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Electrify to decarbonize

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Electrification offers a means to decarbonize the chemical industry. In this Editorial we reflect on opportunities in the area of catalysis that come with an increasing availability of renewable electricity.

Over the last century, the chemical industry has been able to establish effective and reliable paths for the conversion of raw materials into an array of chemicals for different applications. In fact, chemicals are ubiquitous in modern society, no matter if as energy vectors or as building blocks to produce materials and drugs. Unfortunately, the processes required for their production are often energy-intensive and result in high levels of greenhouse gas emissions[1].

In the context of global efforts to, at first, contain and thus reduce emissions until net zero is achieved, multiple stakeholders in the chemical industry have committed to decarbonize their business. The spectrum of initiatives is quite broad and success rests upon a delicate balance between economic drivers and technical possibilities. To render the picture even more complex is a constantly evolving regulatory landscape aimed at reshaping the global economy in terms of climate neutrality. The challenges are therefore many; however, opportunities are emerging too thanks to an increasing demand for low-carbon products that constitutes an important stimulus for technological development and innovation.

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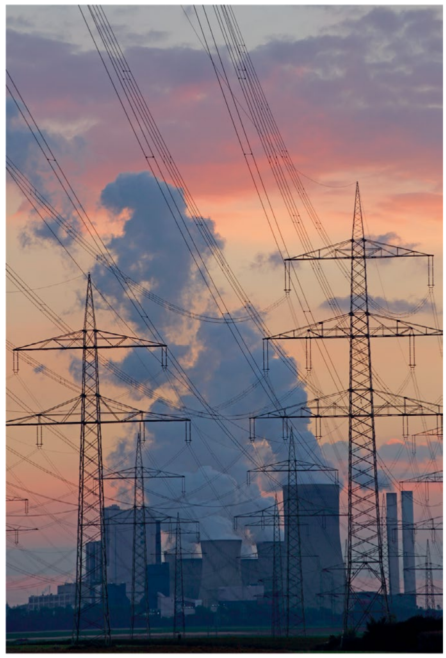
Electrification will play a central role in the transformation of the chemical industry.



Several bulk chemicals are produced through endothermic processes that require a large quantity of energy to generate heat. As the availability of renewable energy is expected to increase[2], the integration of electrical heating – in place of established approaches based on natural gas combustion– can significantly reduce emissions, while offering advantages in terms of overall energy efficiencies, as shown recently in the case of steam methane reforming[3]. While most of the burden is on reactor engineering – at least in the case of resistive heating – alternative heating approaches such as induction may also benefit from developments in terms of catalyst design. By integrating, for instance, magnetic susceptors with catalytically active phases it is possible to generate reaction systems in which the catalyst controls not only reactivity but also the reaction environment – in this case the temperature of the reactor[4].

Electricity can also be used to trigger reactivity through the generation of plasma. A gas activated in the plasma state contains a variety of charged and ionized species that can promote reactivity pathways inaccessible under conventional thermal reaction conditions. While this approach is not intrinsically catalytic, it can be combined with catalytically active materials taking advantage of different reaction configurations – for instance the catalyst can be located in the plasma generation unit or downstream to it – and is already being explored in the context of CO_2 conversion as well as N_2 fixation, among others[5]. For plasma-based catalysis to be successfully applied to the production of platform chemicals, energy efficiency must be optimized, especially in light of the relatively high energy costs required for the generation of plasma. Moreover, insights on reactivity are necessary to advance the field and will require a deeper understanding of the intertwined effects of plasma and catalysts. Here, advanced in situ characterization approaches are expected to make the difference.

It goes without saying that on the path to electrify chemical manufacturing, electrocatalytic approaches deserve special attention. Hydrogen generation, for instance, remains a central pivot for the overall strategy, considering its role as both energy vector and as reductant of choice for many indispensable processes across the industry – for example, the Haber–Bosch process. At present, the capacity to produce hydrogen through electrolysis is still limited, but important efforts are ongoing to ramp up production at the gigawatt-scale, as in a recent demonstration by Siemens Energy in Berlin, for example. Besides H_2 production methods, approaches for the conversion of CO_2, N_2 and a variety of small organic compounds such as acetylene have already established themselves in the scientific literature and will hopefully soon reach practical implementation. It is also worth mentioning that, over the past years, electrocatalytic methods have proved successful for an array of synthetic organic transformations, opening the way to also decarbonize the production of fine and specialty chemicals.

These are just some examples of areas where electrification is progressing rapidly, while many other technologies and innovations based on the use of regenerative energy are on the way and will slowly transform the field of catalysis. Here, the effective interaction of scientists from both academia as well as industry is key to success. We therefore welcome dedicated meetings such as the Infoday "Electrification of catalytic

CREDIT: MARGA BUSCHBELL STEEGER/GETTY IMAGES processes" recently organized by the German catalysis society, which constitute important moments to share knowledge and establish collaborations that will eventually bring the field forward.

At *Nature Catalysis*, we will continue to monitor developments in this vibrant area of research over the next year and hope to feature examples of relevant exciting discoveries in our pages soon.

Happy Holidays.

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References

1. Mallapragada, D. S. et al. *Joule* **7**, 23–41 (2023).
2. *Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach* (IEA, 2023); https://www.iea.org/reports/net-zero-roadmap-a-global-pathway-to-keep-the-15-0c-goal-in-reach
3. Wismann, S. T. et al. *Science* **364**, 756–759 (2019).
4. Wang, W. et al. *ACS Catal* **9**, 7921–7935 (2019).
5. Bogaerts, E. & Neyts, E. C. *ACS Energy Lett.* **3**, 1013–1027 (2018).