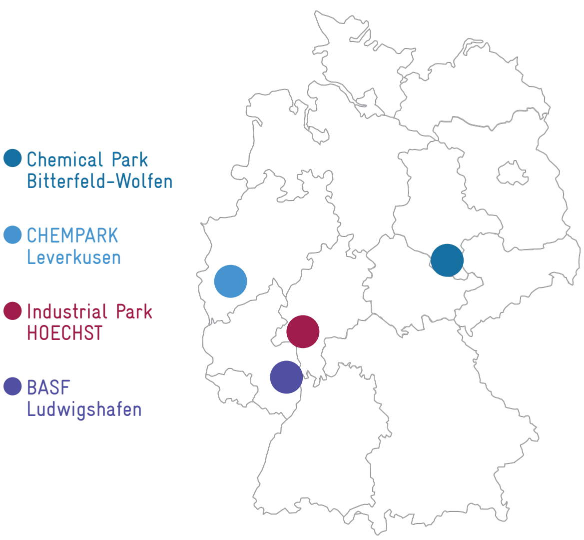
VERBUNDSTANDORTE

The **Verbund** in Chemical Parks: Promoting net-zero targets in the chemical industry

INTRODUCTION

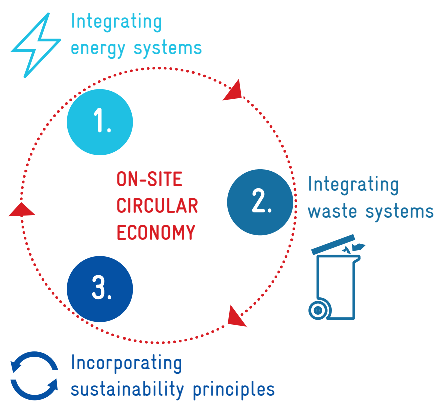
In Germany, the chemical industry mostly operates within the confines of chemical parks. Over 1,000 companies currently have operations in one of Germany's roughly 60 chemical parks, which employed around 250,000 people in 2021.[1] The largest in the country include BASF Ludwigshafen, Industrial Park HOECHST, CHEMPARK Leverkusen and Chemical Park Bitterfeld-Wolfen. Generally, these are fenced-off compounds with limited access, while companies operating within chemical parks are located in close proximity to one another as well as to centralized on-site infrastructure facilities that provide e.g. energy, wastewater treatment, and waste disposal.

THE LARGEST CHEMICAL PARKS IN GERMANY



Chemical parks in Germany are operated by specialised private companies responsible for the day-to-day park operations, in many cases even initiating and coordinating networking activities among the resident companies. They are also responsible for taking care of on-site infrastructure and providing additional demand-oriented services for chemical manufacturers. Chemical parks are created based on cooperation between the resident companies with the aim of increasing efficiency in chemical production. As one of the most important factors in closing the loop for on-site circular economies, this approach to cooperation holds the potential to make a significant contribution to reducing the greenhouse gas (GHG) footprint of such chemical parks. They close the circular economy loop in three ways:

1) by integrating energy systems that generate energy and manufacture basic feedstock,
2) by integrating waste systems that dispose of waste and generate energy and
3) by incorporating sustainability principles in the context of chemical park operations.



1: https://www.vci.de/die-branche/chemieparks/listenseite.jsp

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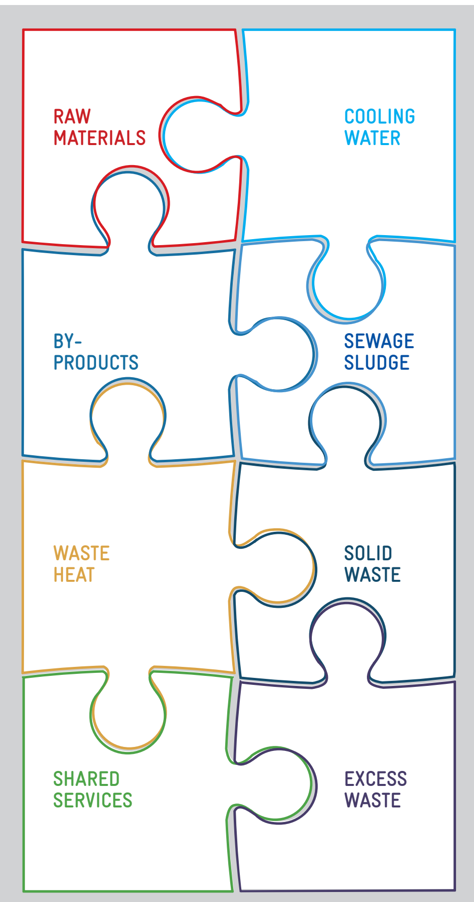
With its roadmap for promoting efforts to mitigate climate change, the German chemical industry has set an intention to reduce overall GHG emissions and become carbon neutral by 2050. This objective can, however, only be achieved if targeted measures are effectively implemented at the chemical parks themselves.[2] With specially adapted infrastructure as well as supply and disposal systems integrated into their production facilities, chemical parks offer a promising framework for achieving these objectives in an economically viable manner. Apart from their technical benefits, they also serve as a basis for creating business and regulatory environments that foster innovation.

CHEMICAL PARKS AS VERBUNDSTANDORTE



2: https://www.vci.de/services/publikationen/broschueren-faltblaetter/vci-dechema-futurecamp-studie-roadmap-2050-treibhausgasneutralitaet-chemieindustrie-deutschland-langfassung.jsp

CHEMICAL PARKS AS **VERBUNDSTANDORTE**

Chemical parks operate on the principle of having all their activities and facilities interconnected in some way:

- Resident companies extend their supply chains on site and purchase raw materials from other companies in the chemical park, where they are produced as intermediates
- By-products produced by one company are used as feedstock for other plants or by other companies on site
- Waste heat that cannot be used for internal plant processes is transferred to other companies for thermal uses
- Resident companies are offered shared services from on-site providers
- Cooling water and process wastewater are treated after use – either at the discharging chemical plant itself or at a central wastewater treatment plant – and subsequently fed into the water supply network for on-site reuse in cooling or as process water
- Sewage sludge is incinerated on site, with the waste heat used to generate electricity and steam
- Solid waste is collected, separated and either processed for reuse, recycled or incinerated
- Excess waste along with electricity and heat generated via cogeneration at the incineration facilities is fed into park-wide distribution networks to reduce primary energy demand

In Germany, this sort of interconnected structure is called a **Verbund**, and the chemical parks themselves are referred to as **Verbundstandorte** – ‘integrated sites’ or ‘integrated production sites’. The concept serves to highlight the value generated by efficiently using resources through networking efforts, allowing chemical parks to make a significant contribution to mitigating climate change. Ideally, plans governing the **Verbund** should already be outlined in the site master plan and leveraged as a site differential during marketing campaigns. New investors can be screened to identify whether they will be a good fit for the existing network, in terms of adding value to the chemical park or complementing it in a beneficial manner.

SUSTAINABLY MANAGING AND OPERATING CHEMICAL PARKS

Most chemical parks in Europe were created by converting production sites belonging to large chemical companies, such as NOVARTIS, BAYER or HOECHST. The original aim was to turn site operations from a cost centre into an independent and entrepreneurial legal entity. As such, these chemical parks draw many of their characteristics from the Responsible Care Charter created by the chemical industry. This charter aims to forge a common understanding around the principles of sustainable action, including:

- the assumption of responsibility,
- governance,
- customer orientation,
- cooperation and
- communication.

Companies that have recently settled in chemical parks are likewise expected to abide by this underlying mindset. As an example, at CHEMPARK – which serves as the primary production site for Bayer – all resident chemical companies are obliged to sign and adhere to the ICCA Responsible Care Global Charter.[3] [4]Resident companies are also committed to pursuing the chemical industry's roadmap for achieving net-zero CO_2 emissions.

The business model for chemical parks as **Verbundstandorte** draws on a cluster-based planning and management approach. Chemical parks are developed with specialised facilities that are configured to the needs of specific industries and sectors, generating a win-win situation for the industries housed within them. These parks also promote regional economic development. This can occur through effective institutional arrangements, for instance with research facilities and universities, or through the construction of facilities and services that satisfy the specific demands of the resident companies developed in cooperation with park operators and the local private sector. This ensures that chemical parks are not merely stand-alone entities but sites that integrate the interests of industry, commerce and residents as well as social considerations. Operators are thereby able to diversify potential sources of revenue, form the basic requirement of selling or leasing land and providing infrastructure to offering businesses complementary support services.

CHEMPARK LEVERKUSEN

Photo: ©Federal Waterways Engineering and Research Institute (CC BY 2.0)

3: https://www.hoechst.de/de/responsible-care.html
4: https://icca-chem.org/resources/responsible-care-global-charter/

CLOSING THE LOOP IN THE CIRCULAR ECONOMY

Large-scale chemical parks such as CHEMPARK or Industrial Park HOECHST are home to comprehensive circular economy platforms for water and waste:

- The resident production companies cover nearly the entire value chain for chemical and pharmaceutical products
- The park management offers a set of shared services while also operating diverse infrastructure facilities, including:
  – A comprehensive waste management service (from consultancy to collection), waste stream management and separation at a disposal centre, with process wastewater treated at a central facility and non-contaminated water (such as that used for cooling) collected in a separate piping system, cooled and reused
  – A fermentation site, for example, at Industrial Park HOECHST where global-scale biogas production is fed with regional organic waste and air as well as nitrogen and wastewater from the park network used for generating steam, electricity and biogas and then converted to methane through a purification process to reduce on-site demand for natural gas
  – Utilities for energy generation, with chemical waste and residue-derived waste incinerated in co-generation (CHP) plants – for which the mix and usage of different fuels are continuously optimised to increase CO_2 efficiency
  – Parkwide process-water management, from the water supply to wastewater, allowing for water to be used repeatedly and ensuring process quality at the production facilities

Besides offering environmental benefits and curbing CO_2 emissions, the **Verbund** approach also provides cost savings to companies, increasing competitiveness when compared to conventional chemical parks and boosting attractiveness for new investors.

INDUSTRIAL PARK HOECHST

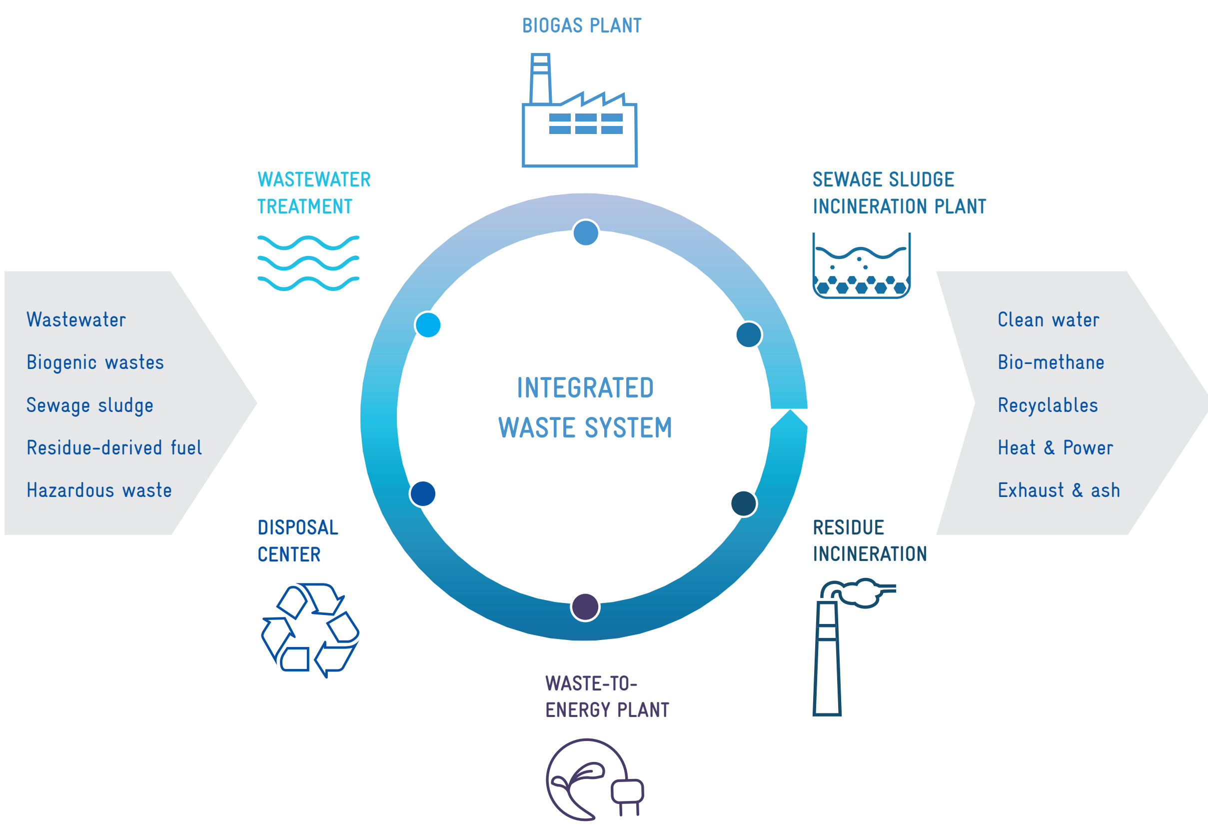
Photo: ©Infraserv GmbH & Co. Höchst KG

INTEGRATED SYSTEMS FOR WASTE MANAGEMENT AND ENERGY GENERATION

Chemical parks feature integrated systems designed to make optimal use of waste. Sources of waste typically include wastewater from production plants, organic waste from agriculture and green areas, sewage sludge, substitute fuels and hazardous materials. For park operators, one of the biggest challenges is knowing how to reprocess this waste. At Industrial Park HOECHST, the answer was to expand infrastructure on site and build dedicated facilities for recovering materials and energy that could be reused inside the park.

- Wastewater is treated via a two-stage biological treatment process (achieving a level cleaner than river water), which can be used for cooling or as process water.
- Biogenic waste is fermented into biogas and purified into biomethane, by removing by-products such as nitrogen and oxygen, and subsequently fed into the natural gas pipeline.
- Sewage sludge is dried and incinerated in a co-generation plant that produces steam and electricity while ash is purified and used as fertiliser.
- Hazardous waste containing more than 10 per cent organic components is incinerated and disposed of at landfills if the organic content is lower (with a low caloric value).
- A disposal centre is used to collect solid waste and separate it for recycling and reuse.
- An on-site power plant with residue-derived fuel (RDF) receives feedstock from the industrial area as well as from sources outside of the park.

Incinerators are operated both as waste-to-energy plants and as co-generation plants. The generated electrical energy and steam are fed into the industrial park networks to supply other chemical companies, thereby reducing their primary fuel demand and, in turn, contributing to the industry's net-zero objective. This offers clear economic advantages for the resident companies as they receive compensation for each kW fed into the grids, turning waste into a value generator.



PARK OPERATOR'S CONTRIBUTIONS TO THE PATH TO NET-ZERO CHEMICAL PRODUCTION

The linear product flow common to chemical companies generally only goes in a single direction: from raw materials to chemical and pharmaceutical products. By integrating waste reprocessing, park operators create a transition from a linear process industry to a circular economy. Production waste is processed in waste-to-energy facilities, concurrently generating energy and heat that are fed into the production processes for chemicals and pharmaceuticals. Additionally, the primary products from these waste-to-energy facilities – biogas, biomethane, energy and steam – are renewable energy sources, offering a substantial contribution to reducing CO_2 emissions at the chemical plants. Further benefits are also attained from processes such as carbon capture and utilisation (CCU) at the chemical parks. One concrete example can be found at Dormagen CHEMPARK, where CO_2 is sequestered from flue gas produced by the coal-fired power plant located near COVESTRO's production facilities. After purification, the CO_2 is used as a raw material to produce polyurethane.

These examples show how effective sector-coupling aimed at net-zero chemical production at chemical parks can be applied between chemical companies and the park infrastructure facilities. This solution improves the efficiency, flexibility and reliability for the park's energy system.

NETWORKING IN CHEMICAL PARKS AS SUCCESS FACTOR FOR GHG MITIGATION

The establishment of Energy Efficiency Networks (EEN) is a joint initiative between government and industry in Germany. The basic idea is for different companies within a certain region or industry to voluntarily join together into an informal network with the aim of increasing their energy efficiency and reducing CO_2 emissions over an extended period of time. Experience from the past eight years shows that cooperation through the EEN framework has generated numerous success cases. A common standardised approach is applied that consists of conducting analyses of energy potential, holding regular network meetings, exchanging information on specific energy topics and individual energy efficiency measures, and participating in energy efficiency monitoring.

In addition to the fact that they are energy-intensive production facilities, chemical parks also serve as prime candidates for establishing EEN due to the close spatial proximity between production and infrastructure facilities and, above all, the trusting cooperation common among the resident companies, including park operators. Establishing a cooperation network generally depends on having an initiator or catalyst to generate momentum and coordinate the networking process – a task usually assumed by the chemical park operator.

CURRENTA initiated an EEN at CHEMPARK in 2015 and, to date, eight major chemical companies have joined the network. The park operator sets rules, coordinates the exchange of information and organises cooperation agreements to ensure the confidentiality of individual discussions related to energy exchanges. The original target of achieving an annual reduction of 100,000 MWh or 20,000 tonnes of CO_2 has since been surpassed, even while production volumes have increased over the same period of time.[5]

REUSING WASTE HEAT THROUGH INTER-COMPANY EXCHANGES

Many chemical processes involve energy conversions, be they endothermic or exothermic. For the chemical industry, excess heat can represent a major environmental issue when released into the atmosphere rather than being reused. One beneficial alternative is using waste heat to generate electricity or refrigeration or as a heat source within the same factory. The close proximity of chemical plants at chemical parks also facilitates the process of feeding waste heat into a park-wide distribution network for steam or hot water, or for use in other industrial processes when transferred directly to adjacent companies. The type of reuse and the associated technology depends on local conditions such as temperatures, enthalpy and user requirements, along with additional factors such as energy costs and required investments. Conducting a

5: https://www.chempark.de/de/aktuell/pitems/2021-10-01-energie-effizienznetzwrk-im-chempark-uebertrifft-die-eigenen-ziele.html total site analysis is a common instrument chemical park operators use to assess and plan **Verbund** structure along with CO_2 reductions in their parks.

AN EFFECTIVE REGULATORY FRAMEWORK FOR INNOVATION TO ACHIEVE NET-ZERO TARGETS

The conditions found at chemical parks offer an ideal real-world environment for testing out transformations toward a CO_2-neutral chemical industry. While chemical parks are well suited for developing and applying new technologies under real-life conditions, existing legal and regulatory frameworks are not always permissive to this end. With this limitation in mind, the German Federal Ministry for Economic Affairs and Climate Action sought to come up with a responsible way to foster innovation processes.[6]

The solution created is referred to as 'regulatory sandboxes', a special kind of open-innovation 'living lab' centred around customers. The idea behind them is to allow experience with new technologies to be gathered quickly and to assess the associated opportunities and risks.

Based on the experience and information gathered, government agencies can subsequently put together the most appropriate regulatory frameworks for a possible roll-out. As such, a certain degree of legal flexibility is granted at these regulatory sandboxes, such as in the form of experimentation clauses. Apart from being strictly monitored, regulatory sandboxes are operated for a limited time and restricted to certain parts of a given sector or area.

Under the prerequisites set, companies can test out innovative technologies through demonstration projects, investigate the implications of these new technologies on their business models and up- or re-skill employees at the chemical parks. This also presents an opportunity to take advantage of the huge potential for mitigating GHG emissions through chemical recycling and PtX-technologies in the favourable environment of chemical parks. Recent examples include pilot units currently under construction at the Innovation Campus at the Industrial Park HOECHST, including an INERATEC power-to-liquid plant and an ARCUS Greencycling Technologies pyrolysis facility for recycling end-of-use plastic waste – fully supported by the chemical park **Verbund** structure.

Photo: BASF Ludwigshafen, ©BASF SE

6: https://www.bmwk.de/Redaktion/EN/Dossier/regulatory-sandboxes.html

CHEMICAL PARK CONTRIBUTIONS TO THE NATIONAL HYDROGEN STRATEGY

The combined hydrogen know-how of chemical park operators and resident companies accumulated over many years can serve as an excellent basis for producing chemicals based on green hydrogen and green electricity in the future. Numerous examples of successful cooperation already exist:

- Industrial Park HOECHST has installed hydrogen filling stations for cars and regional trains.
- COVESTRO stores green hydrogen in liquid organic hydrogen carriers (LOHC) at CHEMPARK Dormagen, where excess heat is fed into the parkwide steam distribution system run by park operator CURRENTA.
- INEOS utilises a PEM-water electrolyser for green ammonia production in Cologne, where excess heat is fed into CURRENTA's parkwide steam network while excess hydrogen is fed into the nationwide hydrogen network.
- COVESTRO uses post-combustion CO_2 capture from the power plant at CHEMPARK Dormagen and from INEOS' ammonia manufacturing as feedstock for polyurethane manufacturing.

These current or planned projects represent milestones in implementing the national hydrogen roadmap in Germany, which aims to reduce CO_2 emissions in the industrial, transport and energy sectors using hydrogen technology.[7]

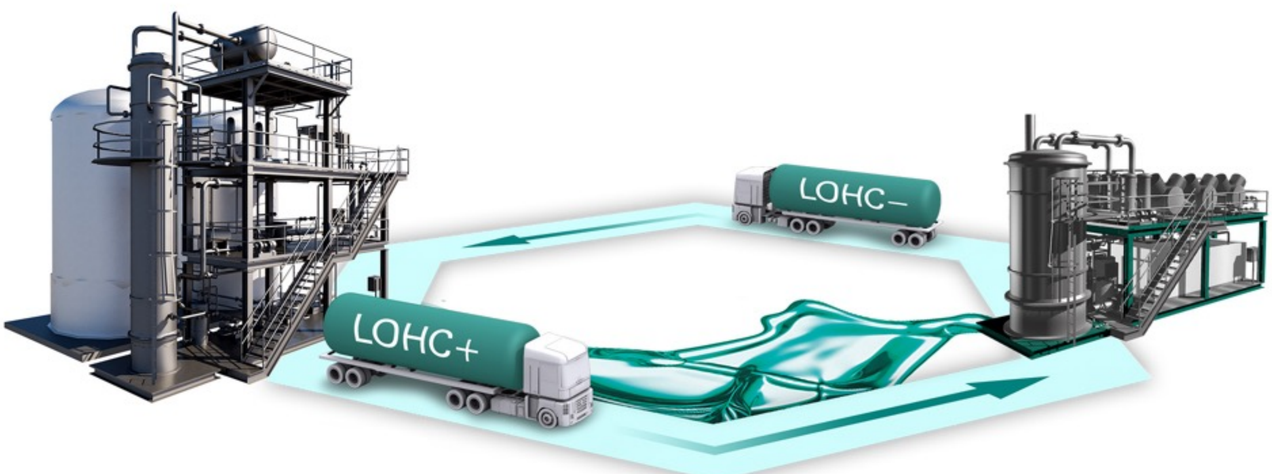


Illustration: ©Hydrogenious Technologies

7: https://www.bmbf.de/bmbf/en/news/national-hydrogen-strategy.html

DIGITISATION AS A DRIVER OF THE SUSTAINABILITY TRANSFORMATION AT CHEMICAL PARKS

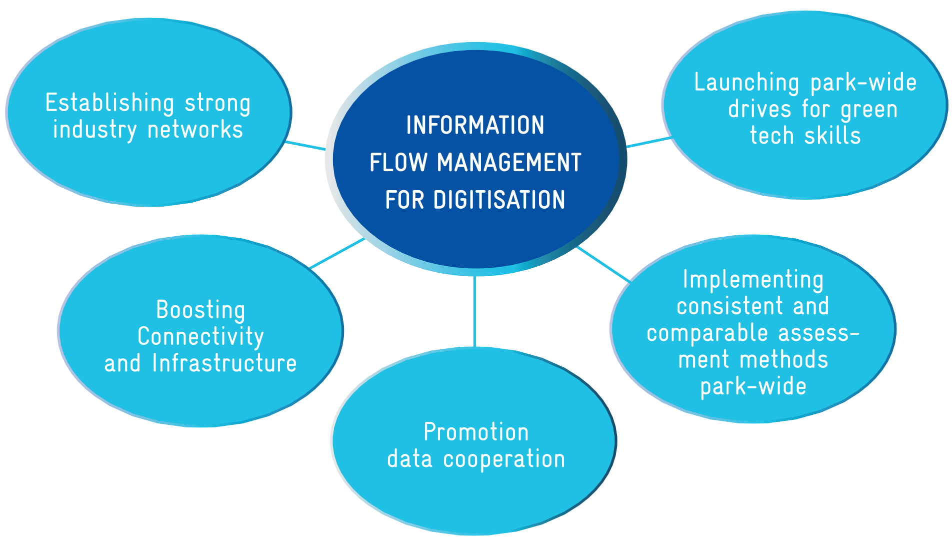
An IBM business survey shows how products and services developed within the framework of the 'twin-transformation' can offer considerable advantages over conventional products in terms of economics, quality and environmental impacts.[8] While specific technologies that promote industry 4.0 may vary across sectors, some of the guidelines developed from the survey for the digitisation of industries and industrial parks can be applied to all digitisation projects in chemical manufacturing.

The ability to create higher service levels is a key driver for the sustainability transformation. Offering superior levels of service that address companies' business models ultimately promote the implementation of smart circularity as they provide closer proximity to customers, better access to product data and easier execution of closed product loops.

Chemical companies possess extensive knowledge of their products and can share this for the benefit of their customers: to achieve higher production performance, energy savings, GHG mitigation and other optimisations during the use phase of their products.[9] This allows them to extend the scope as well as the specific use of recycling. Chemical parks can satisfy the conditions required for fostering the twin transformation by:

- Establishing strong industry networks that can learn from one another, with park operators serving as an interface between the companies and sharing best practices.
- Boosting connectivity and infrastructure, especially as strategic digital solutions rely on high-speed and high-quality connectivity provided by robust network infrastructure.
- Promoting data cooperation to enhance access and use of sustainability data for making intelligent decisions and reducing energy use, with artificial intelligence and the Internet of Things relying on access to high-quality and interoperable data.
- Implementing consistent and comparable assessment methods park-wide to boost the uptake of digital technologies that promote the sustainability transformation.
- Launching park-wide drives for green tech skills such as data literacy, computational thinking and critical thinking, allowing for digital solutions to be translated and applied to business and industrial uses.

In summary, major chemical parks have already demonstrated that digitisation plus Industry 4.0 technologies joined with a cluster-based business model for park management are key success factors for GHG mitigation as well as the overall sustainability transformation of these parks.



8: IBM Institute for Business Value, Research Insights: Sustainability as a transformation catalyst (2021)
9: Alcayaga, A. & Hansen, E. G. (2022): Internet of Things Enabling the Circular Economy: An Expert Study of Digitalisation Practices in B2B Firms (IQD Research 2022, No. 1). Institute for Integrated Quality Design (IQD), Johannes Kepler University Linz (JKU), Austria

CONCLUSION

Pursuing the consistent application of this **Verbund** structure in the context of chemical parks can go a long way in establishing an extensive circular economy among resident companies. In addition, through cooperation, organisation, technology development and innovation, this approach provides a variety of opportunities for promoting GHG mitigation efforts in chemical production and sector coupling among other industrial activities on-site, as summarised in Figure 1. To leverage these advantages, it is essential for chemical park operators to assume the role of a **Verbund** manager in terms of planning, operating and promoting their chemical park.

Photo: ©BASF SE

OVERVIEW OF POTENTIAL CONTRIBUTIONS OF CHEMICAL PARKS FOR MITIGATING GHG EMISSIONS

VERBUND ACTIVITY	IMPACT ON GHG MITIGATION
Adhering to the ICCA Responsible Care Charter	Self-commitment by chemical producers to achieve objectives of net-zero production
Utilising by-products on site	Reduction of primary energy demand for feedstock production
Generating biogas from biogenic waste and feeding it into gas grid after purification	Reduction of demand for primary energy and natural gas
Incinerating sewage sludge in a CHP plant and feeding steam and electricity into the park-wide grid	Reduction of primary energy demand for electricity and steam generation
Incinerating residual waste in a CHP plant and feeding steam and electricity into the park-wide grid	Reduction of primary energy demand for electricity and steam generation
Generating electricity from residue-derived fuel	Reduction of primary energy demand for electricity and steam generation
Establishing energy-efficiency networks	Reduction of primary energy demand
Exchanging waste heat for use in other companies	Reduction in primary energy demand
Creating a regulatory and business environment conducive to innovation	Testing and piloting of innovative routes for chemical manufacturing to exploit GHG mitigation potential
Optimising processes through park-wide digitisation	Reduction of primary energy demand and off-spec products by avoiding deviations
Operating water electrolyser based on green electricity and feeding excess energy into the steam grid	Reduction of fossil-based chemicals as feedstock
Executing post-combustion CO_2-sequestration from power station flue gas for chemical manufacturing	Reduction of CO_2 emissions through carbon-capture and utilisation on site
Storing CO_2 and feeding excess energy into the park-wide steam grid	Reduction of CO_2 emissions through carbon-capture and utilisation on site, reduction of primary energy demand

Figure 1

ABOUT CAPCI

The Climate Action Programme for the Chemical Industry (CAPCI) aims to enable key actors in selected developing countries and emerging economies to identify and tap mitigation potentials in chemical production and associated value chains. The project focuses on information, knowledge sharing, stakeholder dialogues and capacity building for the mitigation of greenhouse gases in the chemical industry in developing and emerging countries, including Argentina, Ghana, Peru, Thailand and Vietnam. Key partners include authorities such as the ministries of industry and environment, which are generally responsible for climate and chemicals policies, as well as chemical industry associations in the partner countries.

At international level, the UN Climate Secretariat with its Capacity Development Network (PCCB-Network) and the International Council of Chemical Associations (ICCA) are key partners. Regarding the technological options for GHG mitigation, CAPCI has a broad focus that includes energy supply and use, resource efficiency, lifecycle approaches, circular economy and options related to products as well as production processes. The information, capacity building, knowledge transfer and targeted advice provided by the project are oriented towards realistic and efficient pathways and solutions. CAPCI is funded by the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) through the International Climate Initiative (IKI).

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