Digital Transformation Initiative
Chemistry and Advanced Materials Industry

In collaboration with Accenture

January 2017
The Digital Transformation Initiative

The Digital Transformation Initiative (DTI) is a project launched by the World Economic Forum in 2015 as part of the System Initiative on Shaping the Future of Digital Economy and Society. It is an ongoing initiative that serves as the focal point at the Forum for new opportunities and themes arising from latest developments in the digitalization of business and society. It supports the Forum’s broader activity around the theme of the Fourth Industrial Revolution.

To find out more about the DTI project, visit http://reports.weforum.org/digital-transformation
Foreword

Digital transformation is emerging as a driver of sweeping change around the world. Connectivity has shown the potential to empower millions of people, while providing businesses with unparalleled opportunities for value creation and capture.

The Chemistry and Advanced Materials industry played a leading role in previous industrial revolutions, through its products and innovations, in areas such as pharmaceuticals, plastics and consumer electronics. Today, the Chemistry and Advanced Materials sector is an important enabler of the Fourth Industrial Revolution. Its contributions allow other sectors to turn ideas and innovations into sophisticated products supporting digitalization. But the industry itself is also being transformed through digitalization. Digitalization helps increase productivity and safety across the industry’s value chain and supports the design of new offerings. Further, the industry needs to closely monitor pockets of digital disruption.

While it is clear that digitalization will be a source of transformational change across industries, a number of challenges must be overcome. In many cases, the gains from digitalization have been inequitable, with the benefits not reaching those who need them most. At the same time, the exponential increase in global information flows has created new risks around data privacy and security, and businesses across sectors are grappling with challenges related to changing customer expectations, cultural transformation, outdated regulation and skill shortages. The World Economic Forum is committed to helping leaders understand these implications and supporting them on the journey to shape better opportunities for business and society.

In 2015, the Digital Transformation Initiative (DTI) analysed the impact of digital transformation on six industries (automotive, consumer goods, electricity, healthcare, logistics and media) and on three cross-industry topics (digital consumption, digital enterprise and societal implications). In 2016, the initiative was extended to cover seven additional industries, including Chemistry and Advanced Materials, and two new cross-industry themes (the platform economy, and societal value and policy imperatives). Through its broad focus, the DTI has driven engagement on some of the most pressing topics facing industries and business today and provided business and policy leaders with an informed perspective on how to take action.

This White Paper was prepared in collaboration with Accenture, whom we thank for its support. We also express our gratitude to the Steering Committee and the more than 30 experts from industry, government and academia who were involved in shaping this project’s insights and recommendations.

We are confident that the findings will contribute to improving the state of the world through digital transformation, both for business and society.

Fernando J. Gómez
Head of Chemistry and Advanced Materials Industry
World Economic Forum

Bruce Weinelt
Head of Digital Transformation
World Economic Forum
Executive Summary

At the heart of the Fourth Industrial Revolution

The Fourth Industrial Revolution combines advanced technologies in innovative ways, dramatically reshaping the way people live, work and relate to one another. As in previous industrial revolutions, the Chemistry and Advanced Materials industry is playing a major enabling role. It is largely through the industry’s contributions that other industries can turn their ideas and innovations into sophisticated products: touch screens, rechargeable batteries in portable devices, organic light-emitting diodes in flexible electronics and lightweight materials used to build drones, among many other examples.

At the same time, the Chemistry and Advanced Materials industry is itself being transformed through digitalization. The industry has embarked on the digitalization journey, broadly seeking opportunities to benefit from digital technologies in areas such as operational excellence or the extension of traditional product offerings with digital components. The sector is closely monitoring pockets of digital disruption, including digitally accelerated biotech enabling the direct-route production of chemicals, or disintermediation by platform or marketplace players. Though the timing and scale of disruptive impact are hard to predict, the industry is aware that these developments could fundamentally change the sector and its rules of engagement.

Digital themes

Research leading to this White Paper identified three digital themes that are expected to have a profound impact on Chemistry and Advanced Materials companies, as digitalization transforms the industry over the next decade:

- **Digitalize the enterprise.** Digital technologies are already making the industry’s operations more efficient. Advanced digital technologies, such as the Industrial Internet of Things (IIoT), automation, analytics and artificial intelligence, will take core operational functions, including R&D, manufacturing and supply chain, to the next level and will augment workforce capabilities.

- **Go beyond the molecule.** Digitalization presents the Chemistry and Advanced Materials industry with opportunities to launch new digitally enabled offerings, create outcome-oriented business models and improve customer interaction.

- **Collaborate in ecosystems.** Accelerated innovation cycles will drive the industry to build flexible and interconnected innovation ecosystems. Intense collaboration and data sharing along the value chain will help to better address customers’ requirements and manage volatility.

Putting a value on digital transformation

To estimate the value of digital transformation, the value-at-stake methodology was applied. This methodology assesses the impact of digital transformation initiatives on the industry, customers, wider society and the environment. It provides value estimates of global industry operating profits at stake from 2016 to 2025, and the contribution to societal value that digital transformation can make in that time frame. The key findings from the analysis of the Chemistry and Advanced Materials industry include:

- Across value migration and value addition to the industry, the estimated cumulative economic value for the period 2016 to 2025 ranges from approximately $310 billion to $550 billion.

- In terms of non-economic benefits, digitalization has the potential to reduce CO\textsubscript{2} emissions by 60-100 million tonnes, save 20 to 30 lives and avoid 2,000 to 3,000 injuries over the next decade.

The primary aim of the value-at-stake framework is to highlight trends and areas where digitalization can make an impact, rather than provide precise value estimates. It is important to understand that value estimates relate to future developments and are based, with varying degrees of certainty, on assumptions about technology adoption curves, benefit ranges and multiple other parameters. The intention is that the value-at-stake framework can start a discussion about the potential for digitalization to create value for the industry and society. The analysis is both an art and a science, with room for further iteration and refinement, aiming to provide a baseline and a common language for a private-public dialogue. The goal is to initiate and trigger a multistakeholder dialogue and engagement around the societal impacts of digital technology in order to build a digital revolution that serves all.
Challenges to digitalization

Digital leaders in the industry do not generally feel hindered in designing and implementing their digital transformation. Nevertheless, common challenges related to digital implementation exist:

- **Workforce, organization and technology.** Competing in the digital era requires complementing workforces with digital skills, and managing opportunities and changes in working style and the type of work performed by the existing workforce – across all levels of the organization. Internal competition with current business’ priorities, data management and the integration of information and operational technology are examples of organizational and technological challenges to be addressed.

- **Cybersecurity.** Managing cybersecurity is considered as an imperative – and a challenge. Digitalization heightens vulnerability to cyberattacks, and protecting a growing array of connected hardware, software, networks and platforms is becoming increasingly complex.

- **Ecosystem collaboration.** Digital leaders need to address concerns about intellectual property protection, data ownership and privacy to access the full power of ecosystem collaboration.

Key considerations for a successful digital transformation

Unlocking digitalization’s full potential requires resourcefulness, creativity and a willingness to embrace constant and rapid change. The research for this White Paper highlighted key areas that leaders should consider as they shape and implement their digital transformation journey:

- **Prepare your organization.** Driving and implementing a digital strategy, with direct support from board-level executives, are key to successful digitalization. Digital transformation is not just about the technology; digital leaders should consider and manage it as an ongoing culture change effort, across all levels of the organization. Companies should also rethink their competency requirements and supplement their workforce with digital skills.

- **Ensure cybersecurity.** Due to the increasing threat of attacks, appropriate attention should be paid to cybersecurity, and it should be firmly included in digital strategy roadmaps. Further, it requires bolstering with sufficient investment, skills and capabilities.

- **Define your role in ecosystems.** Chemistry and Advanced Materials companies should work on identifying and understanding network partners, dynamics in the network, and the role they want to play within the relevant innovation, supply and distribution, and offering ecosystems. Digital leaders should instil appropriate governance for ecosystem collaboration to balance steering, privacy and collaboration requirements.
Industry and Digital Context

The Chemistry and Advanced Materials industry is again playing a lead role in an industrial revolution – on this occasion, a digital one.

a. Enabling the Fourth Industrial Revolution

This White Paper focuses on how digitalization is transforming the Chemistry and Advanced Materials sector, but it should also be acknowledged that the sector’s products are a major enabler of digitalization itself.

The Chemistry and Advanced Materials industry played a leading role in previous industrial revolutions. It has supported the innovations – pharmaceuticals, plastics and consumer electronics, to name just a few – that have transformed our societies over the past 150 years. Today, the industry is again at the heart of an industrial revolution – on this occasion, a digital one – that is dramatically reshaping the way people live, work and relate to each other. The industry’s central role in this upheaval, which has been described as the Fourth Industrial Revolution, stems in part from the immense scale of the Chemistry and Advanced Materials sector (see Figure 1) and its integration into many aspects of our everyday lives.

Figure 1: The Vast, Global Chemistry and Advanced Materials Industry

<table>
<thead>
<tr>
<th>Everyday products containing chemicals</th>
<th>~100,000 Chemicals on the market today</th>
</tr>
</thead>
<tbody>
<tr>
<td>~10 million People employed in the industry</td>
<td>~2% Contribution of the industry to global GDP</td>
</tr>
<tr>
<td>$3.5 trillion Chemical sales in 2014</td>
<td>$6.9 trillion Forecast chemical sales in 2030</td>
</tr>
</tbody>
</table>

Sources: World Economic Forum/Accenture analysis; European Chemical Industry Council; press research

The industry is an important enabler of the Fourth Industrial Revolution. It is largely through its contributions that other sectors can turn their ideas and innovations into sophisticated products. As the examples in Figure 2 show, materials are what make the virtual real.


**Figure 2: Chemistry and Advanced Materials: Enabling the Digital Revolution**

<table>
<thead>
<tr>
<th>MOBILITY</th>
<th>Electric vehicles</th>
<th>Growth rates for key innovations</th>
<th>Examples of relevant products from Chemistry and Advanced Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOBILITY</td>
<td>Drones</td>
<td>Annual sales of electric vehicles</td>
<td>Plastics, composites and battery technologies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2020: 4.9 million</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MOBILE &amp; SMART DEVICES</th>
<th>Smartphones and tablets</th>
<th>Mobile devices in use</th>
<th>Plastics, composites and battery technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2015: 8.6 billion</td>
<td>Substrate, backplane, transparent conductor, barrier films and photoresists</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2020: 12.1 billion</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MOBILE &amp; SMART DEVICES</th>
<th>Flexible displays <em>(e.g. wearable devices, VR, TVs)</em></th>
<th>Market for AMOLED** displays</th>
<th>Substrate, backplane, transparent conductor, barrier films and photoresists</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2016: $2 billion</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2020: $18 billion</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CONNECTIVITY &amp; COMPUTING</th>
<th>High-speed internet</th>
<th>Fixed broadband speed</th>
<th>Chlorosilane for ultrapure glass</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2015: 24.7 Mbps</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2020: 47.7 Mbps</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CONNECTIVITY &amp; COMPUTING</th>
<th>More efficient and smaller integrated circuits</th>
<th>Processor logic gate length</th>
<th>Dielectrics, colloidal silica, photoresists, yield enhancers and edge-bead removers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2015: 14mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2019: 7mm</td>
<td></td>
</tr>
</tbody>
</table>

* Defence, commercial and homeland security sectors  ** Active-Matrix Organic LED

**Example: Chemicals Making the Internet Faster**

High-speed transmission of data is the backbone of the information age. Governments see powerful broadband networks as a great opportunity to increase economic growth. Fibre-optic network technologies are replacing copper cables and taking broadband technology to the next level. Chlorosilanes are a good example of how chemicals determine product performance: light signal transmission in fibre-optic cables is only possible over long distances with ultra-pure glass. Chlorosilanes in the cables deliver the fibre-optic properties needed for fast, trouble-free data transfer. Chemistry and Advanced Materials companies, such as Evonik Industries, provide the chlorosilanes for this technology.²

Whereas the role that some industries play in enabling digitalization is readily noticeable, the important contribution of the Chemistry and Advanced Materials sector is less well recognized. Closing this gap in recognition should be food for thought for the industry and could help it forge a stronger identity in the digital world.

**b. Digital in the industry context**

The impact of the digital revolution is being felt both inside and outside the Chemistry and Advanced Materials industry. The sector is itself being transformed through digitalization. New technologies are being applied across the industry’s value chain; digital natives are entering the sector; the digitalization of customer industries is generating shifts in demand; and the industry should closely monitor pockets of digital disruption.

A recent survey revealed that Chemistry and Advanced Materials executives strongly believe in the transformational effect of digitalization on their industry.³

**94%**

Percentage of executives who expect digital to revolutionize the industry

**87%**

Percentage of executives who say that firms that don’t embrace digital will lose their competitive edge and possibly face extinction

In the following section, the digital technologies that are most relevant to the sector are described, how the industry approaches digitalization is examined, and its expected impact on the sector is assessed.

**Digital technologies and the current approach to digitalization**

The application of digital technology has a long tradition in the Chemistry and Advanced Materials industry. Process-control systems and sensors have been used in production for decades. So, the industry is not starting its own digital transformation from zero, although factors differentiate the current period.
Today, rapid advances in technology and falling prices offer unprecedented opportunities to apply digital technology in almost any aspect of a business. The industry can draw on a sophisticated toolbox of digital technologies to further advance its digitalization agenda: for example, applying analytics and artificial intelligence in the R&D context.

Further, the value that digitalization can help create for the industry and wider society is significantly boosted through the effect of deploying and combining multiple digital technologies. The non-exhaustive overview of technologies illustrated in Figure 3 represents the building blocks for digital themes and initiatives (see next section).

![Figure 3: Selection of Digital Technologies Relevant to the Chemistry and Advanced Materials Industry](image)

Now that it has recognized the potential of digitalization, the industry is exploring effective strategies to further leverage digital technologies. Chemistry and Advanced Materials companies are travelling at different speeds on their digitalization journey: some are formulating or reshaping digital strategies and roadmaps, sometimes as an explicit part of their corporate strategy; some have set up digital incubators or are in the middle of implementing digital projects; others have already finished selected digitalization projects (e.g. in the field of digital plant) or even launched their first digitally enabled offerings on the market.

Responsibility for driving digital agendas in an organization can lie with a variety of roles, ranging from chief digital officers, chief information officers and chief technology officers to dedicated project leads. The digitalization journey often starts at an operational level – on-site or in the supply chains – in pursuit of efficiency gains. Today, digital strategies are also being applied increasingly in the context of customer interactions, to improve collaboration across the value chain and even to define new solutions and offerings or business models.

“A lot of energy and momentum in the field of digital can be observed, Chemicals are catching up. It is not the question if, but rather what and how it will be done.”

Frithjof Netzer, Senior Vice-President, Project Lead 4.0, BASF
The impact of digitalization on the industry

The question is not whether the Chemistry and Advanced Materials industry will be changed through digitalization, but rather at what pace and to what extent the change will happen. Research for this White Paper shows that the impact of digital transformation on the Chemistry and Advanced Materials industry is expected to be twofold (see Figure 4). The industry overall is assumed to follow a rather evolutionary approach to digitalization, with some pockets of digital disruption that – if they gain significant scale – could drastically change the sector.

Figure 4: How Digital Transformation Could Impact Chemistry and Advanced Materials

Chemistry and Advanced Materials incumbents have recognized the potential of digital opportunities, and the reasons to follow an evolutionary approach to digitalization are multiple. The industry offers sophisticated products to many markets with a very broad application range, from adding end-product functionality to making customer production processes more efficient. Digitalization can add value to the overall Chemistry and Advanced Materials offering through, for example, add-on analytics services to identify the most suitable applications, but products will remain the core of that offering. The sector operates in a business-to-business (B2B) environment where long-term commitments and risk minimization play a large role. In this context, the digitalization of customer relationships and business models happens at a different pace than in the business-to-consumer (B2C) world. Finally, the industry is investment- and asset-intense, and safety and liability issues are at the top of the CEO agenda and thus have the highest priority in any operational transformation. With this context in mind, digitalization is expected to transform some key aspects of the way the industry operates, its offerings and its approaches to collaboration:

- **Higher levels of efficiency and productivity.** The sector has a long history of applying digital technologies in its operations. Progress in digital technology offers opportunities to further increase efficiency, productivity and safety throughout the industry’s value chain. Amid high levels of competition and margin pressure, operational excellence is becoming ever more important. In particular, companies with structural cost disadvantages must strive for operational optimization. Digitalization is a promising way to achieve this.

- **Digitally boosted innovation.** Developments driven by resource availability and sustainability demands (e.g. lightweight construction or water management) or by demographic shifts (e.g. ageing populations in some regions generating higher demand for healthcare) mean that the industry must keep innovation rates high. Digital innovation can assist in the design of new offerings and solutions, help boost R&D productivity, and decrease times to market.
Data management and insight generation. Insights generated from data and analytics will form the basis of many digitalization benefits, whether in the operations context or in better understanding customer needs and shaping respective offerings. Access to data, the integration, management, security and analysis of data, and the extraction of the right insights from data are emerging as key capabilities.

Workforce impact. Digitalization is expected to impact the opportunities and type of work available in the Chemistry and Advanced Materials sector, its way of working, and the skill and job requirements across all levels and functions. The growing importance of ecosystems will mean much more work is carried out by distributed and mixed teams. Finally, technology will take an even greater role in upskilling and training employees, and in knowledge management.

Digitally enhanced offerings. These offerings, which complement chemicals and materials sales, are expected to become more important in the industry’s portfolio. For example, digitalization offers opportunities, especially for downstream companies close to end-customer markets, to enhance product offerings with analytics services that improve product performance for customers.

Digital ecosystems. These are expected to grow in importance, as they allow Chemistry and Advanced Materials companies to flexibly complement internal capabilities with external ones. Different types of ecosystems are already emerging to address multiple issues. Innovation ecosystems enable the multiplication of R&D productivity by drawing in specialist capabilities. Supply and delivery ecosystems can better manage volatility across supply chains and increase resilience (which is expected to remain a priority in managing demand and production footprint shifts in customer industries). Offering ecosystems combine critical capabilities from players in different industries to deliver solutions for complex customer problems, instead of “just” products. Digitalization can be considered the glue that holds ecosystems together, for example, through cloud-based collaboration platforms.

Despite a widespread appreciation of digital’s impending impact, several of the interviewees from large Chemistry and Advanced Materials companies did not believe that new entrants or digital disruption would have a deep transformational effect on the industry in the near future. But that is just a snapshot of the situation today. Digital industry leaders well understand the potential of digitally fuelled new entrants, disintermediation and disruption along the value chain. Examples of pockets of disruption are already visible today (see Figure 5), and others could develop faster than expected.

Acceleration of biotech through digital. Biotech start-ups like Zymergen and Synthace use digital technology to enhance R&D. The digitalization of research procedures, data analytics, machine learning and robotics all dramatically increase R&D productivity and speed – and thus the likelihood of breakthrough innovation. For the Chemistry and Advanced Materials industry, this could make the identification of specific microbial strains that enable direct-route microbial-based production of fine and specialty chemicals much more probable (including novel chemicals not present in current production networks).

Figure 5: Examples of Pockets of Disruption in the Chemistry and Advanced Materials Value Chain

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Authors, associations, academia and other stakeholders

SUPPLIERS, SERVICE PROVIDERS

R&D / Laboratory and Innovation

Material Sourcing and Acquisition

Product Manufacture

Inventory Management and Distribution

Marketing and Sales

CUSTOMERS, CUSTOMERS’ CUSTOMERS

Acceleration of biotech through digital

Added value beyond chemicals and materials

Disintermediation

Source: World Economic Forum/Accenture analysis
economically derivable from hydrocarbon feedstocks). Instead of producing speciality chemicals in multiple process steps using multiple input substances and catalysts, genetically modified bacteria could produce speciality chemicals in fewer stages – or even just a single step. This would drastically change production routes, processes, assets and cost structures for fine and speciality chemicals, along with upstream impacts regarding changes in the supply of inputs and feedstock.

- **Added value beyond chemicals and materials.** The plummeting cost and increasing capabilities of digital technologies like 3D printing are enabling innovative and agile start-ups to enter spaces traditionally dominated by incumbents. New players are gaining traction at the customer-facing end of the value chain, as 3D printing becomes a viable alternative for prototype design and – soon – large-scale series production. By fully integrating 3D-printing software, hardware and advanced materials and formulation capabilities, new entrants can provide customized services that offer more than just granulate and additives. New players could set themselves up at the intersection between the sector and customer industries. Chemistry and Advanced Materials companies would still supply plastics and additives, but they could be pushed further away from the customer, losing value-added margins.

- **Disintermediation.** New entrants can threaten chemical distribution approaches and companies by providing B2B platforms similar to Alibaba or Amazon Business, leveraging deep platform, logistics and B2B business knowledge and capabilities. This scenario is more likely for commodity than speciality chemicals, as customers typically expect some formulation expertise and value-added services from distributors of the latter. Advances in artificial intelligence and automation could further open this market to new entrants by, for example, enabling them to take over some basic application consulting tasks.

The need for chemicals and materials in modern economies will always exist. But digitally fuelled disruption raises fundamental questions of how chemicals and materials will be produced and distributed, which parts of industry margins will be generated by product-only and added-value offerings, and what the competitive landscape and margin distribution will look like across the value chain and its participants. There naturally is a lot of uncertainty about the scale and timing of digital disruption, especially as it can occur fast and be driven by an increasingly heterogeneous group of new entrants. Today, it seems unlikely that digitalization will disrupt the sector and its value chain in the near future (in contrast to industries like travel and hospitality). However, the industry acknowledges its disruptive potential and closely monitors market and technology developments for upcoming disruption.
Future Horizons: Digital Themes and Initiatives

The digital vectors that have the greatest potential to create value for the Chemistry and Advanced Materials industry, its customers and wider society are assessed.

Three digital themes are expected to have a profound impact on Chemistry and Advanced Materials companies, as digitalization transforms the industry over the next decade:

**Digitalize the enterprise.** Digital technologies are already making the industry's operations more efficient. Advanced digital technologies, such as the Industrial Internet of Things (IIoT), automation, analytics and artificial intelligence, will take core operational functions, including R&D, manufacturing and supply chain, to the next level and will augment workforce capabilities.

**Go beyond the molecule.** Digitalization presents the Chemistry and Advanced Materials industry with opportunities to launch new digitally enabled offerings, create outcome-oriented business models and improve customer interaction.

**Collaborate in ecosystems.** Accelerated innovation cycles will drive the industry to build flexible and interconnected innovation ecosystems. Intense collaboration and data sharing along the value chain will help to better address customers' requirements and manage volatility.

Within each theme, digital initiatives (Figure 6) combine technologies that are expected to have a significant impact on the industry’s value chain, its workforce, adjacent industries, the environment and wider society.

Figure 6: Digital Themes and Initiatives in the Chemistry and Advanced Materials Industry

Source: World Economic Forum/Accenture analysis
Digital technologies are already boosting the industry’s efficiency and will further do so across core operating functions, such as R&D, plant operations and the supply chain. They will also augment workforce capabilities and further improve health and safety.

**Digital R&D**

With digital transformation, a lot of the research activities that were happening in test tubes have moved into micro-reactors, micro-fermentation and computer simulations, enabling us to conduct experiments with very small quantities and much more efficiently over broad parameters.

Pramod Yadav, Co-Chief Executive Officer, Life Science Ingredients, Jubilant Life Sciences

Today’s R&D functions are under pressure to constantly deliver new products to the market – even though blockbuster chemical innovation is becoming harder to find – and to do so at the lowest possible cost.

**Average share of revenue spent on R&D**

- **0.5% to 1.5%**
  - Petrochemicals companies

- **~3%**
  - Commodity chemicals companies

- **~8%**
  - Speciality chemicals companies

Digital technologies can improve all aspects of the R&D cycle:

- **Ideation.** In the ideation phase, tools such as analytics, automatic trend sensing and pattern recognition can be applied to vast amounts of internal and external data, while text analytics can scan social media. This helps companies better understand customer requirements down the value chain and thereby improve the steering of R&D efforts.

- **Experimentation.** Experiments will become cheaper and go more quickly as they move from physical to virtual environments. This is thanks to greater computing power, analytics, artificial intelligence and machine learning that enable scope focusing, digital molecule design, chemical characterization and application simulations. As virtual testing and modelling use fewer physical inputs, such as chemicals, water and energy, the environmental impact is reduced. Using simulations to partly replace or prepare mid-scale and industrial-scale testing avoids the costly blocking of production facilities for setup and test runs.

- **Automation.** Digitalized research procedures, telematics, robots and autonomous systems can handle experiment procedures such as pipetting, diluting, dispersing and even recipe mixing, releasing skilled R&D staff to work on higher-value-adding activities. Smart robots, which learn from their experience of working autonomously in the physical world, are in the early-adoption stage in R&D. Electronic laboratory notebooks and collaboration tools improve and automate procedures and workflows.

**Example: BASF – Using Computer Modelling to Reduce Energy and Waste**

Modelling sits alongside experimentation as an essential part of BASF’s R&D philosophy. Researchers complement experimental work by modelling the underlying physico-chemical processes and simulating experiments using commercial and in-house computational tools. Catalysts and polymer processes are two key areas of interest. One of the applied software solutions is designed to handle the difficult requirements of batch and semi-batch systems. In one project, BASF used it to build a high-fidelity, detailed kinetic model of its batch expanded-polystyrene process, then applied dynamic optimization techniques. The company identified a 30% reduction in batch time, resulting in significant energy savings.

**Example: Zymergen – Bringing Robotics, Proprietary Software and Analytics to Industrial Microbiology**

Zymergen, a Silicon Valley start-up, focuses on the complex field of industrial microbiology. From components in lightweight plastics to improved materials for patient health and on-market commodities, the company has developed more efficient and reliable ways of optimizing microbes for industrial fermentation. It takes a big-data approach, using the latest in software tools, big-data technology and machine-learning techniques to quickly design “custom” microbes to produce basic industrial materials such as plastic. Zymergen’s robots and protocols enable it to build and test thousands of microbe strains with the resources typically required to build and test tens of strains. This platform has enabled the start-up to increase a customer’s net margin by more than 50% in one year and to halve the time to bring new products to market compared with traditional approaches.
Digital plant

“The industrial players will remain conservative during the foreseeable future. They will collect as much data as possible but, in the end, I still believe that the ultimate and important decisions will be made by human beings.”

Michael Hilt, Head, Business Unit Process Industry, Fraunhofer Institute for Manufacturing Engineering and Automation IPA

Chemical plants today are already considered to be highly automated environments. New technologies, however, can take them beyond traditional control systems. Recent Accenture/Independent Chemical Information Service (ICIS) research shows that industry executives increasingly understand the potential value of a digital plant, with more than half identifying “reducing plant operations/costs” as one of their top five business priorities.

Ageing assets are contributing to high levels of unplanned outages, especially in North America and Europe. As this trend develops, pressure is increasing to improve key performance indicators (KPIs), such as availability rates and overall equipment effectiveness, and to reduce costly unplanned downtime (for example, a shutdown at a major cracker in the United States can cost more than $1 million per day).

Average age of ethylene crackers in different geographies

<table>
<thead>
<tr>
<th>Geography</th>
<th>Age (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern Europe</td>
<td>39</td>
</tr>
<tr>
<td>Western Europe</td>
<td>38</td>
</tr>
<tr>
<td>North America</td>
<td>32</td>
</tr>
<tr>
<td>Middle East</td>
<td>12</td>
</tr>
</tbody>
</table>

Applying digital technologies in the plant context helps optimize production processes, improves the reliability of assets and enables remote monitoring and supervision.

- **Optimize processes.** Further automation, advanced process control and optimization enable companies to better balance controllable variables in the production process and thereby improve production results in terms of yield (e.g. first pass yield), quality (reduce total quality cost) and energy consumption. Many companies, for example, can only analyse and assess a set number of batches at a time, which limits their ability to optimize conditions on a broader scale. Applying digital technology enables the monitoring and analysis of hundreds of batches at any given time. Using big data and predictive analytics on broad data sets generates insights that allow enterprises to rapidly control and change operating conditions and variables to improve process quality. Energy monitoring and analytics help to identify energy usage patterns and inefficiencies.

- **Improve asset reliability.** Further digitalizing assets and equipment with, for example, smarter sensors, allows companies to monitor asset condition, process quality, throughput and emissions continuously. Assets can send signals on their status and performance, which, in combination with real-time analytics and in-memory computing, enables immediate intervention to prevent equipment failures and breakdowns. Combining real-time asset condition information with predictive analytics enables companies to predict the likelihood of asset failures and plan maintenance accordingly. Digital asset management and related maintenance strategies can extend the lifetime of an asset and the period between required turnarounds.

- **Enable remote monitoring and supervision.** Transmission of asset and production status information in real time, coupled with decision-support analytics and automation, enables improved remote monitoring, surveillance and steering strategies across Chemistry and Advanced Materials production sites.

To exploit the opportunities that come with the digital plant initiative, certain prerequisites need to be in place: IIoT; connectivity between sensors, assets and control rooms; cybersecurity; and data intelligence, integration and insight generation. For example, today, chemical facilities generate and collect vast volumes of data during the manufacturing process, but only a small amount is being used for more timely decision-making. The challenge is often to structure the data that are available and extract meaningful, actionable insights.

**Example: Solvay/Butachimie – Partnering with Siemens on the “Factory of the Future”**

The Solvay/Butachimie industry platform in Chalampé, France, is one of the world’s biggest manufacturing facilities for polyamide 6,6 and its intermediary products. Solvay and Butachimie have partnered with Siemens to upgrade the production facilities. Using integrated software, digitalization guarantees a trouble-free, continuous exchange of data from plant design through installation, operation and modernization to engineering and cloud-based services. Continuous data updates mean the plant can use a virtual twin – equivalent to the physical plant in every respect – for the simulation and optimization of commissioning, operation and maintenance. A cohesive engineering concept means tasks relating to process engineering, electrical planning and automation technology can be performed simultaneously.
Sadara Chemical Company is an alliance between Saudi Aramco and The Dow Chemical Company. The aim was to build a chemical company with a focus on digital plant operations. The largest integrated chemical complex ever built in a single phase – with 26 state-of-the-art manufacturing units, more than 3 million tonnes of capacity per annum and an investment of about $20 billion – will start operations in 2017. The distributed control system will run more than 50 separate production lines. ABB has supplied the safety systems, instrumentation and electrical equipment, as well as the process analytic hardware that keeps track of chemical reactions. It also provides an enterprise-wide, mobile plant operations management solution that enables personnel to perform maintenance inspections, and operator and quality rounds to capture information in the field with mobile devices and synchronize it with the plant status database.

**Digital supply chain**

As the Chemistry and Advanced Materials industry has become more global and more complex, an effective supply chain has become ever more critical to the efficient, safe and reliable sourcing and delivery of materials, formulas and compounds. Digitalization can bolster supply chains through better sourcing (e.g. supplier usage and spend analytics, virtual malls and supplier portals); supply chain planning (e.g. demand-sensing analytics, digitally enabled supply chain control towers, and dynamic inventory analytics and management); and product management and handling (e.g. advanced warehouse automation).

Digital supply chains are more resilient and flexible. Stock-outs can be reduced, and asset utilization increased through optimized demand and supply balancing. Improved capabilities in demand sensing and dynamic inventory management allow for further automation. Digital technology can also support short- and long-term planning, for example, through inputs such as weather forecasts, commodity prices and real-time order information.

**Example: The Dow Chemical Company – Transportation Risk Management**

Dow Chemical makes approximately 7,000 shipments per day globally and has the largest privately owned railcar fleet in North America. Cylinders are tracked with barcodes and transportation assets with radio-frequency identification, cellular and satellite global positioning systems (GPS). GPS technology on the company’s cars creates a wireless connection with sensors monitoring car security, environmental conditions and mechanical health. Dow also uses cellular GPS technology for intermodal container shipments with sensors that measure temperature, humidity, shock and light. Data flows are transmitted into event management software that can generate rule-based email or text-message alerts to trigger responses to critical events.

**Example: Syngenta – Supply Chain Strategy Leveraging the Power of Fourth-Party Logistics**

Swiss agrochemicals and seeds producer Syngenta’s logistics strategy involves operating model structured around an externalized central operating desk, and facilitated by fourth-party logistics providers (4PL) specializing in logistics execution. A cloud-based solution connects the service providers’ systems and other elements of the 4PL strategy to ensure flexible onboarding of providers, information flows and clear ownership of data.

**Augmented workforce**

Chemistry and Advanced Materials companies need to embrace the digital revolution. They need to have the right ‘digital talent’ in-house and have to hire young engineers. I am so astonished by how many students have their own small 3D printers in their rooms at college. This really gives them a sense of creativity, spirit and a different mentality.

Jennifer Lewis, Founder, Voxel8

Applying digital technologies to augment workforce capabilities in an operational context can significantly improve worker safety, productivity, operational workflows, knowledge management and training. The industry has dedicated much effort to increasing worker and plant safety, which has paid off in a declining occupational injury and illness rate, as Figure 7 illustrates. Further increases in worker safety are thought to be one of the biggest benefits from digitalization. The use of wearables, especially in combination with upgrades to site infrastructure and applications, can further improve safety and efficiency for workers in an operations context. Standardized electronic workflows, combined with equipment-status information, can make regular maintenance tasks safer. For example, a combination of IIoT, mobile devices and electronic workflows can alert a maintenance technician in real time that a certain outlet is not in the right position and therefore block the electronic workflow to prevent potentially harmful operation of equipment. In the event of accidents, wearables providing real-time environmental, health and position information can speed up rescue times drastically.
Chemistry and Advanced Materials companies need to adapt to shifts in the demographics of the industry’s workforce. Digital technologies offer powerful tools to respond to these changes. Demographic changes in the industry workforce are being driven by two developments: retiring baby boomers and the growing influence of millennials. Today, companies in developed markets, such as Japan, Europe and North America, face the challenge of an ageing workforce and the risk of vital knowledge and insight being lost as workers retire. In the United States, for example, a relatively high proportion of industry workers is older than 45 (Figure 8).

Meanwhile, millennials are becoming an increasingly important source of labour. A global shortage of suitably qualified and motivated recruits is putting the skills base of the sector under further strain.

### Figure 8: Percentage of US Workers Aged over 45

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Workers</td>
<td>33%</td>
</tr>
<tr>
<td>Food Processing Workers</td>
<td>35%</td>
</tr>
<tr>
<td>Chemical Engineers</td>
<td>42%</td>
</tr>
<tr>
<td>Other Production Workers</td>
<td>43%</td>
</tr>
<tr>
<td>All Occupations</td>
<td>44%</td>
</tr>
<tr>
<td>Metal Workers</td>
<td>46%</td>
</tr>
<tr>
<td>Chemical and Material Scientists</td>
<td>48%</td>
</tr>
</tbody>
</table>

Source: U.S. Bureau of Labor Statistics

#### 33%
Proportion of global population made up of millennials by 2020

#### 37%
Proportion of those millennials who will come from India and China

The industry’s appeal to the best talent differs across regions. India, for example, takes a more favourable view of its access to talent – especially at the intersection of Chemistry and Advanced Materials and information technology – than Europe, North America or Japan.

The integrated and real-time sharing of knowledge across a business will become increasingly important as the adoption of mobile and cloud solutions grows. Equally vital will be the ability to transfer valuable industry skills and knowledge quickly and effectively to younger colleagues who replace retiring workers, both through formal training and on-the-job collaboration. Cloud platforms powered by
mobile and data analytics allow the capture, sharing and transfer of skills and knowledge in systematic and targeted ways across the workforce. One-to-many learning will be delivered consistently through any device in any context and location, at whatever time employees choose.

Purposefully adopted digital technologies will also boost efficiency. For example, a cloud-enabled two-way video link on mobile devices enables experts to inspect and suggest actions to correct malfunctioning equipment in real time anywhere on the planet. Digitalization also helps speed up capital projects and turnarounds. There is a major cost and safety factor for the industry when assets are down and hundreds of contractors are on site to support a turnaround. Electronic workflows, real-time status tracking and on-site updates to electronic project schedules with video-supported sign-off can significantly reduce waiting times between process steps. Location information and electronic workflow documentation increase the accuracy of contractor billing.

Example: Air Liquide Connected Eyewear – Visualizing Information in Augmented Reality

Connected eyewear, integrated into a safety helmet to pass on vital real-time information while keeping the wearer’s hands free, is undergoing feasibility tests at Air Liquide. It conveys sounds and images to remote support teams, who can then deliver immediate technical assessments or adjustments. The instructions are passed on visually – and instantly – on the screen of the field worker’s glasses.

Example: Accenture and Marathon – Relaying Gas Detector Alarms in Real Time

Marathon Oil is an American petroleum and natural gas exploration and production company that has collaborated with Cisco, AeroScout, Industrial Scientific and Accenture to implement a new safety solution. It provides individuals in refineries with a device for continuous gas monitoring for abnormal or lower explosive levels of hydrogen sulphide, oxygen, nitrogen dioxide, carbon monoxide and sulphur dioxide. There is a panic button for medical and other emergencies, and motion sensors in case an individual is unconscious and stops moving. All alarms are managed by operators in a central control room. The solution’s other benefits include real-time location tracking to reduce rescue time, safety procedure improvements via check-in/-out handling, an automated incident creation system, and automatic bump testing and monitor calibration. In the future, artificial intelligence supporting alarm decisions and rescue coordination could become a reality.

b. Go beyond the molecule

To offer digitally enabled services and outcomes alongside sales of chemicals and advanced materials, the industry needs to integrate new players, services and business models.

Digitally enabled offerings and business models

Digital technologies are making outcome-driven business models possible. Connectivity, the availability of relevant customer data and analytics enable companies to better identify, measure and target customers’ desired outcomes, and make their product and service performance predictable and measurable. This means commercial offerings can be generated to deliver on those desired outcomes and track the results.

The research for this White Paper found that new digital business models are still considered a challenge for companies in the Chemistry and Advanced Materials sector, as is the case in other industries. Evidence from a recent Accenture survey of 700 chief executive officers supported these findings:

84%
Percentage of chief executive officers who believed their company could create new, service-based income streams from the IIoT

27%
Percentage of chief executive officers whose companies had made concrete progress in this field

7%
Percentage of chief executive officers whose companies had developed a comprehensive strategy backed up by investments in this area

The sector has multiple opportunities to “digitally enable” its offerings. For example, product sales could be accompanied by analytics services to identify the best possible product for the customer, to optimize the customer’s utilization of the chemicals, or even their whole production process. “As-a-service” models offer companies plug-in, scalable, consumption-based services. New services and business models are expected to frequently require the integration of a broad set of specific capabilities, which calls for a partnering ecosystem. Figure 9 illustrates some of the possibilities for outcome-based business models.

So far I don’t see many digital business models in the chemical industry […] However, the closer the business is to end consumers, the easier it is to think of digitally enabled business models.

Henrik Hahn, Head Digital Strategy, Evonik Industries
Figure 9: Outcome-Driven Business Models from Selling Products to Guaranteeing Outcomes

TODAY’S SELL

- Products such as seeds, fertilizers, pesticides
- Water-treatment chemicals
- Industrial lubricants
- Paints
- Treatment chemicals
- Fixed pricing
- Fixed quantities

TOMORROW’S GUARANTEE

- A certain yield
- Quantity of clean water
- Guaranteed machine service hours
- Years of preservation / aesthetic solutions
- Quantity of noxious substances removed
- Value-based pricing dependent on outcomes
- Automatic refill, fluid as a leased service

Source: Accenture Chemical Industry Vision 2016

Example: AkzoNobel Intertrac Vision – Boosting Fuel Efficiency with Advanced Analytics and Coatings

AkzoNobel’s big data service Intertrac Vision helps shipping firms save fuel and cut emissions. It analyses more than 3.5 billion data points to determine the right coating for a specific ship. These coatings reduce biofouling (the accumulation of microorganisms, plants and algae on a ship’s hull), thereby reducing drag and boosting fuel efficiency.

Example: Carbon3D – Reducing Overheads and Making Service Agreements Easy

California-based start-up Carbon3D works at the intersection of hardware, software and molecular science. At the heart of its business is the 3D printer M1, which can create real production parts 25 to 100 times faster than other 3D printers. Its parts can achieve price parity with traditional manufacturing methods, with runs of up to 45,000 units. For customers such as Ford and Delphi, the subscription-pricing model reduces overheads in capital equipment purchases and the complexity of additional service agreements. Customers also retain the ability to upgrade as new products are released.

Example: Clariant – Helping Oil and Gas Operators Improve Efficiency and Customer Service

Clariant Oil Services’ VeriTrax Delivery is an integrated chemical delivery and data management system to help oil and gas operators obtain more frequent and accurate information about their chemical usage, product spend and tank levels. It integrates a GPS capability with a computer tablet, and a pump system with a smart meter, adding value to the oil and gas sector by driving down costs (through fewer site visits), boosting efficiency and accelerating business processes, such as budgeting procedures. When a chemical delivery is made, GPS immediately identifies the well or dispatch location, and smart meters capture the amount of product dispensed and upload the information to an enterprise resource planning system.

Advanced customer interaction

B2B customers are increasingly expecting the same simplicity and high standard of interaction that consumers demand when making purchases. This phenomenon has been termed “liquid expectations”. As sales and services frontiers blur, more than 70% of B2B buyers said they would purchase more online if it were easier and more convenient to do so.
E-commerce: Not just a B2C phenomenon

The following figures debunk the myth that e-commerce is for B2C only:

81%
Percentage of business executives who said that providing a personalized customer experience is among their top three priorities⁵⁵

60%
Percentage of business executives who are seeing a positive return on investment from personalization⁶⁶

63%
Percentage of B2B buyers aged 18 to 35 who have made purchases on Amazon Business (40% have made frequent purchases)⁷⁷

2x
Projected size of the B2B e-commerce market compared to B2C e-commerce by 2020 (today the market is already bigger)

Some companies are already exploiting these changes in customer behaviour and expectations. Mumbai-based B2B marketplace Bizongo focuses on e-commerce for the chemical and plastics industry, providing a mobile app for suppliers to manage inventory, prices, enquiries and orders, and also to live-chat with potential buyers. Alibaba operates the largest B2B online platform for small businesses, handling sales between importers and exporters from more than 150 countries. These platforms may reduce switching costs and offer add-on transactional services, and are expected to gain market share, although long-term contract- and service-based supply agreements, focusing on consistency and minimizing risks for customers, will continue to exist.

Digital technology supports companies in improving their understanding of customers, their interactions with them, and their customer service:

- Understanding the customer. Customer analytics, trend-sensing technology and dynamic pricing analytics can foresee developments downstream in customer – and even in customers’ customer – industries. Acting on these insights, companies can respond quickly with customized offerings.

- Interacting with the customer. Digital tools and technology can improve customer interaction, both in sales and service. Chemical companies could, for example, integrate their systems with those of their distributors and customers to provide customized ordering and services – and help drive increased retention and share-of-wallet with partners. Companies can get closer to customers by using digital technology, for example through digital sales channels and a seamless end-to-end omnichannel customer experience. To stay in step with rising expectations, companies can give their B2B customers the online B2C tools they are accustomed to, such as product search and configuration, comprehensive catalogues and easy transactions.

- Serving the customer. Automation, avatars and bots in “simple” sales and service situations will streamline interaction steps that are not highly valued by customers and thereby improve efficiency. Thinking further, the application of artificial intelligence and machine learning in customer service or even more complex application consulting could even open up the field for new entrants in chemical distribution. Remote video expert assistance can be applied for real-time issue or optimization consulting in customer-production processes, locking in customers and lowering the cost base.

Example: Major Oil and Gas Company – Using Cognitive Agents to Improve Supplier Management

Working with Accenture on behalf of a major oil and gas company, IPsoft looked at using Amelia – a cognitive agent that can perform a wide variety of service desk roles – to transform customer experience. Amelia was fully trained to respond to the top 25% of questions from more than 500 suppliers. To provide the most effective first response, it was integrated into an existing self-service portal for suppliers. A secure log-in meant that whenever a supplier initiated a conversation, Amelia knew instantly who it was speaking to, providing personal context and eliminating time-wasting basic questions. It also allowed for varying levels of access to information depending on the individual participating in the conversation.⁷⁸ In the long run, it is possible that cognitive agents like Amelia can take over more complex tasks and even provide customized application-consultancy services to Chemistry and Advanced Materials customers.

Example: The Dow Chemical Company – Understanding Customers’ Needs

Understanding end-market needs poses a challenge for Chemistry and Advanced Materials companies because of their position in the value chain. The Dow Chemical Company has developed collection, organization, analysis and visualization methodologies that unlock insights from business-relevant internal and external text sources. Dow sells only to other manufacturers, not directly to consumers, but has found it valuable to mine social media to gauge consumer sentiment on its enterprise customers’ products. Armed with those insights, Dow has been able to suggest alternative approaches and improvements to its customers that benefit the end consumer.⁷⁹
**Accelerated circular economy**

The growth model applied by economies and most companies for the past 250 years has been based on the availability of plentiful, exploitable and inexpensive natural resources, following a “linear” approach of “take, make, waste”. However, the growing consensus among researchers is that the linear model will no longer be viable.

The circular economy is an alternative to the linear “take, make, waste” approach. It decouples economic growth from the use of scarce resources, allowing economic development within the bounds of available natural resources. To achieve this, the circular economy follows three key principles: “preserve and enhance natural capital (by controlling finite stocks and balancing renewable resource flows); optimise resource yields (by circulating products, components, and materials at the highest utility at all times in both technical and biological cycles); and foster system effectiveness (by revealing and designing out negative externalities)”. Research has identified five main circular business models that companies can apply to capitalize on the opportunities of the circular economy, including product-as-a-service or recovery-and-recycling models.

Chemistry and Advanced Materials companies are embracing circular economy concepts, often driven by product-related innovation, e.g. in the space of plastics recycling or bio-based plastics. Digitalization can further accelerate circular economy initiatives, either within sector boundaries or along the value chain. Opportunities for digitalization in this area include:

- **Avoiding waste in sector operations.** As laid out in the “Digitalize the enterprise” section of this White Paper, digitalization in the industry’s operations helps preserve raw materials, conserve energy and reduce CO₂ emissions, for example through increased efficiency levels and decreased off-specification production rates.

- **Optimizing customer production processes.** Industry companies can improve the impact of their products in customer-production processes by, for example, implementing IoT-supported analytics for these processes. A deep understanding of specific production parameters and conditions allows companies to adapt either the formulation of chemical products or their application within customers’ production processes to increase efficiency and help preserve resources.

- **Generating transparency along the circular value chain.** Consumers increasingly demand transparency across value chains. Regulation requires traceability for products and materials, especially in sensitive areas, such as materials intended for food packaging. Digitally supported track-and-trace solutions (for example supported by blockchain technology to ensure information security) allow companies to efficiently and safely exchange information across all phases and steps of a product’s life cycle, from raw materials to finished product. Taken further, this concept could enable firms to aggregate information about the origin, journey, exact composition and carbon footprint of a material or product across the entire supply chain. This would ease regulatory compliance and recycling efforts, and satisfy demand from the public for traceability and transparency of products and materials.

**Example: Materials Marketplace – Cloud-Based Platform to Track and Exchange Materials**

The Materials Marketplace is a project from the US Business Council for Sustainable Development, the World Business Council for Sustainable Development, and the Corporate Eco Forum to scale up B2B material reuse across companies. This marketplace facilitates company-to-company industrial reuse opportunities for surplus raw materials, industrial by-products and packaging through a cloud-based collaborative platform. The platform matches traditional and non-traditional industrial waste streams from participating companies with new product and revenue opportunities (e.g. using off-spec polymers for other manufacturing purposes). Users can easily post available or desired materials, receive expert recommendations and transact reuse opportunities. Phase 1 of a US pilot project, which ran from June to August 2015, involved 23 companies from different industries, including four from the Chemistry and Advanced Materials sector. During the pilot, 78 facilities were engaged and 150 materials weighing 2.4 million tons were uploaded to the marketplace. Building on the success of the pilot, the marketplace plans to expand to more than 100 participating organizations in the United States, and scale to other regions through combined organizational networks.

**c. Collaborate in ecosystems**

Future materials discovery and deployment will be founded on collaboration between companies, across a complex and highly interconnected ecosystem.

“We and our partners have to develop a common understanding of the value of shared information and knowledge. This is not a tech issue to exchange data; it’s a matter of trust.”

Henrik Hahn, Head, Digitalization Strategy, Evonik Industries

Collaboration and competition in the Chemistry and Advanced Materials industry of the future are likely to evolve. One of the biggest changes is expected to be the growing importance of collaboration within ecosystems, with competition between ecosystems often crossing industry boundaries.
Increased cooperation between industry players can already be seen. A 2016 Accenture study found that 40% of the executives surveyed agreed that adopting a platform-based business model and engaging in the ecosystems of their digital partners were critical to their business success.

80%
Percentage of enterprises with advanced digital transformation strategies predicted to create or partner with industry platforms

50%
Percentage of large enterprises predicted to do the same

Innovation ecosystem

The principle of “connected innovation” is already breaking down internal silos to include more parts of an organization in the innovation process. As a next step, companies will need to rethink external boundaries and create an innovation ecosystem – an extended network of alliance partners, universities, entrepreneurial companies, software or infrastructure suppliers, customers and their downstream customers. The research for this White Paper showed that many companies in the sector have already engaged in or are experimenting with innovation ecosystem initiatives.

Within this kind of ecosystem, innovation can come from multiple sources and involves collaboration with a variety of partners. R&D is no longer an isolated function and is instead at the centre of a web of flexible partnerships. Digital technology plays a key role in creating connections and supporting collaboration through open systems (using application program interfaces, for example), enabling extensive information sharing and giving virtual teams the tools they need to work together seamlessly. R&D cloud collaboration is another enabler, that is composed of technology stacks and supporting services optimized for scientific research and collaboration activities, which can be extended to external partners.

Example: BASF Creator Space – Connecting People to Tackle Urban Living, Energy and Food Challenges

BASF’s co-creation programme, “Creator Space”, is designed to encourage collaboration with customers and partners, and to build a deeper understanding of the challenges relating to urban living, energy and food. Topics addressed in 2015 include Mumbai’s water supply problems and smart energy. Concepts are tested during a period of rapid, assumption-based experimentation, both in the lab and with customers, influencers and potential delivery partners. Seed funding for promising ideas increases the likelihood of success and the reach of the entire system’s innovation capability.

Value chain collaboration

The industry is expected to benefit greatly from collaboration in ecosystems, thereby smoothing planning and transactional procedures, as well as complementing internal with external capabilities for new offerings.

Collaboration in supply and delivery ecosystems becomes particularly important in managing increasingly complex, less linear chains, along with demand changes and volatility in demand and supply. Collaboration and planning platforms can be used to exchange forecasts, stock information, delivery schedules and paperwork between customers and suppliers, in real time, ahead of product flows, for joint planning purposes. This improves visibility, automation and synchronization along the chain and ultimately gets better results in related key performance metrics, such as delivery reliability or decreased stock-outs.

Ecosystem collaboration between companies enables them to combine critical capabilities and offer solutions for complex problems to customers, instead of “just” products. For instance, Monsanto’s Climate Corporation has opened its Climate FieldView platform software infrastructure to third-party developers. The intention is to build a centralized platform to simplify the complex digital agriculture landscape for farmers and make it easier for other agriculture innovators to bring valuable new technologies to farmers faster.

According to Accenture’s Technology Vision 2016, trust is a cornerstone of the digital economy. When working closely with stakeholders outside an organization’s boundaries, gaining the trust of individuals, ecosystems and regulators is crucial. Beyond that, questions related to data access, ownership, usage and security need to be addressed and businesses must possess strong security and ethics at each stage of the value chain and customer journey.

83%
Percentage of executives who agree that trust is the cornerstone of the digital economy

82%
Percentage of executives who say a lack of security and ethical controls on data could exclude them from joining other companies’ digital platforms or broader ecosystems
The Chemistry and Advanced Materials industry transforms matter in sophisticated multistep procedures. Its output serves as input to further chemical processing or customer production processes. In this context, major priorities for the industry can be outlined as follows:

– Raw material costs typically equate to 50-60% of a company’s revenues (varying by sub-sector), so accessing and managing the supply of raw materials or feedstock – and volatility in that supply – is an important issue.

– Chemical and material processing is asset intense; it often requires large-scale investment and assets can run for decades. Driving operational excellence, managing production KPIs (e.g. availability and utilization rates) and securing workers’ safety are major priorities.

– As the industry supplies its products to almost every other sector, demand is often driven by global economic growth. Commodityization and downstream orientation, as well as squeezed margins, are realities for the industry, especially as companies from emerging markets gain prominence and new chemical clusters emerge. In this context, mastering innovation capabilities – to develop new products and applications that secure market share and margins, or to reduce current production costs – is growing in importance.

Digitalization can help form a cohesive response to typical industry priorities – increasing operational excellence or better managing volatility, for example. Digital technologies show a tremendous potential to move the industry beyond current growth and productivity levels and to deliver value for the industry, customers, wider society and the environment. Digital value creation in the Chemistry and Advanced Materials industry is a function of financial performance, as well as customer, environmental and societal value (see Figure 10).

**Figure 10: Maximizing Value in Chemistry and Advanced Materials**

EBIT = earnings before interest and tax
Source: World Economic Forum/Accenture analysis
Taking these value drivers into consideration, a detailed value-at-stake model has been applied to assess the impact of digitalization on the Chemistry and Advanced Materials industry. The value-at-stake methodology assesses the impact of digital transformation initiatives on the industry, customers, society and the environment. It provides likely value estimates of global industry operating profits at stake from 2016 to 2025, and the value contribution that digital transformation can make in that time frame:

- **Value to the Chemistry and Advanced Materials industry.** Value at stake for the industry is measured as financial performance and considers two elements: the potential impact on the industry’s operating profits that will be generated from digital initiatives (value addition), and operating profits that will structurally shift between different industry segments or new entrants (value migration).

- **Value to customers.** Digitalization brings value to customers in terms of innovation or increased supply reliability and efficiency, for example. As the Chemistry and Advanced Materials sector supplies many industries with very heterogeneous customer structures, the digitalization effects on customers are captured qualitatively in this White Paper.

- **Value to the environment and society.** Value at stake for society measures the impact of digital transformation on society (e.g. on employee safety) and the environment (e.g. on CO₂ emissions). Its net impact on employment has been calculated separately and is not included in the monetary value at stake for society.

Further explanation of our value-at-stake methodology can be found in the appendix to this White Paper.
Value-at-Stake Analysis

Digitalization is opening up new opportunities for value creation in the Chemistry and Advanced Materials industry.

This section highlights the cumulative value impact that digitalization can bring to the industry, society and environment over the next decade. It should be noted, that the value-at-stake analysis relates to the evolutionary approach of the industry to digital transformation.

a. Technology maturity and key mechanisms

Assumed adoption trajectories of the outlined digital initiatives are major drivers of the value-at-stake analysis. For all the digital initiatives outlined in this White Paper, the sector’s starting points and estimated time to bring these initiatives to scale in the Chemistry and Advanced Materials industry have been taken into account. The complexity of each digital initiative and its implementation will also have a major impact on the time frame for widespread adoption of that initiative in the industry.

Besides the estimated initiative adoption rates, the following are major mechanisms that have been considered for the value-at-stake analysis:

- **Cumulative benefits for the Chemistry and Advanced Materials industry.** The value-at-stake analysis estimates cumulative benefits from digitalization over the next decade. It takes a global perspective on the sector, acknowledging that adoption rates and related benefits of digital initiatives vary depending on geography and companies’ positions in the value chain. Some digitalization benefits that are valid at a single-company level (e.g. avoiding lost sales due to stock-outs, reducing customer attrition) are not included in this industry-wide value-at-stake analysis. It is assumed that a single company could capture these benefits, but industry-wide effects would be balanced across companies.

- **Industry-specific initiatives and aspects.** This White Paper focuses on parts of the business that are specific to the industry (e.g. R&D and manufacturing). Though digitalization promises large benefits in back-office functions (e.g. automation in finance or human resources departments), these are not included in the analysis because of their general, cross-industry nature.

- **Major and direct benefits.** Digitalization benefits can be manifold across a company’s functions and businesses. The value-at-stake analysis calculates direct benefits to the industry and society. Indirect and secondary effects (e.g. efficiency increases in customer production processes or expected job generation in supplier/adjacent industry segments) are acknowledged, but not included in the analysis.

b. Summary of value-at-stake findings

**Cumulative value-at-stake headlines**

Digital transformation represents a substantial opportunity for the Chemistry and Advanced Materials industry (see Figure 11). Across value migration and value addition to the industry, the estimated cumulative economic value for the period 2016 to 2025 ranges from approximately $310 billion to $550 billion. In terms of non-economic benefits, digitalization has the potential to reduce CO₂ emissions by 60 to 100 million tonnes, save 20 to 30 lives and avoid 2,000 to 3,000 injuries over the next decade. Value-at-stake results are displayed as ranges to reflect the uncertainty, heterogeneous estimates and assumptions among research and industry leaders about starting points, adoption rates and benefits related to digital initiatives.

Key findings by theme include:

- **Mainly through productivity and efficiency gains, digitalize the enterprise** could deliver ~$190 billion to ~$280 billion in value to the industry, save 20 to 30 lives and prevent 2,000 to 3,000 injuries.

- **Go beyond the molecule**, especially with digitally enabled business models and offerings, could be worth ~$120 billion to ~$270 billion, and generate 100,000 to 225,000 jobs.

- **For collaborate in ecosystems**, the value at stake in “innovation ecosystems” is covered by digital R&D, and the value at stake in “value chain collaboration” is included under digital supply chain.

- The value at stake from **digital plant** is considerable, but lower than expected given the importance and costs associated with the industry’s manufacturing operations, mainly due to expected adoption rates.

- **Digitally enabled offerings and business models** show the highest potential, but also the highest range of uncertainty. Industry leaders acknowledge the value-added potential of complementing product sales with digital services, and this is underlined by the fact that the first offerings have already been launched. At the same time, adoption rates and their impact on the industry’s sales mix are regarded as difficult to estimate.

- Balanced against the benefits, digitalization could lead to a reduction of 630,000 to 670,000 jobs in the industry globally by the end of the next decade. For the value-at-stake calculation it is assumed that efficiency and productivity gains will have an impact on the size of the industry’s workforce. This does not contain any prescriptive element (as individual companies could use productivity gains to increase output or for activities with higher added value), but highlights that
Digitalization will affect certain roles in the industry. The figures consider a potential direct effect on industry jobs. This needs to be balanced against the positive impact on employment that is expected in adjacent or supplier industries, such as analytics and information technology (which have not been included in the analysis). Further, it should be remembered that digitalization is expected to help to mitigate the issues of an ageing workforce and many workers retiring in certain geographies.

It should be noted that the primary aim of the value-at-stake framework is to highlight trends and areas where digitalization can make an impact, rather than provide precise value estimates. It is important to understand that value estimates relate to future developments and are based, with varying degrees of certainty, on assumptions about technology adoption curves, benefit ranges and multiple other parameters. The intention is that the value-at-stake framework can start a discussion about the potential for digitalization to create value for the industry and society. The analysis is both an art and a science, with room for further iteration and refinement, aiming to provide a baseline and a common language for a private-public dialogue. The goal is to initiate and trigger a multistakeholder dialogue and engagement around the societal impacts of digital technology in order to build a digital revolution that serves all.

<table>
<thead>
<tr>
<th>ECONOMIC BENEFITS</th>
<th>NON-ECONOMIC BENEFITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value migration</td>
<td>Value addition</td>
</tr>
<tr>
<td>($ billion)</td>
<td>($ billion)</td>
</tr>
<tr>
<td>Digital R&amp;D</td>
<td></td>
</tr>
<tr>
<td>Digital Plant</td>
<td>-</td>
</tr>
<tr>
<td>Digital Supply Chain</td>
<td>-</td>
</tr>
<tr>
<td>Augmented Workforce</td>
<td>-</td>
</tr>
<tr>
<td>Digital Offerings and Business Models</td>
<td>-</td>
</tr>
<tr>
<td>Advanced Customer Interaction</td>
<td>-</td>
</tr>
<tr>
<td>Accelerated Circular Economy</td>
<td>Benefits not quantified</td>
</tr>
<tr>
<td>Innovation Ecosystems</td>
<td>Value-at-stake included in Digital R&amp;D</td>
</tr>
<tr>
<td>Value Chain Collaboration</td>
<td>Value-at-stake included in Digital Supply Chain</td>
</tr>
<tr>
<td>Cumulative total 2016 - 2025</td>
<td>5-6</td>
</tr>
</tbody>
</table>

Source: World Economic Forum/Accenture analysis
Value-at-stake findings by digital initiative

Value at stake: Digital R&D

The application of digital technology to all aspects of the R&D cycle will increase the efficiency and effectiveness of R&D operations. Digitalization will impact R&D cost baselines by automating – and accelerating – laboratory processes and thus free researchers to focus on where their added value is. Further digitalization is expected to increase success rates across R&D portfolios and increase overall time-to-market speeds for new products (see Figure 12). This has tremendous potential to boost industry revenues and profits, though a quantitative appraisal needs to be performed at the level of a single enterprise.

Figure 12: Digital Application Areas and Value-at-Stake Impacts: Digital R&D, 2016-2025

<table>
<thead>
<tr>
<th>Digital application areas (selected)</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big data analytics, trend sensing, machine learning, artificial intelligence and virtual experiments in ideation and experimentation</td>
<td>Increased efficiency in R&amp;D operations</td>
</tr>
<tr>
<td>Telematics, IIoT, robots and autonomous systems for automation of lab procedures</td>
<td>Increased R&amp;D success rates, faster time to market</td>
</tr>
<tr>
<td></td>
<td>Reduced number of test runs, less material/energy/etc. usage, debottlenecking of mid-scale and industrial-scale test capacities</td>
</tr>
</tbody>
</table>

Source: World Economic Forum/Accenture analysis

Figure 13: Digital Application Areas and Value-at-Stake Impacts: Digital Plant, 2016-2025

<table>
<thead>
<tr>
<th>Digital application areas (selected)</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced automation and process control</td>
<td>Improved yield (e.g. decreased off-spec volumes)</td>
</tr>
<tr>
<td>Real-time process, quality, emission control and analytics</td>
<td>Improved energy efficiency</td>
</tr>
<tr>
<td>Predictive / condition-based maintenance and digital asset management (e.g. IIoT, analytics)</td>
<td>Reduced number of required turnarounds</td>
</tr>
<tr>
<td></td>
<td>Reduced emissions</td>
</tr>
<tr>
<td></td>
<td>Increased worker safety</td>
</tr>
<tr>
<td></td>
<td>Reduced lost revenue due to (unplanned) production outages</td>
</tr>
</tbody>
</table>

Source: World Economic Forum/Accenture analysis

Value at stake: Digital plant

The industry is continuing its historical effort to optimize and streamline production processes. Nevertheless, its digital leaders see potential to further digitalize plant environments with technologies such as the IIoT, sensors and production analytics (see Figure 13). For example, these technologies could drive the automation and optimization of production processes to improve production yield/to-spec product quality and energy efficiency. Meanwhile, digital asset status information enables effective predictive/condition-based maintenance and digital asset management, smoothing maintenance procedures and reducing the risk of unplanned outages.
Value at stake: Digital supply chain

Digitalization is expected to improve many aspects of the industry’s supply chains. For sourcing, technologies such as supplier and spend analytics, automatic sourcing agents for simple tasks, virtual malls and supplier portals can increase transparency and allow better sourcing decisions and results. Demand-sensing analytics, advanced forecasting and improved sales and operations planning, dynamic inventory analytics and management, and digitally enabled supply chain control towers promise to enhance transparency, planning and steering across the supply chain (see Figure 14). Particularly for packaged materials, there is potential for further automation in warehouse operations.

Value at stake: Augmented workforce

Deploying intelligent and connected wearables and mobile devices such as tablets, mobiles, “glass” solutions and safety devices with environment and health sensors (e.g. hazardous gas detection) as standard equipment for on-site workers is expected to drastically improve worker safety and workflow efficiency (see Figure 15). If workers’ on-site locations are transmitted, they can be found faster in case of accidents and be warned about dangerous situations. Electronic workflows linked to overall maintenance and turnaround schedules, real-time bidirectional document access and collaboration (e.g. for asset information), two-way video-supported remote expert assistance, and contextual interaction with sensor-equipped assets can increase efficiency in on-site operations, maintenance and turnaround situations.

Figure 14: Digital Application Areas and Value-at-Stake Impacts: Digital Supply Chain, 2016-2025

<table>
<thead>
<tr>
<th>Digital application areas and impacts</th>
<th>Value-at-stake impacts (all figures cumulative, 2016-2025)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital application areas (selected)</td>
<td>Total value to industry ($ billion)</td>
</tr>
<tr>
<td></td>
<td>Reduced CO₂ emissions (million tons)</td>
</tr>
<tr>
<td></td>
<td>Lives saved (#)</td>
</tr>
<tr>
<td></td>
<td>Injuries reduced (#)</td>
</tr>
<tr>
<td></td>
<td>Net impact on jobs (#, 000s)</td>
</tr>
<tr>
<td>Digital Supply Chain</td>
<td>40-70</td>
</tr>
<tr>
<td>• Supplier and spend analytics,</td>
<td>-</td>
</tr>
<tr>
<td>automatic sourcing agents, virtual</td>
<td>-</td>
</tr>
<tr>
<td>malls and supplier portals</td>
<td>-</td>
</tr>
<tr>
<td>• Demand-sensing analytics,</td>
<td>-</td>
</tr>
<tr>
<td>advanced forecasting and improved</td>
<td>-</td>
</tr>
<tr>
<td>S&amp;OP planning, dynamic inventory</td>
<td>-</td>
</tr>
<tr>
<td>analytics, digitally enabled SC</td>
<td>-</td>
</tr>
<tr>
<td>control tower, warehouse automation</td>
<td>-</td>
</tr>
<tr>
<td>• Improved procurement / sourcing</td>
<td>-</td>
</tr>
<tr>
<td>results</td>
<td>-</td>
</tr>
<tr>
<td>• Reduced distribution / logistics</td>
<td>-</td>
</tr>
<tr>
<td>cost</td>
<td>-</td>
</tr>
<tr>
<td>• Increased efficiency in</td>
<td>-</td>
</tr>
<tr>
<td>administrative supply chain</td>
<td>-</td>
</tr>
<tr>
<td>• Optimized inventory levels</td>
<td>-</td>
</tr>
<tr>
<td>• Reduced lost revenue due to stock-out situations</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: World Economic Forum/Accenture analysis

Figure 15: Digital Application Areas and Value-at-Stake Impacts: Augmented Workforce, 2016-2025

<table>
<thead>
<tr>
<th>Digital application areas and impacts</th>
<th>Value-at-stake impacts (all figures cumulative, 2016-2025)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital application areas (selected)</td>
<td>Total value to industry ($ billion)</td>
</tr>
<tr>
<td></td>
<td>Reduced CO₂ emissions (million tons)</td>
</tr>
<tr>
<td></td>
<td>Lives saved (#)</td>
</tr>
<tr>
<td></td>
<td>Injuries reduced (#)</td>
</tr>
<tr>
<td></td>
<td>Net impact on jobs (#, 000s)</td>
</tr>
<tr>
<td>Augmented Workforce</td>
<td>85-120</td>
</tr>
<tr>
<td>• Intelligent connected wearables,</td>
<td>-</td>
</tr>
<tr>
<td>location and sensor information</td>
<td>20-30</td>
</tr>
<tr>
<td>• Connection to infrastructure,</td>
<td>2,000-3,000</td>
</tr>
<tr>
<td>electronic workflows, document /</td>
<td>-</td>
</tr>
<tr>
<td>data access, remote expert support</td>
<td>-</td>
</tr>
<tr>
<td>• Learning/knowledge management</td>
<td>-</td>
</tr>
<tr>
<td>• Increased worker safety – worker</td>
<td>-</td>
</tr>
<tr>
<td>injuries and fatalities avoided</td>
<td>-</td>
</tr>
<tr>
<td>• Increased efficiency across on-site</td>
<td>-</td>
</tr>
<tr>
<td>operations and maintenance</td>
<td>-</td>
</tr>
<tr>
<td>• Faster turnaround execution and</td>
<td>-</td>
</tr>
<tr>
<td>more accurate contractor billing</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: World Economic Forum/Accenture analysis
Value at stake: Digitally enabled offerings and business models

This initiative shows the highest potential for the industry, but also the highest level of uncertainty. Industry leaders acknowledge the on-top revenue and earnings before interest and tax (EBIT) contribution potential of complementing product sales with digital services (see Figure 16). This is underlined by the fact that many companies are already investigating opportunities in digital business models and some first offerings are already on the market. The range of opportunities is broad: analytics can help define the optimal product/application for a specific customer issue; combining IIoT, data exchange and analytics can improve product usage and impact in customer manufacturing processes. But, at the same time, the speed of adoption in the market and impact on the industry’s sales mix are regarded as difficult to estimate.

Value at stake: Advanced customer interaction

Digital technology is set to impact many aspects of how Chemistry and Advanced Materials will market, sell and service products and applications. Analytics and trend-sensing technology will improve the sector’s understanding of customer requirements, which can be leveraged to shape product and service offerings. Concepts from the B2C world are expected also to transfer into B2B sales and service interactions (e.g. omnichannel experience and personalization). Technologies such as artificial intelligence/machine learning and avatars can take over simple customer interactions in sales and service, and thereby increase operational efficiency. It is expected that new commercial platforms and marketplaces for the sale and distribution of chemicals and advanced materials will emerge to challenge the market share of current distributors. Digitalization will also offer opportunities to reduce customer attrition and increase share of wallet through better customer understanding and retention mechanisms (see Figure 17), but these benefits accrue on a single company level and are not included in our industry-wide value-at-stake analysis.

Figure 16: Digital Application Areas and Value-at-Stake Impacts: Digitally Enabled Offerings and Business Models, 2016-2025

<table>
<thead>
<tr>
<th>Digital application areas and impacts</th>
<th>Value-at-stake impacts (all figures cumulative, 2016-2025)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Digital application areas (selected)</strong></td>
<td><strong>Impacts</strong></td>
</tr>
<tr>
<td>Digitally Enabled Offerings and Business Models</td>
<td></td>
</tr>
<tr>
<td>Utilization of digital technologies or a combination thereof to design or support a digitally enabled service or business model</td>
<td>Additional EBIT contribution from digitally enabled offerings and business models</td>
</tr>
</tbody>
</table>

Source: World Economic Forum/Accenture analysis

Figure 17: Digital Application Areas and Value-at-Stake Impacts: Advanced Customer Interaction, 2016-2025

<table>
<thead>
<tr>
<th>Advanced Customer Interaction</th>
<th>Digital application areas and impacts</th>
<th>Value-at-stake impacts (all figures cumulative, 2016-2025)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Digital application areas (selected)</strong></td>
<td><strong>Impacts</strong></td>
</tr>
<tr>
<td></td>
<td>- Customer analytics, trend sensing, dynamic-pricing analytics</td>
<td>New entrants in commercial platforms / marketplaces</td>
</tr>
<tr>
<td></td>
<td>Omnichannel experience; eCommers platforms with B2C-like functionality, online product effect simulations, mobile solutions for Salesforce</td>
<td>Efficiency increase in marketing, sales and customer service</td>
</tr>
<tr>
<td></td>
<td>Artificial intelligence / machine learning in customer service, avatars and bots in ‘simple’ sales and service interactions, remote video expert assistance</td>
<td>Reduced customer attrition</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increased share-of-wallet / up-and cross-selling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Customer-specific pricing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Qualitative benefits acknowledged</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Additional revenue/EBIT due to reduced customer attrition, increased share of wallet, customer-specific pricing not considered in industry-wide analysis</td>
</tr>
</tbody>
</table>

Source: World Economic Forum/Accenture analysis
Value at stake: Accelerated circular economy

Digitalization will help realize some circular economy concepts. Digital technology can help minimize resource/energy consumption and avoid waste in operations as well as customer production processes. Further, digitalization can increase transparency around the circular value chain in terms of traceability, life-cycle understanding and product information. This White Paper acknowledges digitalization as one of the circular economy’s multiple enablers; a quantitative impact assessment should be subject to further research.

Value at stake: Innovation ecosystem

Collaboration and security technology are prerequisites for fully exploiting the potential of innovation ecosystems. Engagement in innovation ecosystems is expected to affect R&D KPIs, including success rates, times to market and costs. The benefits of innovation ecosystems have been considered in the value-at-stake calculation of digital R&D (Figure 12).

Value at stake: Value chain collaboration

The industry should benefit hugely from collaboration in ecosystems, which can smooth planning and transactional procedures, and complement internal capabilities with external ones for new offerings. Collaboration and planning platforms in supply and delivery ecosystems will improve visibility, automation and synchronization along the chain, ultimately boosting key performance metrics, such as delivery reliability and number of stock-outs. The benefits of digitally enabled supply and delivery collaboration are included in the value-at-stake analysis for the digital supply chain (Figure 14). Collaboration in ecosystems is considered a prerequisite for deploying digitally enabled offerings and business models, and is therefore not subject to a separate value-at-stake analysis.
Challenges from Digitalization

The interviews and interactions with the industry’s digital leaders suggest they don’t generally feel hindered in planning and executing their digital transformation.

“"I don’t think that there are many roadblocks. It’s more about standardization and where governments and agencies can jump in.”

Michael Olosky, Head, Innovation and New Business Development, Adhesive Technologies, Henkel

Nevertheless, besides company-specific challenges, digital leaders face a set of common challenges.

Workforce
- To successfully compete in a digital world, companies must supplement their workforce with deep digital skills in areas such as analytics and data architecture. Ideal skill sets that combine, for example, analytics and process engineering are rare and hard to identify, and competition makes it difficult to recruit for them.
- Building a workforce with a high digital quotient requires more than simply recruiting digital talent. The industry has to manage opportunities and changes in working style and the type of work performed by the existing workforce. This is true across all levels of an organization, from management to site personnel.

Cybersecurity
- Cyberattacks (e.g. data theft or even the sabotage of connected assets) could severely harm employees, customers and other stakeholders. Therefore, the management of an increasingly complex cybersecurity space is considered an imperative – and a great challenge. The deployment of digital technology, such as IIoT, connected devices, digital assets and collaboration platforms, dramatically increases both the vulnerability to cyberattacks and the complexity of cybersecurity measures needed to defend against them.

Organization and technology
- Publicly listed incumbents might be hindered from deep, digitally fuelled change. This could be the result of corporate culture, industry character (e.g. safety aspects, regulation) or investors’ short-termism. It might mean companies pursue short-term, incremental innovation rather than transformational change.
- Creating new digital business models or digital offerings is one of the more challenging digital initiatives. Identifying the right ideas, managing internal competition for resources, establishing a partner system and commercializing offerings for customers are all seen as issues to be tackled.
- Analytics-based insight generation is a key driver of digitalization’s benefits, both in a production context and in the provision of new services. Preparing the groundwork for data transparency, quality and integration that enables meaningful insight generation is not to be underestimated.
- The integration and interoperability of enterprise systems (information technology/operational technology integration, for example) is not only a technical challenge but includes organizational alignment efforts, too, as responsibility for information technology and operational technology is often spread across multiple departments.

Ecosystem collaboration
- Collaborating effectively in ecosystems requires the exchange of data and information across value-chain participants. Concerns about intellectual property protection, data ownership and privacy must be tackled, and companies also often need to review internal procedures and policies to effectively collaborate in digital ecosystems.

Regulation
- Current legislation and regulations are not considered as inhibitor to change. The industry strongly supports the right to the protection of personal data. A more harmonized approach to data privacy regulation on a global scale could increase efficiency in implementation, as digital leaders would not need to consider multiple sets of national legislation on data privacy.
Key Considerations for a Successful Digital Transformation

The opportunity is huge for Chemistry and Advanced Materials companies to become digital leaders, but the value that digital transformation can create is not guaranteed. Unlocking its full potential requires resourcefulness, creativity and a willingness to embrace constant and rapid change. The research for this White Paper highlighted key questions that leaders should consider as they shape and implement their digital transformation.

Set the right digital strategy

Digital transformation is not yet “business as usual” for most organizations. Leaders should therefore have a digital strategy and roadmap in place – at the board level or at least with direct attention from the board. The digital landscape is poised to change fast, so Chemistry and Advanced Materials companies should closely monitor the start-up scene and market for both opportunities and threats to their businesses.

Key questions for digital leaders:
- In which strategic context is digital transformation placed in your company? Is it part of the strategic planning cycle, for example? Is it regularly reviewed? Does your company have board-level support and the digital literacy needed for a successful digital transformation?
- Have you reviewed and quantified your digitalization priorities along your value chain? Does your digital roadmap contain “quick-win” initiatives to prove the value and feasibility of digital technologies to your organization? Have you considered embedding the value to society of digital transformation in your investment decisions?
- How does your company ensure it won’t miss disruptive developments or opportunities in the market? Do you have effective mechanisms in place to identify and observe pockets of disruption and to screen start-ups? Do you need to create or bolster corporate-venturing capabilities? Are corporate venture-capital activities bringing scale and protection to the existing business?

Manage cultural change

Many of the individuals interviewed understand digital transformation as a change journey across all levels of the organization. Some of them even consider managing change as the most critical factor for success. Corporate cultures in Chemistry and Advanced Materials companies, which are often described as “classically chemical engineering-driven”, will need to become more open and agile to cope with constant change. Cultural transformation should be driven by the chief executive officer and leadership team, alongside people hired from outside an organization to further infuse digital thinking and mindsets.

Key questions for digital leaders:
- How can you ensure that the culture change related to digital transformation is understood, supported and visible at every level of your organization? Do you need to relate progress in digital transformation to target setting and the compensation of executives?
- Where should you assign responsibility for digital transformation in your company? What kind of organization best suits your transformation goals? What kind of authority and role, especially in relation to line business, should the person or entity responsible for the digital agenda have?
- Do you have sufficient people with digital mindsets in the right positions across your organization? Are they able to challenge the status quo and drive digital transformation? How can you reconcile encouraging digital venturing and risk-taking with the industry’s traditionally risk-averse mindset?

Bring your workforce into the digital age

Digital leaders in the industry acknowledge that companies need to rethink their competency requirements and supplement their workforce with deep digital skills. They understand that, in the digital era, they need to compete for the best talent against digital natives, emerging start-ups and digitally advanced competitors. Chemistry and Advanced Materials companies must have strategies in place to leverage developments or opportunities in the market? Do you observe pockets of disruption and to screen start-ups? Do you need to create or bolster corporate-venturing capabilities? Are corporate venture-capital activities bringing scale and protection to the existing business?

Key questions for digital leaders:
- Did you thoroughly evaluate the opportunities and impact of digital transformation on your workforce? How should recruiting, training and knowledge management measures be adapted?
- Have you identified the digital skill sets your company needs to compete in the digital era? Are you considered an attractive employer for millennials? Are you using digital technologies (social or mobile, for example) to improve your employer branding?
- How should you extend your collaboration with leaders from academia and universities to ensure industry-related academic curricula are adapted?

Ensure cybersecurity

IIoT, connectedness, data and other factors are driving digital transformation but, at the same time, they increase companies’ vulnerability to cyberattacks. On account of the
increasing threat of cyberattacks, digitalization requires appropriate attention, investment and capabilities to be assigned to managing cybersecurity.

Key questions for digital leaders:
- At which levels is cybersecurity discussed in your company? Is it, for example, an important board-level issue? Is your organization sufficiently equipped with the appropriate skills and capabilities for effective cybersecurity?
- Do your investments in cybersecurity and risk management initiatives match your company’s (digital) risk profile and sufficiently support digital transformation? Are cybersecurity aspects considered in your digital strategy and concepts for digital initiatives?

**Successfully collaborate in digital ecosystems and accelerate cross-industry partnerships**

Chemistry and Advanced Materials companies should work on identifying and understanding network partners and dynamics in the network, and the role they want to play within the relevant R&D, commercial and distribution ecosystems. Digital leaders need to instil appropriate governance for ecosystem collaboration (internal processes, engagement rules and procedures, policies) to balance steering, privacy and collaboration requirements when working with, for example, fast-paced start-ups.

Key questions for digital leaders:
- How do you provide enough flexibility in digital partner management to quickly onboard and collaborate with changing ecosystem partners?
- Are you planning to increase collaboration with your customers, your customers’ customers and your suppliers as part of your innovation process? Have you considered crowdsourcing activities and initiatives, such as hackathons, as part of innovation management?
- Have you evaluated value-creation opportunities from industry platforms to integrate data and applications with business partners?
- Have you considered leveraging a partner ecosystem to offer a full solution suite to your customers?

Industry leaders should also focus on explaining the contribution made by Chemistry and Advanced Materials companies, and the industry as a whole, to the end product. This is especially relevant to high-value components that are critical in boosting the performance of existing digital technologies. Industry leaders should ensure they have a clear and quantified understanding of the value of the materials they are contributing to the customer’s digitalization and to society more widely. They could take further steps together with their peers or industry associations to reframe the industry’s image as an enabler of the digital revolution in other industries.

**Identify, develop and launch new business models**

Companies should imagine what their business models would look like if their core businesses were complemented with digital services or even digital business models. Following an “asset-light and idea-heavy” approach for digital transformation, moving from selling products to providing performance-related outcomes, is one of the many options. To accelerate the development and launch of new business models, an improved strategy toolkit – including build, buy, partner, invest and incubate options – can help. This is especially valuable in embracing and getting ahead of disruption, in acquisitions or when moving into the disruption space.

Key questions for digital leaders:
- Which techniques do you use to generate ideas for digital services and business models? Do you apply concepts and software development approaches, such as design thinking, experimentation, free space, Scrum or Agile? Which of the different stakeholder groups do you involve in idea generation (for example, business and functional representatives, customers, customers’ customers, suppliers)? Do you systematically monitor developments in adjacent or other industries to generate ideas?
- How disruptive are you in evaluating ideas for digital business models and services? Have you evaluated options to augment your traditional offerings with digital services (e.g. using analytics to boost the performance of products in customer processes, or digitally enhanced delivery services)?

**Key considerations for regulators and policy-makers**

To realize the value for society and the industry from the digital transformation will require focused collaboration and determined action on the part of all major stakeholders – including coordinated regulatory efforts to maximize digitalization’s value across industries and wider society.

**Ensure regulatory certainty and consistency across jurisdictions**

Chemicals regulation is governed by a variety of national laws and is subject to international initiatives aiming to define the direction of future regulation. Currently, differences exist between regulation in the United States and the European REACH framework. Digital technologies, especially platforms for communication and collaboration, could significantly simplify and accelerate the harmonization process while satisfying societal needs for transparency.

**Harmonize policies related to data sharing**

Data generation, sharing, analysis and storage are important enablers of the digital transformation, IIoT adoption and ecosystem collaboration, for example. Developing harmonized data structures would support the interoperability of IIoT devices and systems. Governments should ensure that current concerns on data privacy and usage, security and interoperability can be resolved. Today, governments are expected to intelligently observe the developments of digital technologies and be open to a dialogue with the industry on best practices related to collecting, sharing and using data. This will lead to more informed, proactive decisions ahead.
Value at stake methodology overview

Value at stake is a framework designed to assess the impact of digital transformation initiatives on the industry, customers, society and the environment. It provides a differentiated and evidence-based understanding of the extent of impact that digital transformation will have on the industry, and where potential value creation opportunities exist. It provides likely value estimates of global industry operating profits at stake from 2016 to 2025, and the contribution that digital transformation can make to customers, society and the environment in that time frame.

Industry value

Value at stake for the industry comprises two elements: first, the potential impact on the industry’s operating profits that will be generated because of the digital initiatives (value addition); second, operating profits that will shift between different industry players (value migration).

Value to society

Value at stake for society includes three elements: customers, society and the environment. Each element is measured as follows:

1. Value impact for customers: the potential gain to customers (both B2B and B2C) in the form of cost and time savings, discounts and ability to earn additional profits (for B2B only)
2. Value impact for society: the impact (both financial and non-financial) of digital initiatives on productivity gains and jobs, as well as on worker safety.
3. Value impact on the environment: the estimated impact of the digital initiatives on increasing or reducing CO₂ emissions

Approach

The value at stake has been calculated using a top-down approach involving three key steps:

1. Identifying the total addressable market and adoption/penetration rates over the next 10 years for digital initiatives based on secondary research, industry reports, existing use cases and interviews with subject and industry experts
2. Creating a value tree to represent the value categories for industry and society mentioned above
3. Testing, revising and validating assumptions and results

It should be noted that the primary aim of the value-at-stake framework is to highlight trends and areas where digitalization can make an impact, rather than provide precise value estimates. It is important to understand that value estimates relate to future developments and are based, with varying degrees of certainty, on assumptions about technology adoption curves, benefit ranges and multiple other parameters. The intention is that the value-at-stake framework can start a discussion about the potential for digitalization to create value for the industry and society. The analysis is both an art and a science, with room for further iteration and refinement, aiming to provide a baseline and a common language for a private-public dialogue. The goal is to initiate and trigger a multistakeholder dialogue and engagement around the societal impacts of digital technology in order to build a digital revolution that serves all.
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Endnotes


20. Yankovitz, Kreutzer and Bjacek. op. cit.


26. Ibid.


39 Ibid.
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