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Analysis of Carbon Capture for the Production of Synthetic Fuels in Chile

Executive Summary

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Analysis of carbon sequestration

for the production of synthetic fuels in Chile

Executive Summary

The current green hydrogen boom in Chile has opened the door to the production of carbon-neutral synthetic fuels, which are made from a combination of green hydrogen and CO_2. For the fuel to be sustainable, the used CO_2 must be considered CO_2-neutral, and thereby the emission intensity of the fuel production process must be lower than the emissions of the fossil fuel it replaces. Furthermore, the CO_2 could be captured directly from the atmosphere, so as not to generate additional emissions. Biogenic sources, a carbon-neutral renewable resource, or industrial sources of *unavoidable CO_2* can also be considered. Unavoidable CO_2 emissions are defined as *"those CO_2 emissions associated with processes that cannot be replaced by, or avoided through optimisation of, other processes using renewable energy or alternative chemical processes"*. In both cases, the CO_2 used will be returned to the atmosphere without causing an increase in CO_2, and thus can be considered CO_2-neutral. To certify the CO_2 used is sustainable, the emissions must be unavoidable and accounted for once (at the point of capture or at the end use of the fuel).

In Chile, 33 establishments, mainly belonging to the cement and pulp & paper industries, were identified as having **sources of** sufficiently high **unavoidable CO_2 emissions** (>0.01 MtonCO_2/year)[1] to make carbon sequestration economically feasible. Globally, the steel industry is in the process of transitioning to carbon neutrality by using, for example, green hydrogen instead of coke in the future.

The unavoidable CO_2 emissions of cement producers were in the order of **0.9 to 1.1 million tonnes [Mton] of CO_2**. In the case of the wood industry, it was **2.1 Mton of CO_2**. Finally, in the pulp and paper industry **12 Mton of CO_2** were generated (all for 2018)[2]. Although the numbers presented correspond to the estimated capture potential of the total emissions of these industries, for technical and economic reasons it is likely that only a percentage will be captured. If there was a desire to fully capture of emissions, capture rates in the order of 80%-95% could be achieved using carbon capture technology alone. However, partial capture of CO_2 emissions may be economically more desirable and will depend on factors specific to each installation, such as, for example, the availability of waste heat. Waste heat from processes adjacent to the capture plant can be used to regenerate the solid adsorbents in the low-temperature Direct-Air-Capture (DAC) units, or to produce the steam needed to regenerate the solvents used in the capture process by chemical amine absorption, reducing the overall costs of the CO_2 capture process.

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[1] *The IEA greenhouse gas programme (IEAGHG) sets a limit of 0.1 Mt CO_2 emissions per year above which capture would be economically favourable in terms of costs.*

[2] *These values correspond to estimates made using RETC emissions data for 2018 and 2019. The latter is not definitive and is reported to have errors. In addition, the estimation of unavoidable CO_2 emissions from the industries analysed in this study did not consider GHGs other than CO_2 or the potential absorption of part of these emissions. For this reason, it is possible that the estimated data may differ slightly from the GHG emissions reported in other studies for these industries.*

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Carbon Capture technologies

The most advanced and adopted technologies to date are chemical absorption or adsorption and physical separation (absorption/adsorption); other technologies available in the industry are membranes and cryogenic separation. The selection of the most appropriate capture technology depends on factors such as the initial and desired final CO_2 concentration, operation pressures and temperature, gas composition and flow, integration with the original installation, and the costs associated with the capture system.

Direct-Air-Capturing (DAC)

The alternatives for capturing CO_2 from the air are divided into **high temperature chemical absorption** and **low temperature chemical adsorption**. There are 15 operational plants in the world that are operated by three companies: ***Climeworks*** in Europe, ***Global Thermostat*** in the USA, and ***Carbon Engineering*** in Canada.

- Only **chemical separation** processes can capture low concentrations of CO_2. Due to the high volume of air that must be treated to remove CO_2, processes that require the conditioning of the incoming air (e.g., pressurisation) are not cost-effective.
- **Chemical absorption** processes use hydroxides and require high temperatures (900°C), usually achieved by burning natural gas. Carbon Engineering presents a fully electrified theoretical variant.
- On the other hand, **chemical adsorption** with amines requires much lower temperatures (80-100°C), which makes it possible to supply the necessary heat from 100% electrical processes, or even waste heat from adjacent processes.

Current levelized capture costs (LCOD) are around 280 €/tonCO_2 and are determined based on the current state of technological maturity and the scale of the project. The LCOD is greatly influenced by the cost of electricity and the availability of waste heat from adjacent processes. However, different companies have reported costs in the order of 75-113 €/tonCO_2 for new commercial scale projects.

CO_2 Capturing from Industrial Sources in Chile

Unavoidable emissions in Chile come from three industries with gaseous effluents of CO_2 concentrations between 9-33%, and the effluent is available at lower pressures. This makes chemical separation processes the most suitable, since this process can be achieved with a wider range of CO_2 concentration of the input gases (0.04-100% volume) and does not require high pressures. Based on the characterisation of the gaseous effluent from the cement and cellulose industries, chemical absorption is identified as the most mature technology for separating CO_2 from industrial sources currently in operation, specifically by using amines.

CO_2 capture costs can vary significantly from one installation to another, mainly depending on the concentration of CO_2 in the gas stream, the location of the plant, the power and steam supply, and the integration with the original installation.

In cases where CO_2 is used at a location other than the capture site, transport of CO_2 is required. For large volumes and distances of less than 1,000 km, pipelines are preferred, otherwise transport by ship is required. Importantly, the CO_2 must be stored until it can be shipped. It can be transported as a pressurised liquid. In addition, the CO_2 emitted by transport must be assessed.

Environmental Impacts of CO_2 Capture

- **Water:** Chemical ab-/adsorption technologies, both in DAC and from industrial effluents, use water in closed cycles that are susceptible to losses and therefore require replenishment. In the case of amine-based industrial effluent absorption systems, tests in a pilot plant indicate that water losses are in the range of 6.9 to 39.4 kg of water per tonne of treated industrial effluent gas. In the case of DAC systems, water consumption depends on factors such as relative humidity and ambient temperature, and, in the case of chemical adsorption, also on the concentration of the hydroxide solution. Among the systems using chemical adsorbents, *Climeworks* has reported that its technology is capable of generating water (0.8 to 2 Mton water/MtonCO_2). From an energy demand point of view, however, it is preferable to capture as little water as possible. *Global Thermostat* does not report its water consumption values, however, the HIF project to be developed in southern Chile will use this technology and reports a water consumption of 5.4 Mton water/MtonCO_2 captured. Carbon Engineering reports water use values of 4.7 Mton water/MtonCO_2, at 20ºC temperature and a relative humidity of 64%, but this value increases in drier and warmer environments.
- **Space:** In terms of space usage, up to 7 km² are required per MtonCO_2/year. A large part of the space use is indirect space, which must be left between the contactors (250 m) to allow mixing of the CO_2-poor air leaving the contactor with atmospheric air.
- **Other environmental impacts:** There is the risk of CO_2 leakage. If CO_2 is released at high pressure, solid CO_2 particles of very low temperatures can be formed. In addition, small CO_2 leaks can cause acidification of water and soil, and CO_2 leaks in enclosed spaces can be lethal for workers.

Capture from industrial effluents containing amines causes small solvent emissions to the atmosphere. The amines break down into other products that pose risks to health and ecosystems. It has been identified that the formation of ammonium and ethylamine may occur, which are toxic and can cause skin irritation. In addition, there is a risk of formation of carcinogenic nitramines and nitrosamines. The presence of amines or their derivatives in the atmosphere can contribute to the formation of secondary aerosol, which can adversely affect air quality, and even act as condensation nuclei for cloud formation. They can also contribute to the formation of tropospheric ozone, which is an irritant greenhouse gas that can cause negative effects on the respiratory system, plant reproduction and growth.

Challenges for Chile

The unavoidable industrial and biogenic sources are limited and associated with three main industries, cement, cellulose and wood industry. In order to reach larger volumes, Direct-Air-Capturing will be necessary. In addition, the unavoidable industrial and biogenic sources identified are almost exclusively located in the central southern part of the country, which does not necessarily coincide with the areas of greatest potential for renewable generation at scale. The following advantages of synfuel production in the central area are identified: supply of CO_2 from unavoidable point sources at higher concentrations, which allows to lower capture costs; and hydrogen production close to industrial sites, which would save transport costs and could also generate oxygen as a by-product (e.g., for oxycombustion in plants to have an even more concentrated gaseous effluent and reduce costs further).