The decarbonization of the chemical sector

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The chemical industry ranks among the world's largest sectors, boasting an annual revenue of around $4.7 trillion. Moreover, its products play a crucial role in the extensive global value chains, including those in manufacturing and construction. At the same time the chemical sector holds the unenviable record of being among the largest responsible for CO2 emissions into the atmosphere, which is why it is imperative to introduce modern and effective processes to limit environmental impact as much as possible.

The urgency to reduce the use of chemical processes that generate high levels of CO2 emissions becomes apparent when considering a few key statistics. For instance, various industrial subsectors contribute significantly to the overall CO2 emissions: petrochemical and refineries make up 6.21%, iron and steel account for 5.06%, cement represents 4.14%, fertilizers contribute 1.15%, lime and plasters make up 0.92%, paper and pulp contribute 0.92%, inorganic chemicals account for 0.46%, and other subsectors constitute 4.14%.

Governments have explored various strategies to incentivise chemical companies to develop more efficient and environmentally friendly processes. One such strategy is the proposal for internal carbon pricing, which has multiple intended purposes. It serves as an incentive and raises awareness about the necessity of reducing carbon emissions. Additionally, it aids in strategic planning by allowing companies to assess the comparative profitability of various investments in the event of a national carbon tax being implemented. This approach has gained popularity in recent years. According to a survey conducted by CDP, over 2,000 out of nearly 6,000 companies surveyed either already utilised an internal carbon price or had plans to implement one within the next two years. Another approach, known as "internal trading," bears resemblance to government-operated cap-and-trade systems. In this method, companies have the ability to allocate carbon credits to various business units, which can then trade these credits among themselves should they exceed their emissions reduction targets. Conversely, some companies impose a "carbon fee" upon their business units, with a predetermined monetary value aimed at encouraging initiatives that reduce emissions, such as improving energy efficiency. The funds generated from these fees can be directed toward investments in renewable energy supplies or carbon offset programs.

From a more technical point of view, when it comes to decarbonisation, there are basically 4 approaches taken by the chemical companies that are listed in figure 1.

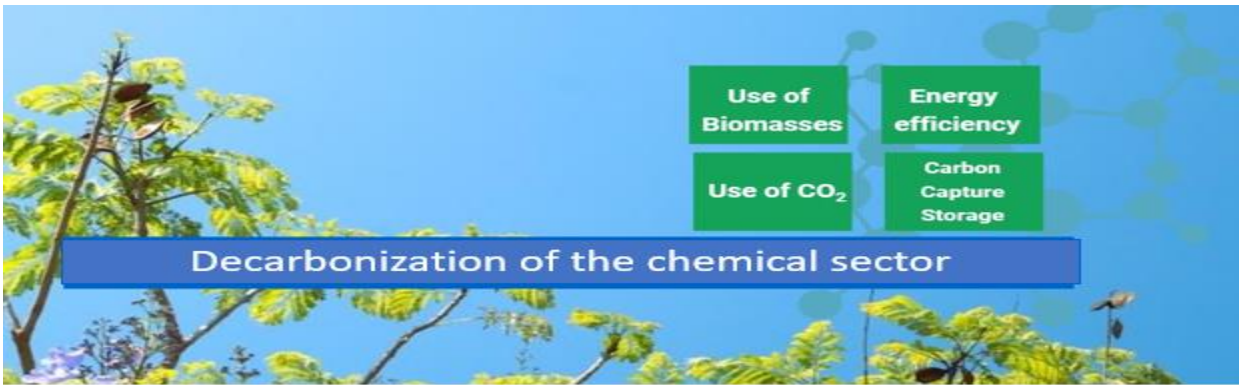

Fig. 1

The most effective is obviously the use of CO2 as reagent/feedstock in industrial chemical reactions. The challenges associated with the conversion of CO2 are primarily related to both its kinetic and thermodynamic stability. CO2 cannot be converted into commodity chemicals or fuels without significant inputs of energy and contains strong bonds that are not particularly reactive. As a consequence, many of the available transformations of CO2 require

Molecule	Quantity produced (2022)
Salicylic acid	30 Kilotons
Urea	112,000 Kilotons
Cyclic carbonates	40 kilotons
Ethylene and Propylene carbonates	600 Kilotons

Table 1

stoichiometric amounts of energy-intensive reagents. Table 1 list some of the major commodity chemicals that are currently synthesized from CO2 on an industrial scale globally, whose global production exceed the 150,000 kilotons. Table 2 instead listed some of the major fine and commodity chemicals that are currently synthesized from CO2 on a pilot plant scale. It is worth to mention that the companies active in these sector are spread across three continents and are in most case multinational companies.

Another effective approach taken by the chemical companies to reduce their carbon footprint has been the use of more efficient process less energy intense. In particular many companies have devoted a lot of efforts to optimize the steam generation process with the introduction of heat pumps that transfer energy from a low temperature source to a high temperature. This works with a coolant that evaporates in a circuit under low pressure by adding heat - from the plant or used cooling water. The gas is then compressed by a compressor. It condenses and gives off useful heat. Then the cycle starts all over again.

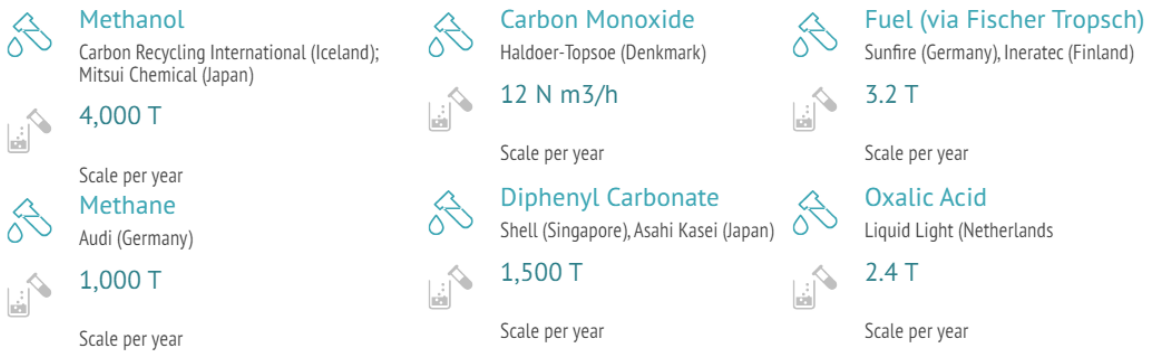

Table 2

If heat pumps and compressors are operated with electricity from renewable sources, the entire process is climate-neutral, thus without CO2 emissions. By using waste heat from chemical plants and cooling water systems to generate much of the steam big companies use in production, heat pumps are drastically reduce the need for fossil fuels.

However, decarbonising the chemical industry requires changes in technology through low-carbon innovations identified in the previous sections and a broader sociotechnical transition that entails changes in behaviour, culture, policy, industry strategies, infrastructure, and science. To accelerate and bring the transition toward the decarbonisation process in energy-intensive processing industries, more insight into the sociotechnical barriers that hinder the transition process is needed.

Another aspect of the decarbonization of the chemical sector is the introduction of feedstock from biomasses. In fact, using renewable raw materials helps to save fossil resources and contribute to reducing greenhouse gas emissions. Moreover it has been observed that customers are increasingly interested in products based on renewable raw materials as they are often perceived as healthier, more natural and having a positive environmental impact. Last, but not least the use of renewable raw materials broadens raw materials basis and thus reduces the dependency on fossil resources.

An interesting example in this sense is the German group BASF that in 2021, has purchased around 1.3 million metric tons of renewable raw materials. These renewable raw materials are derived from various value chains, vegetable oils, fats, grains, sugars and wood.

A very positive aspect is the fact that now all the big multinational companies are reporting the tons of CO_2 produced. Particularly interesting are the cases of BASF and Dow which are respectively #1 and #2 in the ranking of the chemical industry, that are reporting since 2021 the CO2 emissions reduction in their quarterly financial reports for investors.

According to the IEA, direct CO2 emissions from primary chemical production remained still relatively constant at around **935 million tons** in 2022, as a result of a stagnation

in production. This is in tandem with a relatively stable primary chemicals CO_2 intensity over recent years, at around 1.3 tons of CO_2 per tonne of primary chemicals1. The chemical sector is the largest industrial energy consumer but only the third largest industry subsector in terms of direct CO_2 emissions. Ammonia production is responsible for the highest share of emissions accounting for **45%** of emissions from primary chemical production, followed by methanol (**28%**) and high-value chemicals (**27%**). The IEA also provides a chart of global CO_2 emissions by sector from 2019 to 2022, where you can see the relative contribution of the chemical sector compared to other sectors

In summary, achieving a full decarbonization of the chemical sector remains a formidable challenge. However, it's encouraging to note the availability of processes and technologies that can contribute significantly to meeting these vital objectives. Furthermore, there is a growing awareness throughout society at all levels regarding the need to support chemical companies in their efforts to reduce emissions. This is precisely why many companies have established ambitious targets in this regard.