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Chemistry 4.0

Growth through innovation in a transforming world

Short report

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Foreword by the VCI President

Chemical and pharmaceutical companies in Germany have shown time and again that they can successfully master the tectonic shifts in our competitive environment; examples in the 150 year old history of industrial chemistry are changes in raw materials, relocation of growth centers to emerging economies, and the call to make business more sustainable, which has been receiving broad public support recently.

The key to our competitiveness is the innovative power held in our companies: new and improved molecules, production and business processes. In Europe, our sector has been characterized by globalization, specialization, and focusing on the core business since the 1980s. We have now reached the next level: Chemistry 4.0. Digitalization and circular economy are the key characteristics, and these two elements will fundamentally alter the way we work, as well as support sustainable management.

Digitalizing the chemical industry offers new opportunities as well as risks. Research and development, manufacturing, and business models will be transformed. It is not easy to separate myths from real risks and opportunities, take appropriate measures, and gain a competitive advantage. This transformation offers great opportunities for the highly developed chemical industry in Germany in terms of enhancing its global competitiveness. The chemical and pharmaceutical industry's innovative processes, products, and services make a significant contribution to sustainable development of our society. Our sector will continue to be a traditional supplier of materials, while our role as a service provider will grow in importance at the same time.

Against this background, the VCI, its member companies, and Deloitte Consulting have examined which developments will influence the chemical and pharma business up to 2030, and what we need to do today in order to take advantage of opportunities through transformation tomorrow. From this foundation, we have derived recommendations aimed at the association and its member companies, as well as policy-makers. If we all work together, we will be able to expand the role of the chemical industry as an innovation center for Germany.

I would like to express my special thanks to the many experts, particularly from the member companies, who took part in numerous workshops and contributed to this study, as well as the medium-sized enterprises that responded to the online survey.

Their knowledge and their assessment of the industry's future have made this study possible at all.

A new development in the chemical industry: the era of Chemistry 4.0

The chemical and pharmaceutical industry (in the following: chemical industry) is an important driver for innovation and growth in the German economy. However, fulfilling this role in the long term will require significant efforts; like all industries in Germany, the chemical and pharma sector is faced with elementary strategic and structural challenges.

On the one hand, demand for chemical products in Western Europe will grow only modestly in the decades ahead, moving the focus toward markets in Asia, South America, and, eventually, Africa. Since international and local competitors are expanding their production capacities there, and additional capacities in resource-rich regions are to be expected, the whole competitive environment in the chemical industry is about to face a transformation. In addition, manufacturers in developing and resource-rich countries are expanding their scope to include specialty chemicals that until now had often been covered by German exports. These changes mean a further increase in competitive intensity for the chemical sector in Germany, both in its European home market and in the export markets: in Europe, import pressure on base chemicals and intermediate products from resource-rich regions will go up, while in export markets, competition with local providers and other importers will intensify.

On the other hand, a paradigm change in demand structures and public preferences has been taking place for a while. The desire to use resources in an efficient and environmentally friendly way has noticeable effects on energy supply and consumption habits. The trend toward the Sharing Economy illustrates this transformation. By developing strategies to serve changing customer requirements, companies make an important contribution toward reaching UN sustainability goals. Circular economies will gain in importance, and digitalization will lead to extensive changes in all sectors. These two core topics are of central importance to the trends in the chemical sector up to 2030 and beyond.

As part of these changes, a new phase of development is beginning in the German chemical industry. Following industrialization and coal chemistry (Chemistry 1.0), the emergence of petrochemistry (Chemistry 2.0), and increasing globalization and specialization (Chemistry 3.0), the industry is entering a new phase with Chemistry 4.0, in which digitalization, circular economy, and sustainability play key roles (see diagram).

Chemistry 4.0 | A new development in the chemical industry: the era of Chemistry 4.0

Development from Chemistry 3.0 to Chemistry 4.0

	Chemistry 3.0 **Globalization & Specialization**	**Chemistry 4.0** **Digitalization & Circular Economy**
Drivers for transformation	Globalization, the European internal market, growing competition from gas-based chemistry, the influence of financial markets on corporate strategies, commodification	Digital revolution, sustainability, climate protection, closing material cycles
Raw materials	Increasing use of renewable raw materials and natural gas	Intensive use of data, recycling of carbon-containing waste, H_2 from renewable energies in combination with CO_2 used to produce base chemicals
Technology	New synthesis and production processes through biotechnology and gene technology, enlargement of individual processes	Digitalization of manufacturing processes
Research	Close cooperation between basic research in universities and application-oriented research in companies	Decentralization of R&D in customer markets, utilization of Big Data, joint development with customers
Corporate structure	Internationalization of trade and on-site production abroad, specialization and growth in SMEs, consolidation through M&A, creation of chemical parks	More flexible cooperation as part of economic networks, digital business models, and consolidation
Products	Expanding product range, specialty chemicals oriented to specific customer requirements, new drugs, replacement of traditional materials with chemical products	Expanding the spectrum of value creation: chemical sector becomes a supplier of extensive and sustainable solutions for customers and the environment
Environment, Health and Safety	Environmental protection integrated into production, increasing product safety through expanded review of material properties, Responsible Care	With Chemie³ (ecology, economy, and social affairs), sustainability becomes a comprehensive model and future concept for the industry

Incremental innovations and disruptive changes in the chemical sector

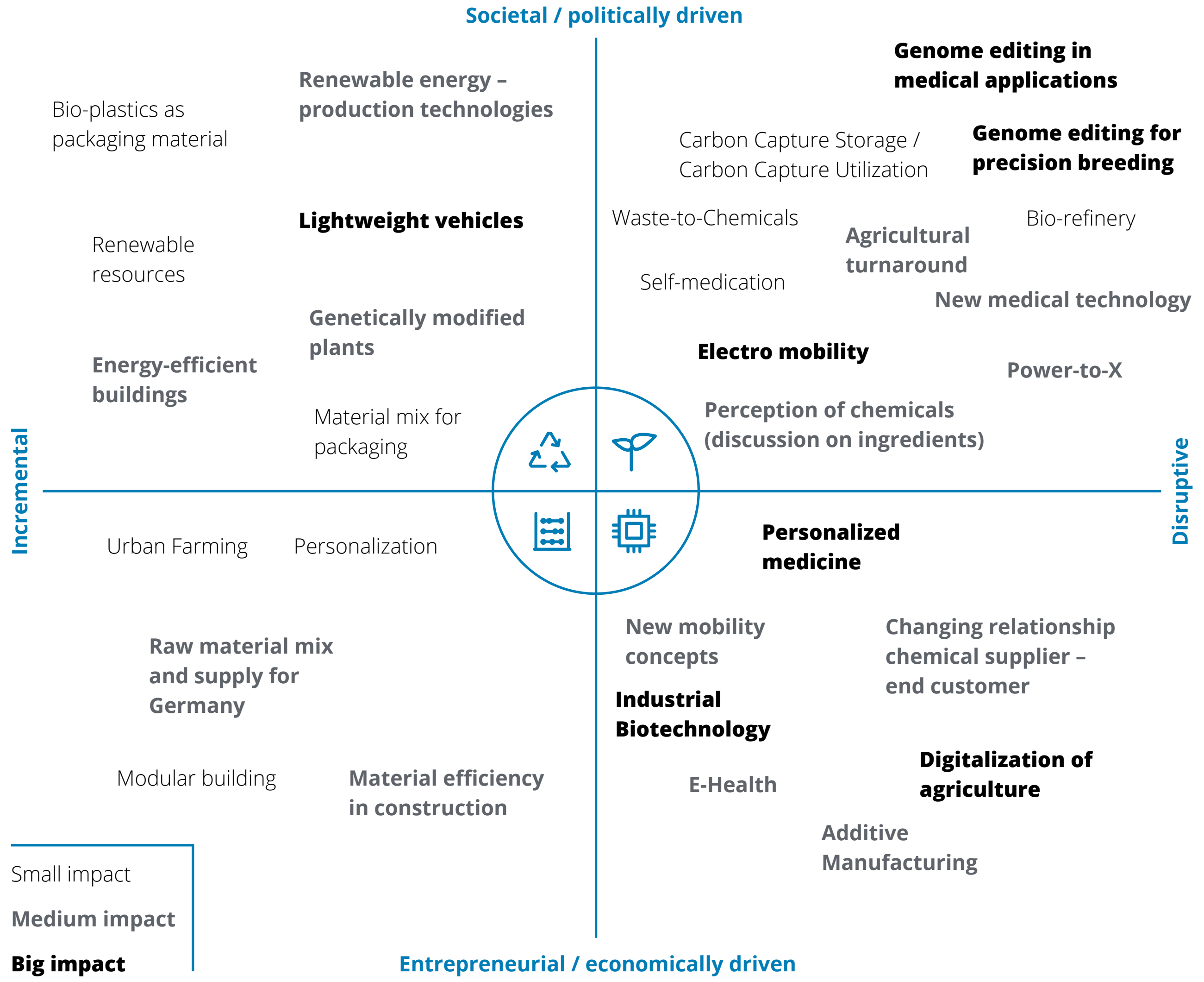
As part of this study, a systematic analysis identified 30 trends that will be of key importance to the chemical industry in Germany until 2030. These trends were analyzed with regard to the underlying drivers, and assessed according to their probable impact (see diagram).

The results show that many innovations in important customer industries of the chemical industry, e.g. in the automotive, construction, and packaging industries, will likely happen gradually. Specific examples of such fields of innovation are lightweight construction using plastics and composite materials in the automotive industry, and more energy-efficient construction materials. These incremental innovation processes are part of the business and success models that already exist in the chemical industry in Germany, and will continue to offer growth opportunities in future.

The chemical sector in Germany is well-positioned to master the challenges of incremental change. A strong industry network in Germany, the innovative power of the chemical industry, and especially well-developed, focused, and customer-oriented medium-sized enterprises are key success factors. As such, these incremental changes continue to offer the chemical sector opportunities for growth, although any competitive advantages gained erode faster and faster due to intensifying competitive pressure.

Chemistry 4.0 | Incremental innovations and disruptive changes in the chemical sector

Trends in the chemical industry up to 2030



An exceptionally large proportion of the changes expected over the coming years has a disruptive character for the chemical industry, however. Several of these expected developments are closely linked to the ongoing digitalization of business models. In addition, many developments have an evident relationship with sustainability topics and circular economy concepts (e.g., renewable raw materials, renewable energy, carbon capture & utilization, biorefineries, bioplastics). On the one hand, these disruptive changes offer opportunities in new growth areas for chemical companies. On the other hand they also pose challenges.

They have a massive influence on technologies, product portfolios, structures of value creation, and business models in the chemical industry, as well as on its clients and suppliers.

Process technologies

Examples of disruptive changes in process technologies can be found in biotechnology and the utilization of renewable sources of energy. The advances in industrial biotechnology will lead to an increased and more efficient application of biological raw materials in production processes (biologization of chemistry). In the medium term, the production of chemicals from electricity, hydrogen, and CO_2 will gain in importance. The chemical sector can play a key role here in linking the energy and industrial sectors by making use of supply peaks in renewable energies to manufacture synthetic raw materials, thus reducing the share of fossil resources.

Product portfolios

An example of fundamental change in demand structures is the increase in electro mobility, which causes demand to decline for many chemical products from catalysts to heat, oil, and gasoline-resistant plastics, as well as oil and fuel additives. At the same time, new business segments are opening around electric engines such as battery technology and battery recycling. Additionally, the demand for lightweight materials increases.

Business models

The digital transformation can also change whole value creation structures. Depending on the scope of the disruptive change, chemical companies will then need to redefine their customer relationships or business models (examples in the following chapter).

The digital transformation of the chemical industry

Digitalization offers an opportunity for chemical companies to collect extensive data in their own businesses, then evaluate and utilize it to improve operational processes within the company. The chemical industry is comparatively well-developed in this area, especially its continuous and discontinuous production processes, as well as its business processes. However, due to new technologies and a systematic collection of large data volumes (digital bulk data, e.g., on customer behavior and preferences, utilization of products, environmental properties of products), digitalization opens new opportunities to make further improvements in the efficiency of processes and operating models, and to develop new business models. In future, data utilization will therefore become more and more important for value creation in the chemical sector. It can be split into three categories:

Transparency and digital processes

...as the first category, include the collection and initial utilization of comprehensive process data within the company. These lift efficiency potentials in the context of largely unchanged manufacturing and business models. Even in an industry that is already comparatively advanced in this respect, digitalization offers new technologies for progress, for example, by further automating manufacturing processes.

Data-based operating models

...intensively utilize operational big data, external data (e.g., about the behavior of markets, customers, and competitors), and advanced methods of analysis for making decisions and increasing efficiency. The industry is currently driving developments in areas like predictive maintenance, networked logistics, and the application of concepts from virtual reality and advanced simulation ('in-silico') for research.

Digital business models

...describe value creation structures that fundamentally alter existing processes, products, or business models. What differentiates them is that products and services are digitally augmented to increase customer utility. Often, this is not created by an individual company, but within digital networks in which different providers join to generate solutions for their customers. Customers are often actively involved in this process, enabling them to specify their individual requirements. The combination of digital services with products from the chemical industry in the digitalization of agriculture, in additive manufacturing (3D printing), and in e-health concepts in the health sector are examples of current developments in this area.

The industry currently finds itself in a phase of change and development. Digital processes and data-based operating models are applied more frequently. Half of small and medium-sized chemical companies (SME) intend to invest extensively into the digitalization of their processes and business activities. Likewise, the importance of digital business models to the future viability of the German chemical industry has been recognized, and digital business models are undergoing dynamic expansion: 30% of chemical SMEs in Germany already achieve 5% of their revenue through digital business models, and a further 40% intend to introduce digital business models in future years. Over the next three to five years, chemical companies are planning to invest a total of more than a billion euros in digitalization projects and new digital business models to achieve this. Digitalization will therefore become an integral part of the business and success model of the chemical industry.

Chemistry 4.0 | The digital transformation of the chemical industry

Digital case examples in the chemical sector

Data-based operating models

1. The further development of ‘in-silico’ experiments aims at simulating larger chemical systems with regard to quantity, foresight and scalability. Advances in quantum computing technologies, in analysis methods such as the atomic force microscope, as well as in machine learning are intended to make these possible. Based on these insights, companies can digitally conceptualize materials with the required chemical, electronic, and physical characteristics, and determine an economically and ecologically efficient manufacturing route.

2. In predictive maintenance, sensors collect realtime big data about the current operating status, with which specifically developed algorithms predict machine failures as well as their cause. In this way, production losses can be avoided through appropriate maintenance measures, significantly reducing the costs and time required for maintenance.

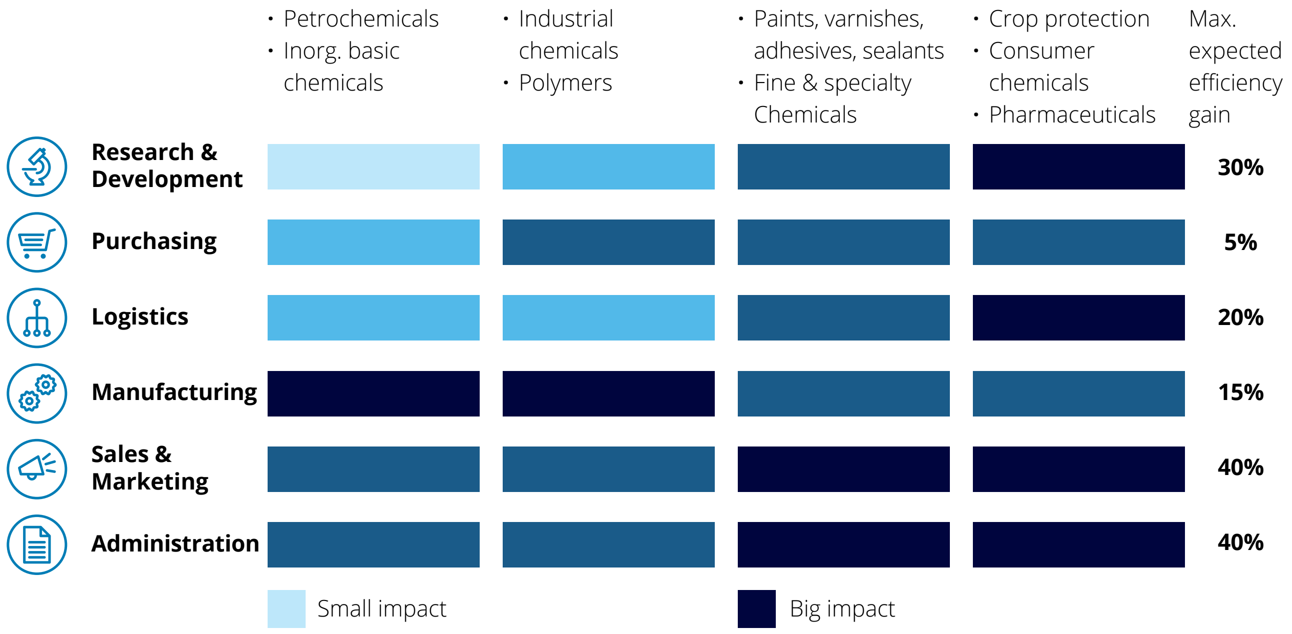
Digital business models

1. In digital agriculture, established companies from the chemical, agricultural and food processing industries form an economic network with new providers, which enable a realtime analysis of weather, soil, plant, and machine data, as well as realtime optimization of agricultural processes. Field View by Climate Corp. is an example of a digital business model in the chemical industry in this network. The platform collects and analyzes images and data about weather and soil conditions to calculate the optimum use of fertilizer, seeds, and crop protection for the farmer.

2. A number of established companies and start-ups are crowding into all areas of additive value creation, e.g. into hardware manufacturing, software development, service provision, and material manufacturing. Such as BASF: the company is working with HP to offer customers novel materials for 3D printing through the Multi Jet Fusion Open Platform. Customers can directly contact BASF via the platform to commission the development of materials for specific 3D applications.

The potential for increasing efficiency through digital processes and data-based operating models differs depending on the specific segment of chemical industry. In upstream segments of the value chain, close to raw materials and energy, efficiency gains in manufacturing come into effect, for example through remote-controlled, preventative, and proactive maintenance and the corresponding operation of plants. In downstream segments, closer to the customer, efficiency gains lie more in the improvement of sales, marketing, and administration.

Overview of implications of digitalization



The chemical industry's key role in the circular economy

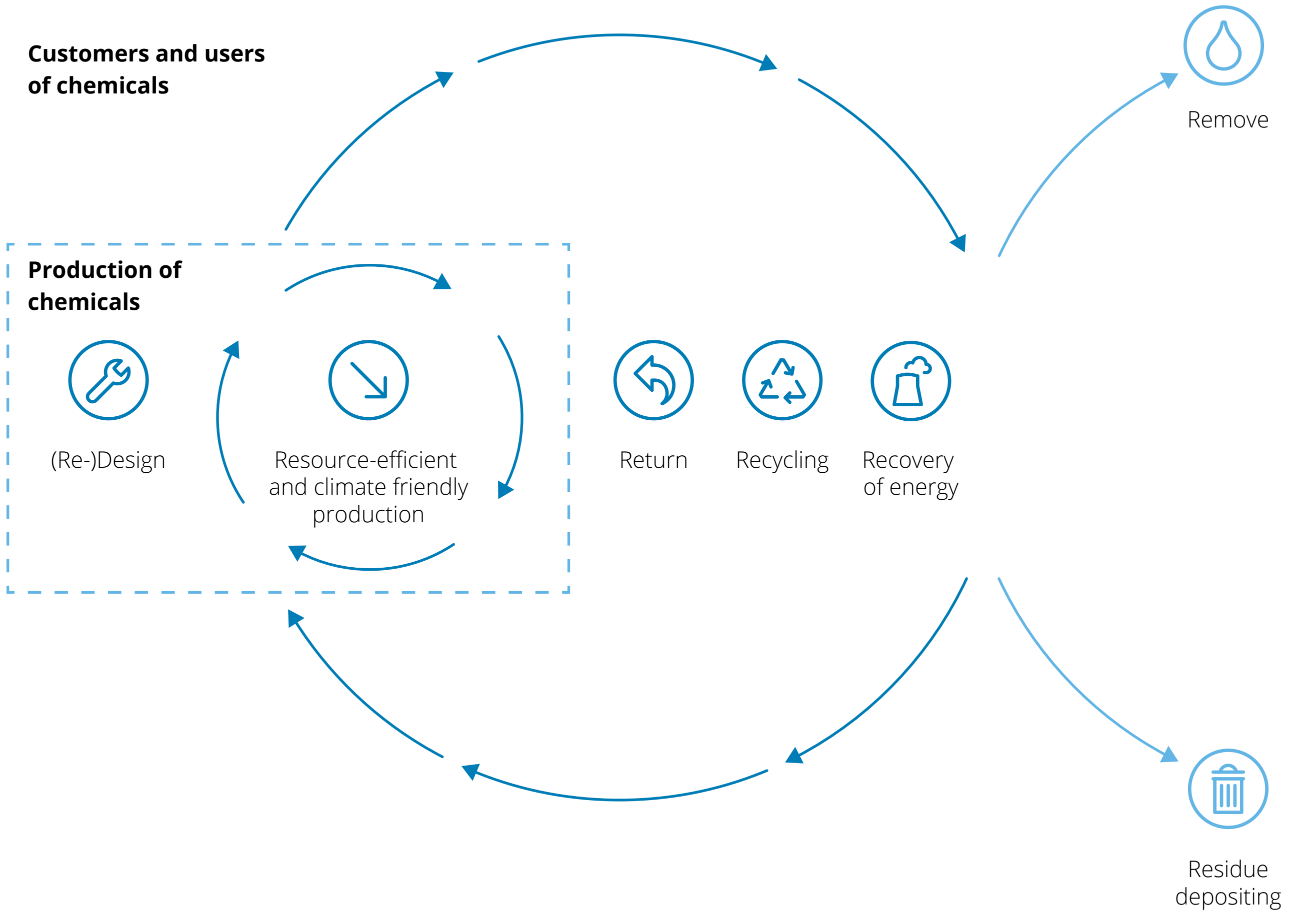
The change in public preferences toward sustainable production and consumption requires the development of new products and business models. In a circular economy, the chemical sector can utilize growth potentials: for example by supporting customers in reaching their sustainability targets or extending their core business with new circular business models, such as chemical leasing. Circular economy requires rethinking: the focus here is less on volume, and more on application utility and value-based pricing.

In this study, the circular economy concept encompasses all contributions toward saving resources (such as raw material base and ecological systems) and includes the following measures:

- Increasing resource efficiency at all levels of the value chain (suppliers, chemical industry, customers)
- Extending the lifespan of products and components, as well as reducing resource consumption in the application phase
- As far as possible, closing cycles by reusing, recycling, energetic utilization, and biological degradation, as well as maximally efficient utilization of residual materials

Accordingly, seven levers can be distinguished for activities in a circular economy (see diagram).

Seven circular economy levers ("Rs") in the chemical sector



Chemistry 4.0 | The chemical industry's key role in the circular economy

It is a task, a challenge, and an opportunity for chemical companies to take all aspects of the circular economy over the whole product life cycle into account. This begins with the production of base chemicals and extends over subsequent refining steps to the utilization phase of the (end) product. Options are avoiding waste by multiple usage, as well as higher efficiency through the utilization of byproducts, waste materials, and CO_2 as raw materials (Waste-to-Chemicals and Carbon Capture Utilization). Additional possibilities are chemical recycling (also called feedstock recycling), biodegradability as CO_2 cycle, and climate protection through "biologization of chemistry" (use of industrial biotechnology, genome editing for precision breeding, biorefineries, and the utilization of renewables as raw materials).

Following this broad definition of circular economy, the chemical sector delivers an increasing quantity of application examples (see p.18).

Chemical companies are actively involved in sustainability and circular economy: all of the large companies analyzed in this study regard sustainability as an important aspect of their corporate strategy, and the concept of circular economy has entered corporate strategies through the levers mentioned above. Sustainability and circular economy are also very important to small and medium-sized enterprises. Over 20% of respondents are looking closely at the effects of a circular economy on their company. Just under 40% of the companies already have a sustainability strategy, and another 25% plan to introduce one in the coming years.

At a sector level, the chemical industry in Germany has already started a number of sustainability initiatives. Of particular importance in this context is the German chemical industry's Chemie³ sustainability initiative.

Digitalization and circular economy represent key future topics in the Chemistry 4.0 era in Germany. Above all, the interplay between the two aspects holds particular potential.

Circular case examples from the chemical sector

(Re)Design

Carbon fiber-reinforced composites can replace steel and aluminum in various vehicle components and reduce the weight of these components by up to 50%. This results in reduced fuel consumption and CO_2 emissions. The advantages over the lifetime of the vehicle outweigh both the disadvantages from higher energy consumption in the production of composite materials and the fact that these cannot be optimally recycled yet. The overall balance of this "Design-to-Performance" is therefore positive.

Resource-efficient production

Since 2016, Covestro replaces 20% of the crude oil usually required in polyurethane manufacturing with CO_2, which is generated by other production processes. Production capacity currently amounts to 5,000 tons of polyol per year. This is an example of climate-protecting and resource-efficient chemical manufacturing.

Return

SafeChem offers its customers a leasing model for solvents, together with manufacturers of cleaning machines, chemical dealers, and waste disposal companies. Through its portfolio in surface and textile cleaning, SafeChem has been able to achieve a reduction in the proportion of solvents in waste water by up to 80%, a reduction in the health risk for employees, and a reduction in the quantity of the newly required solvent by up to 80%.

Recycling

An example of chemical recycling is the Waste2Chemicals initiative. This is a consortium of 8 international companies, including Enerkem, Air Liquide, and AkzoNobel, which intend to begin a joint production of bio-based methanol and ethanol from municipal waste. The technology is compatible with existing waste infrastructure and is intended to enable wastes that cannot be mechanically recycled to be converted into fuels and high-quality chemicals via synthesis gas.

Mutual enhancement between digitalization and circular economy

In all aspects of circular economy, the generation and analysis of digital mass data play an increasingly important role, as does exchanging data. Numerous technological options in the areas of connectivity, computing, and manufacturing technology affect the interface between digitalization and circular economy. Digitalization can thus enable the development of circular business models, accelerate them, and make them more efficient.

The following approaches can serve as examples:

(Re)Design

Detailed, digitally collected and evaluated utilization patterns and specific data on environmental effects enable an improved, data-supported product design to enhance product performance and durability, and utility for the customer.

Resource-efficient production

Detailed and comprehensive insights into production processes as well as the analysis of process information and process simulation enable optimized processes and plant utilization with minimal application of resources. Advanced manufacturing technologies like modular production and robotics allow an increase in efficiency and in the degree of automation.

Return

The analysis of internal and external customer data (for example from social media via 'Social Listening') enables the identification of those cases in which a take-back business model holds advantages - for both customers and chemical companies. To do so, for example the consumption of chemicals over time is analyzed in comparison with other customers and set in relationship to other available information. By using customer data, e.g., through sensors in their manufacturing plants, chemical companies can draw conclusions about their products and recognize when they need to be replaced.

Recycling

Digital traceability and innovative processes, e.g. through modern sorting technologies, create transparency about material information. Recycling is made easier by efficient harmonization of waste capture and logistics, sorting and/or treatment, and subsequent utilization.

Recycling – digital marketplace

The Materials Marketplace, a digital marketplace initiated by the US Business Council for Sustainable Development, is one example of efficient harmonization. Excess raw materials, industrial by-products, and packaging can be offered through a cooperation platform and be bought by participating companies. During the pilot phase, 23 companies from various industries participated, including four in the chemical and advanced materials sector, which listed 150 materials (2.4 million tons).

Recycling – digital transparency

Digital tracking is already in effect in the construction industry, where complex supply chains and long product life cycles are characteristic. Building Information Modeling (BIM) captures all relevant building data and materials digitally across the various partners in a 3D building model. The transparency thus generated about the materials and chemicals in construction waste enables the optimization of its recycling.

Chemistry 4.0 | Mutual enhancement between digitalization and circular economy

These examples reveal that there are significant parallels in the structures of future digital and circular business models. A significant commonality between circular and digital business models is that several companies deliver an extensive range of goods and services to their customers within network-structures. Companies that want to be successful therefore must combine technical and network competencies to develop innovative solutions and successfully establish these in complex and dynamic networks in the market.

In principle, chemical companies already have a high degree of network readiness and ability, because they have been operating in a complex environment from the start: they run complex manufacturing networks at integrated production sites or chemistry parks, and deal with a large number of different suppliers and customers in a broad range of customer industries.

However, the opportunities inherent in digital economic networks are not yet being fully exploited by the chemical industry. To better develop these opportunities, chemical companies not only need to recognize the development and dynamics of economic networks at an early stage, but also identify the role of their own company in these structures (see box) and organize themselves strategically. For many companies, these complex economic networks with new partners from other sectors are still unknown territory, characterized by uncertainties and risks.

Roles in an economic network

Followers contribute to the network but little differentiates them from other suppliers. To followers – e.g. cost leaders within their product line – an economic network offers the advantage of easier customer access without their own sales network and the chance of integrating themselves and their range of products and services in an end-to-end solution.

Partners are companies with more influence and a higher share in value creation. A partner delivers a substantial and specific value contribution, for example due to a particular competence, good customer access, or a special product.

An **Orchestrator** provides central coordination between the various players and their value contributions - a function that is required in complex and multi-layered networks. Besides delivering own services, the orchestrator analyzes both customer requirements and critical success factors, and designs the network in such a way that it can supply a competitive product.

Recommendations

The chemical industry must face the profound technical, economic, and social changes. Companies should scrutinize their current portfolio of products and services and adjust their business models. The chemical industry should continue and accelerate the transformation process that has begun, both as a sector overall and on company level. Political decision makers are called upon to support these efforts with adequate industrial policy and to create globally competitive framework conditions for the chemical industry. Only then will the chemical industry as a core industrial sector be able to make its contribution toward retaining and strengthening Germany as an industrial location in the long term.

Recommended actions for companies and associations

Set strategic goals

Digitalization and circular economy offer new, not yet established growth options, frequently in economic networks. The future significance of both topics demands that the chemical sector in Germany looks even more closely into recognizing disruptions, as well as identifying, assessing, and introducing digital and circular business models early on. Chemical associations can help companies to systematically identify these opportunities and support them by exchanging between them. Companies must define digitalization, the circular economy, and innovation as integral parts of their corporate strategy, and consider the interactions between these. Business models developed by economic networks require extensive analysis of incentive structures, value contributions, and compensation structures, on the basis of which chemical companies should identify their best strategic role.

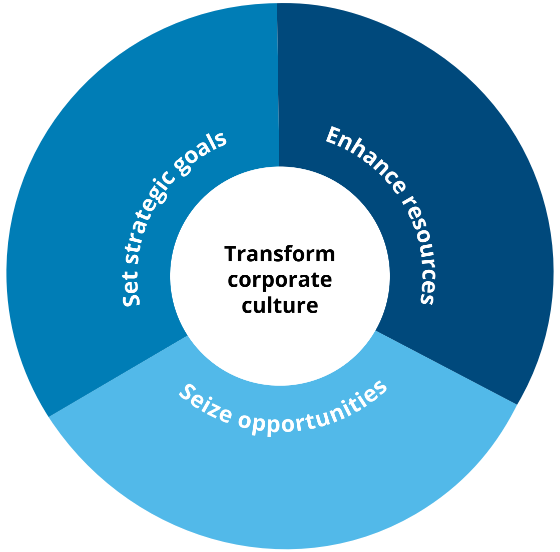
Recommended actions for companies and their associations

Set strategic goals

- Anticipate disruptions
- Make digital and circular an integral part of corporate strategy
- Amend decision criteria

Seize opportunities

- Ideate freely
- Utilize economic networks
- Establish co-operations and platforms
- Develop new concepts for participation



Enhance resources

- Company structure
- Competences
- Investments

Transform corporate culture

- Transparent and open
- Agile and tolerant
- Collaborative and communicative
- Act multi-modal

Transform corporate culture
The successful development and scaling of new business models for digitalization and circular economy, in particular at the interface between both fields, requires corporate cultures that resemble start-ups. Innovation cycles are becoming shorter, and new products and business models must be implemented in an agile and timely way. Important building blocks of the required company culture are transparency and openness, agility and failure tolerance, and a culture of cooperation and communication even across company boundaries.

Large parts of the business model of the chemical industry are based on protecting intellectual property. This is a potential obstacle for a rapid cultural shift toward openness and cooperation across company boundaries. It is important here to debate openly. Associations should actively support the transformation in the sector's culture.

Enhance resources
Digital and circular business models require additional skillsets; in particular, technical and network competencies will gain in importance. The chemical industry is in a good starting position, as its core business is characterized by complex value creation and Verbund structures, as well as cooperation between large companies and SME specialists. However, these resources must be augmented requiring high investments in education, physical assets, and

software. Existing competencies need to be complemented via continuous training measures that are appropriate to requirements and target groups, and targeted employee recruitment should be used to overcome existing barriers and fully exploit growth opportunities. This requires attractive employer positioning of the chemical sector. In order to meet the challenges of digitalization in its work environment, the chemical sector should continue with its social partnership dialog, WORK@industry4.0, in which it is developing a joint understanding of the challenges of and recommends actions for designing the future of work in the chemical industry.

Seize opportunities
Digital and circular business models demand extensive cooperation and economic networks within the chemical sector, but also across industries. Through its associations, the chemical sector can promote the development of platforms for knowledge sharing and initiating partnerships within the industry, position itself as an open and attractive partner for start-ups and technology companies, and expand research collaborations. Chemical associations should additionally develop sets of criteria (Best Practice analyses, toolboxes, guidelines) for adequately evaluating circular and digital business models and implementing them in companies.

Many people are afraid of digital and circular transformations, not least because of the great speed and complexity of change. The chemical industry should take these fears seriously and explain the advantages that innovations bring in order to seize the opportunities of digitalization and circular economy. Beyond intense communication, associations and companies should open their innovation development for stronger participation in by governments and other public interest groups. Thinking and acting in networks, a prerequisite of success in digitalization, should also apply to co-operation with stakeholders in society. Associations and companies should develop new participation concepts to achieve this.

Recommended political and regulatory conditions

Governments should support the efforts of companies and associations with policy measures that promote digitalization and circular economy in Germany. The goal: to create globally competitive conditions for the German chemical industry.

Support digital education
The target-group specific dissemination of digital competencies that match requirements within professional and academic education and training is a success factor for the German economy. Governments can support this knowledge-building by creating suitable framework conditions and infrastructures for teaching digital skills in schools and universities. Universities also need to be open to offer extra-occupational training.

Expand technical infrastructure, improve data security, review data protection rules
Fast and stable internet connections that can provide a broad network to companies, suppliers, customers, and employees, are urgently required. Broadband provision must gain speed, the corresponding infrastructure should achieve full regional coverage by 2025. Alongside this, the expansion of technical infrastructure must be accompanied by the development of a high-performance IT security network between government agencies, companies, and research facilities in Germany and Europe. It should be assessed to what extent data protection measures could impede the development of end user-oriented, individualized business models, and whether adjustments to data protection laws are possible and required. Machine data must be usable to the extent that innovations in the development of products and services are not hampered. Here, contractual agreements on the use and the secure handling of data are preferable to statutory (ownership) regulations.

Promote cooperation and unbureaucratic development of platforms
The public sector should support the development of the necessary network structures and the establishment of cross-industry platforms and innovation clusters for knowledge sharing. What is important here is equal consideration of all sectors, thus recognizing and utilizing all synergies as fully as possible.

Initiate dialog on the necessity of and perspectives on digitalization
Governments should take fears about digitalization seriously and initiate dialog with citizens. This should be supplemented with online forums and accompanying public relations measures on the topic of digitalization. It is important to show that although digitalization requires an ongoing process of change and adaptation, it is also capable of increasing macroeconomic productivity, supporting a self-determined life, and enabling sustainable living. There is a close relationship to Germany's demographic problems: digitalization is an important component in overcoming the economic problems of demographic change in Germany.

Understand circular economy as an integrated and open approach
Circular economy provides efficiency gains at every level of value creation and in the whole product life cycle through the seven levers outlined above. Detailed feasibility analyses are needed to determine which levers can be utilized in individual cases. These should be carried out depending on technical options and take into account environmental, economic, and social aspects. The existing regulatory framework needs to be reviewed for any obstacles impeding expanding circular economy concepts.

Raise public awareness for circular economy
Circular economy cannot be successfully established without the joint efforts of all business sectors as well as consumers. Governments should therefore promote fundamental knowledge of the content of circular economy through relevant dialog and educational offers on a societal level, and be transparent about objectives and costs.

Expand innovation support
Political support measures should accompany the paradigm change in the chemical industry and its customer industries. Investment in future-oriented fields should be stimulated through research funds open to all companies in the form of project funding plus additional tax incentives, start-up finance for novel projects in the circular economy, easier access to venture capital, as well as support for start-ups and private-public partnerships, for example as pilot projects. Such measures would meet the needs of the new dynamic business environment.

Review regulatory framework
In view of the dynamics and openness of current developments in the digital and circular economy, it is important to allow for leeway to act. Government should aim to harmonize laws and regulations throughout Europe and across industries, dismantle contradictory or redundant rules, and reduce regulatory uncertainties through consistent, integrated legislation with high transparency regarding future framework conditions. New and existing regulations should be placed under scrutiny in an 'innovation check', in particular regarding whether and to what extent they support or hamper innovations and enhancements and/or the development of new business models.

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