Brazilian Journal of Analytical Chemistry
2025, Volume 12, Issue 47, pp 6-7
doi: 10.30744/brjac.2179-3425.point-of-view-N47

POINT OF VIEW

How (and when) will the chemical industry react to climate change?

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The impact of climate change has become an undeniable reality. However, even in the face of this implacable truth and its catastrophic consequences, the world is moving at a much slower pace than is needed to reverse, or at least mitigate, this process. Sometimes, it feels like we move forward and backward several times to the point where we do not leave the same place, especially if we think about national policies and alignment among the world's nations. It seems that significant progress in this area will only be achieved in a utopian world with economic prosperity, geopolitical balance, and the convergence of political ideologies.

Compared with the intrinsically variable and sometimes cyclical nature of world politics, the economic sectors, and particularly the industrial segment, are much more stable. Once an organizational strategy is defined it does not change every predefined period of time, although it is adjusted or revised if needed to deal with a new scenario (most of the time motivated by economic drivers). In this way, the industrial sectors have the advantage of being less volatile in their decisions and could keep moving despite political changes; however, they are much less prone to make uneconomical decisions.

Although the chemical industry is not the major contributor to greenhouse gas (GHG) emissions, it accounts for ca. 2.5% of total global CO_2 emissions.[1] Therefore, most companies in this segment have already accepted their responsibility in the fight against climate change and have assumed public commitments toward reducing this impact and even reaching carbon neutrality in their operations. In fact, some companies have already shown consistent results demonstrating improvements on reduction of carbon dioxide (CO_2) emissions through, for example, energy efficiency initiatives or the use of energy from renewable sources. Besides, we can see a lot of research and development in universities and research institutions throughout the world, as well as some industrial deployment, related to sustainable solutions such as the use of renewable sources of energy and/or feedstocks, chemical recycling, CO_2 conversion and/or storage, and many others, with private or public funding. Carbon neutrality would undoubtedly be a major challenge for the industrial sectors, but also an opportunity to transition to more sustainable production, also obtaining chemical products with a lower and even negative carbon footprint. Similarly to other pivotal moments in history, several forces will need to align for a relevant change to occur, but several disruptive and transformational solutions may be developed as a result of this process.

In this context, the pathway to neutralize GHG emissions of the so-called hard-to-abate industries, such as steel, cement, and petrochemicals, faces similar hurdles. Several decarbonization (or defossilization) solutions will need to be adopted, so it is necessary to mention the clichéd expression that there is no silver bullet to achieve the neutralization goals set by several companies for 2050. Indeed, all sets of solutions will need to be evaluated, namely renewable energy, fuel switching to low-emission fuels or

1. According to the International Energy Agency (IEA), in 2022 global chemical production accounted for 0.9 Gt of CO_2 emissions out of a total of 36.8 Gt, https://www.iea.org/energy-system/industry/chemicals (accessed January 30, 2025). The total industrial sector was estimated to emit around 9 Gt (ca. 25% of global CO_2 emissions).

Cite: Rebouças, M. How (and when) will the chemical industry react to climate change? *Braz. J. Anal. Chem.* 2025, *12* (47), pp 6-7. http://dx.doi.org/10.30744/brjac.2179-3425.point-of-view-N47

biomass, biobased feedstocks, equipment/process electrification, low-carbon hydrogen, carbon capture and storage (CCS), carbon capture and utilization (CCU), and others. Therefore, building the pathway to carbon neutrality for a specific industrial sector, such as the chemical industry, involves identifying the best solutions to integrate with such processes. More importantly, the neutralization pathway should be based on location- and site-specific analysis. Even considering the same industrial sector, different solutions can be selected when these specific conditions are considered. For example, in a location with a high energy price and limited access to renewable energy sources, electrification and other energy-intensive solutions may be less promising options. On the other hand, sites with more flexible process configurations and equipment robustness could handle larger amounts of biobased feedstocks to displace fossil feedstocks.

However, most common decarbonization solutions require a high capital investment and are still uneconomical, that is, in the positive CO_2 abatement cost range (*which means there are costs related to emissions avoidance that will reduce the economical results of the overall productive process*). If we consider an arbitrary average CO_2 abatement cost of around 20 U.S. dollars (USD)/t CO_2 ,[2] then the total cost to neutralize the CO_2 emissions from global chemicals production could reach 18 billion USD per year![3] Moreover, an extremely high initial capital investment would be required to build such industrial facilities. Therefore, in the technical field, we must keep investing in the development of new technologies and solutions to reduce the CO_2 abatement costs. In addition to technical aspects, other important local factors also need to be considered to improve economical results, such as policies and regulations, financing and incentives, carbon markets, infrastructure, customer demands for sustainable products at premium prices, and many others that may differ from place to place. Hence, besides the companies' drive for neutrality, other external forces must also be considered so that the energy transition can advance faster and more significantly toward a net-zero industry. Finally, my personal opinion is that unless new competitive and game-changing technologies are developed, all actors in this process — companies, governments, and societies, among others — will have to give up something and reach a compromise so that everyone could win (a planet to live…) in the end.

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2. The CO_2 abatement cost concept considers both operational expenditures (Opex) and capital expenditures (Capex, usually calculated as the annual depreciation).
3. The CO_2 emissions from chemical production in 2022 was considered as a reference (see note 1).