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Chemical Sites as Catalysts for the Transition to a Circular Economy

Carsten Gerhardt

Abstract: The chemical industry, often referred to as the "industry of industries", plays a crucial role in the Circular Economy, an economic model aimed at closing material loops and minimizing harmful environmental impacts. However, the sector in Europe is currently facing unprecedented economic pressure, unlike anything in its history—since the groundbreaking inventions over the past two centuries, like the Haber-Bosch process, coal tar dye chemistry, and the concept of Verbund-sites where the by-product of one process serves as input for the next. This article highlights the opportunities and challenges facing the industry in the context of a Circular Economy.

Keywords: Chemical Industry, Circular Economy, economic future of Europe, Long-term outlook, renewable energies, post-consumer feedstock, bio-based feedstock

Chemiestandorte als Katalysatoren der Circular Economy

Zusammenfassung: Die chemische Industrie, die oft als „Industrie der Industrien" bezeichnet wird, spielt eine entscheidende Rolle in der Kreislaufwirtschaft, einem Wirtschaftsmodell, das darauf abzielt, Stoffkreisläufe zu schließen und schädliche Umweltauswirkungen zu minimieren. Allerdings steht der Sektor in Europa derzeit unter einem beispiellosen wirtschaftlichen Druck, wie es ihn in seiner Geschichte noch nie gegeben hat – seit den bahnbrechenden Erfindungen der letzten zwei Jahrhunderte, wie dem Haber-Bosch-Verfahren, der Teerfarbstoffchemie und dem Konzept des Verbunds, bei dem das Nebenprodukt eines Prozesses als Input für den nächsten dient. Dieser Artikel beleuchtet die Chancen und Herausforderungen, vor denen die Branche im Kontext einer Kreislaufwirtschaft steht.

Stichwörter: Kreislaufwirtschaft, Chemieindustrie, wirtschaftliche Zukunft, Langfristperspektive, biobasierte Ausgangsstoffe, erneuerbare Energien

Europe is losing economic relevance with the rise of Asian economies, especially China. The global market share of the European Chemical industry is going down – in the past 20 years it has shrunk from 27 % to 13 %. The Chemical industry in Europe is facing severe challenges due to energy prices, labor costs and raw material challenges. Its long-term prospects are good, but the question is how it will survive until level-playing fields are established globally. Short and mid-term efficiency improvements and consolidation are needed. This will release space and human capital that can be used for a Circular Economy. The Chemical industry can become the key enabler of the Green Deal. It is capable of recycling the most complex materials, if needed, at molecular level. With this recycling and all the necessary preparatory steps done on today's Chemical production

sites, these will become the hotspots and catalysts for the transition to a Circular Economy for Europe.

The chemical industry is closely linked to overall economic development. Therefore, it is essential to consider global developments in various regions to better understand the current situation of the industry in Europe.

Europe's Economic Significance is Diminishing in Global Comparison

In terms of nominal Gross Domestic Product, the USA ranks first, followed by the European Union, China, Germany, Japan, India, and the United Kingdom. However, when adjusted for purchasing power, China has significantly surpassed the other countries and regions, standing at the top, followed by the USA, the EU, India, Russia, and Japan, while Germany ranks lower. Given India's ongoing economic development, it is expected that the EU will lose one of its top positions in the near future and will only rank fourth globally.

This relative loss of significance for Europe is particularly evident in the chemical industry over the past two decades. In 2002, the share of the European chemical industry in global chemical sales was still 27 %, while it dropped to 13 % by 2024—a reduction of more than half. However, this decline is less due to a weakness in the European chemical industry, which has doubled its revenue from €363 billion to €659 billion during this period, and more due to the rapid growth of the global chemical industry, especially in China. The global chemical sales have nearly quadrupled from €1,352 billion in 2002 to €5,214 billion in 2024. The doubling of European sales and the simultaneous quadrupling of global sales mathematically result in the halving of the European market share during the same period.

The Chemical Industry in Europe Faces Unique Challenges

In this phase of relative loss of significance, the European chemical industry is confronted with three major challenges: First, the crisis of multilateralism and the decline of free and open global trade. Second, the pressure from overcapacities in the Chinese industry that are flooding the European market at dumping prices. Third, the current weakness of key customer industries in Europe, such as the automotive industry, further burdens the chemical industry. These factors lead to significant underutilization of many European chemical parks, often below 75 %, and in some cases even as low as 50 %.

This competitive situation in Europe is challenging but not hopeless. It requires a European chemical strategy with a clear focus on future viability and resilience. Key challenges include high energy prices, overburdening regulations in Europe, and relatively high labor costs compared to the global context. Furthermore, Europe must consider that, unlike China or India, it does not have large, readily accessible markets. With a population of less than 500 million, the EU is only one-third the size of China or India. Additionally, Europe has significantly less access to raw materials than other regions, and its production facilities are, on average, older than those in China, where most facilities have been built in the last 30 years. The availability of skilled labor in Europe is also declining, while it is increasing in China from a higher baseline.

Another issue is a partial lack of understanding of the importance of the chemical industry. For too long, in some parts of society it has been perceived as a burden in

terms of environmental impact rather than as essential for addressing future challenges. To strengthen resilience and reduce dependence on foreign markets, the chemical industry is indispensable.

Long-Term Prospects for the Chemical Industry in Europe are Positive

The long-term prospects for the chemical industry in Europe, which focuses on production for the European market and makes full use of the benefits of a Circular Economy, are positive for three main reasons.

First, energy prices in the industrialized nations of the northern hemisphere are expected to converge in the long term, as renewable energies such as solar and wind in Europe are comparably inexpensive as in China or the USA.

Second, automation and digitalization are expected to lead to a global trend toward high-quality jobs that are comparably expensive across different regions.

Third, the availability of raw materials is also expected to increase, as post-consumer materials are increasingly used as raw materials of the future. A chemical industry that is less dependent on oil or naphtha and relies more on the reuse of carbon from post-consumer streams will be less dependent on imported raw materials.

Today, the costs of renewable energies in Europe are already cheaper than those of fossil fuels, with electricity generation costs for new photovoltaic plants below €0.03 per kilowatt-hour compared to about five times higher costs for coal.

Survival of the Chemical Industry in the Short and Medium Term

Long-term positive prospects are of little use if the chemical industry does not survive until global competitive conditions normalize and a "level playing field" is established. The current unprofitability in many areas of the industry must be addressed in the short term. The industry will consolidate its capacities in unprofitable areas to become profitable again. These adjustments will free up both space and human capital in the chemical parks for alternative uses. We advocate viewing these releases as an opportunity. An example of successful utilization in chemical parks is the Chemelot Chemical Park in the Netherlands, where the Brightlands Research Center has been established. Here, partners from industry, science, and government are working on a green and circular chemistry of the future based on the use of post-consumer plastics as raw materials.

In addition to this medium-term perspective, there are numerous short-term measures to increase productivity that can enhance competitiveness. These include process simplifications, digitalization, automation, and the standardization of operational processes to ensure consistent product quality. Many operational processes can benefit from digital support, and improved planning and control of value chains can further reduce losses. Appropriate governance can significantly accelerate decision-making processes. The sum of these measures can lead to a significant increase in productivity.

The Chemical Industry as an Enabler of the EU Green Deal

At the EU level, as well as in individual member states, there are ambitious goals for the Circular Economy. The EU Packaging Regulation aims for a recycling rate of 55 % for plastic packaging by 2030, with 30 % of all packaging to consist of recycled material. The EU Battery Regulation stipulates that the recycling efficiency of lithium-ion batteries

should reach 70 % by 2030, and a recovery rate of 95 % for cobalt, nickel, and copper should be ensured by 2031. The coalition agreement of the new German government from May 2025 highlights various Circular Economy topics, including chemical recycling and recycling in construction, as well as ambitious goals for the automotive industry. The importance of circularity as a key lever for achieving net-zero targets is widely recognized.

Since 95 % of all products contain chemical products, the chemical industry is directly affected by the recycling targets of the EU and its member states—without it, these goals cannot be achieved. The chemical industry is a central enabler of the European Circular Economy goals. It is not only about making European production circular with a focus on high R-strategies like redesign or reuse, but also about ensuring that products manufactured in Europe and imported products can be returned to molecular levels after use and transformed into new products or high-quality alternatives.

With the EU commission's heightened emphasis on the competitiveness of Europe's industry in the context of the Clean Industrial Deal, the Chemical industry is tasked to close material loops of its products at highly competitive costs.

Closing Industrial Value Chains in Chemical Parks

The large integrated sites of the chemical industry are crucial locations for the transformation to a Circular Economy. These sites are predominantly located in Europe near major metropolitan areas, which will represent their future raw material sources. For example, the sites in Marl, Dormagen, Leverkusen, and Wesseling are located in the Rhine-Ruhr metropolitan region with over 10 million inhabitants, while Frankfurt-Höchst and Ludwigshafen, the largest chemical integrated site in the world of BASF, serve the Rhine-Main region with over 6 million inhabitants. Similarly, other large chemical sites in Central Europe are located near important metropolitan regions. These conditions make Europe ideal for a circular economy based on post-consumer products. The chemical sites near urban centers provide space for the future tasks of pre-processing post-consumer raw materials. This proximity leads to significant savings in logistics costs compared to transporting post-consumer products to Asia, where they would be recycled and then transported back to Europe.

Traditionally, chemical integrated sites have produced hundreds of carbon-based chemical compounds from a few raw materials (primarily naphtha). In the future, the goal will be to produce equally high-quality products from raw materials of diverse origins as previously from fossil raw materials. Post-consumer raw materials are extremely diverse, ranging from used mattresses and shoes to textiles. High-performance composite products are difficult to recycle and typically require multi-stage pre-treatment. To ensure the product quality of recyclates, the chemical industry plays a central role in the preparatory processing stages. Solar panels, electrolyzers, and batteries can only be recycled at a high quality through chemical processes. The preparatory steps, such as disassembly, sorting, and cleaning, require proximity to the subsequent production stages.

If, as a result of industry consolidation, space for processing stages becomes available at large chemical sites, these should be utilized consistently, as should the available workforce capacities.

Additional Carbon from Biogenic Sources in the EU

In the long term, recycled carbon is unlikely to be sufficient to meet the entire demand of the chemical industry. Fortunately, Europe has good conditions to source the necessary "virgin material" from biobased sources. It is crucial that biomass is primarily used for industries that cannot be decarbonized, particularly carbon chemistry with its material use of carbon. In Germany, significantly less than 20 % of arable land would be sufficient to fully meet the material needs of the chemical industry. With high reuse rates of carbon from post-consumer sources, the need for arable land to cover a carbon gap for the chemical industry from biogenic sources could be significantly reduced. Only 5 % of German arable land would suffice for the material carbon needs of the German chemical industry—less than half of the area currently used for growing maize for biogas plants for electricity generation.

Despite a strong emphasis in the last two sections on carbon chemistry, we'd like to emphasize that the same logic holds true beyond polymers. The Chemical industry and its sites play a crucial role in recovering all kinds of critical raw materials, e.g. platinum group metals and other key transition materials.

Complex Challenges in Recycling

The chemical industry faces enormous challenges in the area of recycling. It must not only return centrally generated monomaterials of known origin from Europe with product passports back into the loop but also recycle imported composite materials without precise knowledge of their compositions. Many durable consumer products, such as mattresses and tires, represent compact, easily identifiable sources of raw materials. At the same time, it is necessary to return widely distributed, short-lived consumer products of often low weight back into the loop and prevent their entry into the environment. The greatest challenge comes from chemical or pharmaceutical substances that, for example, enter the environment as pesticides or metabolic products.

For the processes in chemical industry facilities, controlled and known input qualities of the respective raw materials are essential. It is a joint task of post-consumer collection, transport, and sorting systems, along with the chemical industry, to ensure these qualities. This can be particularly effective when important parts of the processing are carried out directly at the chemical sites with their expertise.

The future advanced collection, sorting, purification, and processing facilities will require highly qualified chemists and technicians in the coming years and decades. In this context, the current decline in student numbers in the field of chemistry is concerning. As the "industry of industries", the chemical industry needs sufficient talent to act as a catalyst for the circular transformation in Europe.

Diversity of Input Materials in Future Integrated Sites

The goal is to have a chemical industry that continues to produce the accustomed high quality of chemical compounds from a wide variety of post-consumer raw materials and different biobased raw materials in future integrated systems. With such competencies, Europe will be able to achieve an excellent position in the global market, particularly in machinery and plant engineering. Market leaders in Germany are comprehensively addressing the challenges. Examples include BASF's ChemCycling, various CQ solutions

from Covestro, and the biobased and biodegradable surfactants from Evonik. Both OMV and LyondellBasell are investing in industrial-scale chemical recycling facilities integrated into existing chemical parks. The next step must be to integrate upstream processing stages of post-consumer materials at these sites to achieve maximum efficiency in the supply chain.

The Transformation as a Collective Task

Such a transformation can only be approached as a major collective task involving industry, politics, science, and civil society. In the short to medium term, it is the responsibility of the industry to tap into existing efficiency potentials and adjust capacities within the framework of consolidations. At the same time, it is the task of politics to protect the existing industry where there is currently no fair competition and where the chemical industry outside Europe benefits from unfair competitive conditions. In the long term, it is a joint task of industry and politics to repurpose free capacities for the circular economy. This concerns both the aforementioned areas in chemical parks and the currently released human capacities. The necessary technologies are largely already available in the form of pilot plants. The various technologies of chemical recycling are a good example of this. Now, it is crucial to scale these technologies up to industrial sizes in a timely manner. Furthermore, additional efforts are needed from the scientific community to further develop post-consumer materials and biobased raw materials as feedstock for the chemical industry and bring them into application.

Carsten Gerhardt, Dr. rer. Nat., is the Chairman of the Circular Valley Foundation and Partner in the Global Chemical Industry Practice of EY

Address: Circular Valley Foundation, Friesenstrasse 32a, 42107 Wuppertal, Germany, Phone: +49 202 – 256237 68, E-Mail: carsten.gerhardt@circular-valley.org