprint as kgCO2eq./kgH2 of the three hydrogen production modes** described above. With regard to SMR, assume that about 60% of the emissions come from the carbon contained in the natural gas input used as feedstock, with the remaining 40% coming from the other stages of the process (combustion of fuel to provide energy and steam, power for separation and compression). Assume a Higher Heating Value (HHV) for hydrogen of 39,37 kWh/kg.
2. Calculate **the Capex** (Capital Expenditure) **and the Opex** (Operating Expenditure) for the realization of a plant suitable to treat the 100% of the biomethane produced at the plant of Sant'Agata Bolognese in Emilia-Romagna, Italy.
3. Define an **incentive to produce green hydrogen by electrolysis and from steam reforming of biomethane** necessary to ensure an IRR (internal rate of return) of the initiative exceeding 8%.

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