The petrochemical industry, its economic impact and renewable energies. The main renewable energy projects in Catalonia

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In the global context in which we operate as a society, we have to grapple with major challenges related to the struggle against anthropogenic climate change due to greenhouse gas emissions. Even though this is the first reason for undertaking a veritable industrial revolution, it is equally important to depend less on third countries for energy and raw materials. Recent conflicts and crises have revealed weakness in some aspects of global logistics today. The COVID-19 crisis and wars like the conflict in Ukraine are two clear examples. Therefore, we need to produce energy more cleanly, free of CO_2 emissions, but we also have to seize the opportunities to become less energy dependent.

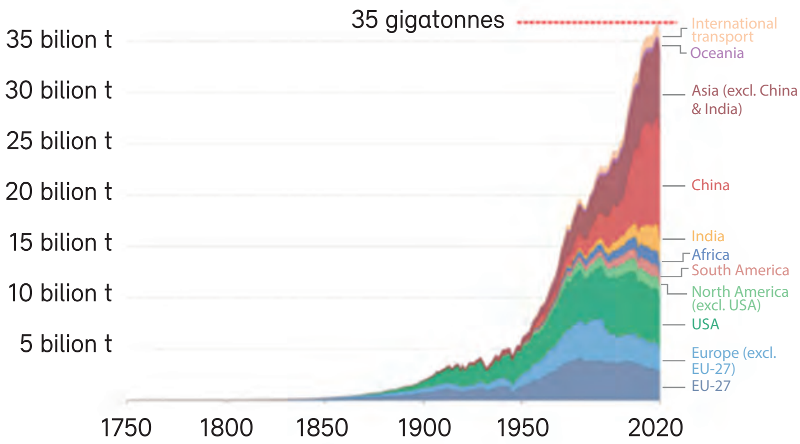
The level of industrial development and the population increase have led us to expend more energy, and today we remain heavily reliant on fossil energies, which lead to higher levels of atmospheric CO_2.

The only solution to the problem of emissions is either to not produce them or to capture them, or both at once. Currently, atmospheric CO_2 concentration is 425 ppm, far above than the 350 ppm before the Industrial Revolution. Therefore, there are global initiatives that have to be undertaken in a coordinated fashion.

Along these lines, the 2021 climate summit maintained the goal of trying to limit the increase in average temperature on Earth to 1.5 degrees above preindustrial levels, as stipulated in the Paris Agreement:

- The leaders of more than 120 countries, representing around 90% of the forests in the world, pledged to stop and reverse deforestation by 2030.

FIGURE 1 **CO_2 emissions due to use of fossil fuels**



Does not include emissions due to changes in land use or from farming (40 Gt).

SOURCE: Our World in Data. Global Carbon Budget (2024) (<https://ourworldindata.org/co2-and-greenhouse-gas-emissions#all-charts>).

- The methane commitment, led by the United States and the European Union, was a pledge from more than 100 countries to lower emissions of this greenhouse gas by 2030.
- A commitment was made for a clean energy transition and decarbonisation.

As a consequence, the concept of decarbonising society has emerged and we have to strive to achieve it by undertaking actions like electrification, CO_2 capture, and the transformation and usage of CO_2 – including green hydrogen – to replace the current grey hydrogen (current uses). Green hydrogen can also be used as a new energy vector, both directly and indirectly (by transforming it).

The use of green hydrogen, along with CO_2 capture and transformation, generates a totally new economy. First, the hydrogen value chain entails different forms of production, storage and transport, along with use as an energy vector and a raw material.

The primary method of green hydrogen production is electrolysis, but it can also be produced through gasification of waste, pyrolysis or photochemistry. It can be stored as compressed gas or in liquefied form, in addition to forms that entail chemical transformations, such as conversion into methanol or green ammoniac. As an energy vector, green hydrogen can generate energy by feeding it into fuel cells and then integrating these cells into hybrid networks that can serve as a continuation of renewables, or in the form of direct injection with – or replacing – natural gas. As a raw material, it can be used in the ways grey hydrogen is currently used for chemical processes; to synthesise green ammoniac, which has multiple uses (including energy); and to synthesise chemical components, including sustainable fuels, if it is combined with captured CO_2, thereby closing a cycle akin to artificial photosynthesis. This would stop the global increase in the concentration of atmospheric CO_2 steadily over time.

There are certain key elements in this entire process, and one of them is green ammoniac. Current production of ammoniac is among the highest in the world, and it is the foundation of products like fertilisers that combat world hunger. It is produced by reacting nitrogen in the air with hydrogen, which until now was grey, that is, fossil in origin, with the heavy emissions associated with it. The process is called Haber-Bosch, and it is currently being transformed so it can be carried out using green hydrogen. The green version of this component can also be used as an energy vector, enabling large amounts of compost to be manufactured remotely in regions rich in renewable energy and then transported to the places where one molecule will be broken down and the resulting hydrogen used. But to do so, chemical complexes, like the current petrochemical complexes, are needed.

$$N_2 + 3H_2 \leftrightarrow 2NH_3 \qquad \Delta H_{298} = -92{,}2\ kJ/mol$$

The other main factor in this whole revolution is CO_2 capture from both highly concentrated sources (between 1 and 18%) such as industrial emissions (exhaust) and directly from the air (at a higher cost because the concentration is lower).

The four main CO_2 capture techniques are absorption, adsorption, cryogenics and separation with membranes. The use of solid sorbents in pressure and/or temperature swing sorption processes (PSA or TSA) has the potential to be the benchmark CO_2 capture technology. CO_2 capture using aqueous amine solutions is currently the most widespread method, but it has many limitations in terms of efficiency per unit of volume, stability and energy consumption in desorption.

Regarding new CO_2 capture technologies, some are based on adsorption in new solids like MOFs (metal organic frameworks), which have a high potential and are increasingly affordable. They are currently in the study phase, as are ionic liquids for absorption technologies. There are also mixed technologies with solids impregnated with this type of liquid. All these technologies should provide enhanced features compared to those commercially available right now within a very short period of time. Therefore, investment to escalate technologies that must urgently be applied is badly needed.

Once CO_2 has been captured, we need to know what to do with it, and this has prompted a debate between urgency and the long-term vision. On the one hand, urgency says that we have to think about immediate storage, but this will not be the long-term solution, which clearly entails transforming and recirculating it, because not everything can be electrified.

The need to establish a CO_2 economy is nothing new, nor is the need for green hydrogen. Several years ago, the 1994 Nobel Prize winner in Chemistry, George A. Olah, published his theory of the methanol economy (*Beyond Oil and Gas: The Methanol Economy*, Wiley 2009), which offered an in-depth study of all these changes that are now being proposed.

One of the transformations already implemented on a large scale at various points in history is based on the Fischer-Tropsch process, which is exactly one century old and was not performed in a “green” way in its old version, given that the hydrogen and CO came from fossil sources. Today, this process is being redesigned to be sustainable, with new catalysers and using green hydrogen and captured CO_2. This process and other similar ones are able to yield 100% sustainable fuels without adding more CO_2 into the atmosphere.

Finally, there is the issue of what geographical locations are best for carrying out these processes. In this regard, we should look at the three stages of the European Green Deal strategy. We are currently in the first stage.

First stage: 2020-2024 (activation)

- Installation of at least 6 GW of renewable hydrogen electrolysers to decarbonise existing ones coupled with hydrogen production, giving rise to 1 Mt of renewable hydrogen in the EU.
- Expansion of the manufacture of electrolysers.
- Planning of carbon capture and transmission infrastructure.
- Establishment of the regulatory and implementation framework for the hydrogen market.

Therefore, it is clear that we have to begin where this grey hydrogen is produced, which in Catalonia is Tarragona and its existing petrochemical complex, where nine tonnes are produced every hour.

This strategy is fairly ambitious and would prompt the entire new clean economy that needs initial guaranteed applications. Over time, as the technology matures (in terms of both usage and manufacture of components) it would pave the way for new uses of the energy vector and by-products, as stated above.

Finally, other projects with new uses (such as heavy transport using hydrogen vehicles and component manufacturing plants) are emerging around these early-stage large scale initiatives. They need to mature and be spread out across Catalonia (currently they are only in Tarragona and Barcelona) in order to give rise to an entire local industrial network.