The Chemistry and Advanced Materials industry is a key enabler of the Fourth Industrial Revolution.

Digital transformation is emerging as a key driver of sweeping change in the world around us. It has the potential to significantly improve consumer lives and create broader societal good, while providing businesses with new 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 by digital innovation. 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.

It is clear that digitalization will be a source of transformational change, but there are a number of challenges that need to be overcome. In many cases, the gains from digitization 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 for data privacy and security. Businesses across sectors are grappling with challenges related to changing customer expectations, cultural transformation, outdated regulation and skill shortages, among others.

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.
INTRODUCTION TO THE DIGITAL TRANSFORMATION INITIATIVE (DTI)

In a world where game-changing innovation has become the norm, DTI provides a unique insight into the impact of technology on business and society over the next decade.

The past 12 months have brought a series of exciting technological breakthroughs. Self-driving Tesla cars can now be seen on the road; Uber is testing autonomous taxis in Pittsburgh; Google DeepMind’s Alpha Go demonstrated a leap forward in artificial intelligence with a famous victory at the board game Go; and augmented reality hit the mainstream with the success of Pokémon Go. Game-changing innovation has become the norm.

Digital innovation is reshaping industries by disrupting existing business and operating models. But it is also having a profound impact on society, presenting a series of opportunities and challenges for businesses and policy-makers.

The Digital Transformation Initiative (DTI) is a project launched by the World Economic Forum in 2015 to serve as the focal point for new opportunities and themes arising from the latest developments in the digitalization of business and society. Over the past two years, DTI has analysed the impact of digital transformation across 13 industries and five cross-industry themes. We have also developed a unique value-at-stake framework to support a consistent approach to measuring the impact of technology on business and wider society. An overview of this framework is included on the next slide.

Our goal is for this framework to provide an evidence base and common language for public-private collaboration focused on ensuring that the benefits of digital transformation are fairly and widely shared.

Bruce Weinelt
Head of Digital Transformation
World Economic Forum

Mark Knickrehm
Group Chief Executive
Accenture Strategy
DTI: A NEW FRAMEWORK FOR PRIVATE-PUBLIC COLLABORATION

Our unique economic framework helps business leaders, regulators and policymakers unlock the $100 trillion of value that we estimate digitalization across all industries could generate over the next decade.

- We have developed a unique economic framework that aims to quantify the impact of digital transformation on industry and broader society.
- Our framework is new and will be iterated further over the next year, but it can already be applied at all levels of government and business, helping stakeholders make the right decisions to deliver the full potential of digital transformation.

- It provides a consistent evidence base and library of definitions for digital concepts, supporting a global, multistakeholder dialogue about digitalization and its implications.
- We have achieved proof of concept of the framework at an industry level (11 industries) and successfully piloted its application at a national / state level (in Denmark, India, the United Kingdom and the Indian state of Telangana).
The industry’s contributions allow other sectors to turn innovations into sophisticated products that enable digitalization.

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 and lives 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 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 as seen in the figure to the right and its integration into many aspects of our everyday lives.

At the same time, the industry itself is being transformed through digitalization. New technologies are being applied across the industry’s value chain; digital natives are entering the sector; and the digitalization of customer industries is generating shifts in demand; and the industry should closely monitor pockets of digital disruption.

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The vast, global scale of the Chemistry and Advanced Materials industry

- **90%** % of everyday products containing chemicals
- **~100,000** Chemicals on the market today
- **~10 million** People employed in the industry
- **~2%** Contribution of the industry to global GDP
- **$3.5 trillion** Chemical sales in 2014
- **$6.9 trillion** Forecast chemical sales in 2030

Source: World Economic Forum / Accenture analysis; CEFIC; press research
The important contribution of the Chemistry and Advanced Materials sector to enabling digitalization is not well recognized, although the industry’s products are used in everything from smartphones to drones.

<table>
<thead>
<tr>
<th>Examples of products from Chemistry and Advanced Materials used in key technologies</th>
<th>Growth rates for key innovations</th>
<th>Examples of relevant products from chemistry and advanced materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric vehicles</td>
<td>Annual sales of electric vehicles 2020: 4.9 million</td>
<td>Plastics, composites and battery technologies</td>
</tr>
<tr>
<td>Drones</td>
<td>Market size for drones* 2015: $10.1 billion 2020: $14.9 billion</td>
<td>Plastics, composites and battery technologies</td>
</tr>
<tr>
<td>Smartphones and tablets</td>
<td>Mobile devices in use 2015: 8.6 billion 2020: 12.1 billion</td>
<td>Substrate, backplane, transparent conductor, barrier films and photoresists</td>
</tr>
<tr>
<td>Flexible displays (e.g. wearable devices, VR, TVs)</td>
<td>Market for AMOLED** displays 2016: $2 billion 2020: $18 billion</td>
<td>Substrate, backplane, transparent conductor, barrier films and photoresists</td>
</tr>
<tr>
<td>High-speed internet</td>
<td>Fixed broadband speed 2015: 24.7 Mbps 2020: 47.7 Mbps</td>
<td>Ultrapure glass chlorosilane</td>
</tr>
<tr>
<td>More efficient and smaller integrated circuits</td>
<td>Processor logic gate length 2015: 14mm 2019: 7mm</td>
<td>Dielectrics, colloidal silica, photo resists, yield enhancers and edge-bead removers</td>
</tr>
</tbody>
</table>

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

Source: Cisco; Fraunhofer Institute, IDTechEx; International Energy Agency; MarketsandMarkets; Navigant Research; Radicati
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. The industry overall is expected 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.

Digitalization is expected to transform some key aspects of the way the industry operates, e.g. through higher levels of efficiency and productivity, digitally boosted innovation, enhanced data management and insight generation, and changes to the industry’s way of working.

Digitally enhanced offerings, which complement chemicals and materials sales, are expected to become more important in the industry’s portfolio. Digital ecosystems are predicted to grow in importance, as they allow Chemistry and Advanced Materials companies to flexibly complement internal capabilities with external ones.

Digitalization of research procedures, data analytics, machine learning and robotics all dramatically increase R&D productivity and speed. Applied to biotech, this could make the identification of specific microbial strains that enable direct-route microbial-based production of fine and specialty chemicals much more probable – with drastic impacts on current value chains.

The plummeting cost and increasing capabilities of digital technologies such as 3D printing are enabling innovative and agile start-ups to enter spaces traditionally dominated by incumbents. By integrating 3D-printing software, hardware, materials and formulation capabilities, new entrants can provide customized services beyond ‘just’ granulate. These players could set themselves up at the intersection between the sector and customer industries, targeting value-added margins.

New entrants can threaten chemical distribution approaches and companies by providing B2B platforms leveraging deep platform, logistics and B2B business knowledge and capabilities.
Three themes are expected to underpin the digital transformation of the Chemistry and Advanced Materials 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 (AI), 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 encourage the industry to build flexible and interconnected innovation ecosystems. Intense collaboration and data sharing along the value chain helps to better address customer requirements and manage volatility.

**Total value at stake**

- **Digitalize the Enterprise**
  - Industry: **$190-280 billion**
  - Society: **$4 billion**

- **Go Beyond the Molecule**
  - Industry: **$120-270 billion**

- **Collaborate in Ecosystems**
  - Included in value at stake for Digitalize the Enterprise
Within each theme, digital initiatives 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.
Digitalization could unlock up to $550 billion of value for the industry and wider society over the next decade. Positive societal impacts include reduced emissions and lower injury rates in the industry workforce.

The majority of the potential value of digitalization in Chemistry and Advanced Materials is likely to accrue to the industry itself ($310-550 billion globally over the next 10 years). Potential value to society is likely to be around $4 billion. Two initiatives (Digitally Enabled Offerings and Business Models, and Augmented Workforce) represent more than 60% of the total value at stake.

**Chemistry and advanced materials: value at stake for industry and wider society (by digital initiative)**

<table>
<thead>
<tr>
<th>Initiative</th>
<th>Industry</th>
<th>Society</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital R&amp;D</td>
<td>28-31</td>
<td></td>
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<tr>
<td>Digital Plant</td>
<td></td>
<td>35-60</td>
</tr>
<tr>
<td>Digital Supply Chain</td>
<td>40-70</td>
<td></td>
</tr>
<tr>
<td>Augmented Workforce</td>
<td>85-120</td>
<td></td>
</tr>
<tr>
<td>Digitally Enabled Offerings and Business Models</td>
<td>110-250</td>
<td></td>
</tr>
<tr>
<td>Advanced Customer Interaction</td>
<td>10-20</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2-4</td>
<td>308-551</td>
</tr>
</tbody>
</table>

Source: World Economic Forum / Accenture analysis
FOCUS ON DIGITALIZE THE ENTERPRISE:
DIGITAL INITIATIVES

Digital technologies will help further increase efficiency across core operating functions (such as R&D, plant operations and the supply chain); augment workforce capabilities; and further improve health and safety.

Digital R&D
Digital technologies such as analytics, machine learning and robotics, are improving all aspects of the R&D cycle including ideation, experimentation and automation. This helps deliver new products to the market at the lowest possible cost. This initiative could generate $28-31 billion of value for the industry through enhanced efficiency and productivity in R&D operations.

Digital Plant
Chemical plants today are already highly automated, but new technologies can take them beyond traditional control systems. Applying digital technologies (e.g. IIoT or real-time analytics), can optimize processes, improve asset reliability and enable remote monitoring. The value of this initiative is $35-60 billion to industry (improved yields and efficiency) and $4 billion to society (reduced emissions).

Digital Supply Chain
Digitalization (e.g. through analytics or automation), can bolster supply chains through better sourcing, supply chain planning, and product management and handling, making them more resilient and flexible. This could create $40-70 billion of value for the industry, thanks to improved procurement, reduced logistics costs and increased efficiency in administrative supply chain functions.

Augmented Workforce
Adopting digital technologies (e.g. IIoT, virtual reality and mobile devices) to augment the capabilities of the workforce can improve worker safety, productivity, operational workflows, knowledge management and training. This initiative could unlock $85-120 billion for the industry through improved workforce safety and more efficient on-site operations and maintenance.

Illustrative examples:
- BASF
- zymergen
- SOLVAY
- syngenta
- Sadara
- AIR LIQUIIDE

Note: Further benefits of digitalization (e.g. reductions in lost sales) that are valid on a single-company level are not included in this industry-wide analysis.
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 enabling outcome-driven business models and complementing product sales with digital services or offerings. Connectivity, large amounts of data and the capability to analyse this data enable companies to better identify and target outcomes desired by customers, and make their product and service performance predictable and measurable. This initiative could generate an additional $110-250 billion of additional value for the industry over the next decade.

**Advanced Customer Interaction**

Digital technologies (e.g. analytics and artificial intelligence) are helping companies improve their understanding of customers, enhance their interactions with them, and offer new ways to serve them. The potential value of this initiative for the industry is $10-20 billion, deriving from increased efficiency in sales, marketing and customer service, and value accruing to potential new entrants in commercial platforms or marketplaces.

**Accelerated Circular Economy**

The circular economy decouples economic growth from the use of scarce resources. Embracing circular economy concepts is often driven by innovation (for example, digitalization is expected to further accelerate progress in plastics recycling or bio-based plastics). Opportunities include avoiding waste in operations in the sector, optimizing customer production processes, and generating transparency along the circular value chain. The value at stake for this initiative has not been calculated.

**Illustrative examples:**

- AkzoNobel
- carbon3D
- austin materials marketplace
- Dow

Note: Further benefits of digitalization (e.g. reductions in lost sales) that are valid on a single-company level are not included in this industry-wide analysis.
Future materials discovery and deployment will be founded on collaboration between companies, across a complex and highly interconnected ecosystem.

**Innovation Ecosystem**

Companies need to rethink external boundaries and create an innovation ecosystem: an extended network of alliance partners, universities, entrepreneurial companies, software suppliers, customers, and their downstream customers. Within this kind of ecosystem, innovation can come from multiple sources and involves collaboration built on flexible partnerships. Digital technology plays a key role in creating connections and supporting collaboration, enabling extensive information sharing and giving virtual teams the tools they need to work together seamlessly. Value at stake for this initiative has been included in the Digitalize the Enterprise theme.

**Value Chain Collaboration**

Companies collaborating in supply-and-delivery ecosystems can use planning platforms 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 value 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. Value at stake has been included in the Digitalize the Enterprise theme.

Illustrative example: [BASF]
Here are just three of the many examples that can be found in our white paper on digital transformation in Chemistry and Advanced Materials.

<table>
<thead>
<tr>
<th>Company</th>
<th>Example Description</th>
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<tbody>
<tr>
<td><strong>Air Liquide:</strong></td>
<td><strong>Visualizing Information in Augmented Reality</strong></td>
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<tr>
<td></td>
<td>Leveraging its expertise in running production units and the multiple competencies</td>
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<td></td>
<td>acquired in recent years, “Connect” is part of the Air Liquide Group’s quest to</td>
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<td></td>
<td>invent the plant of the future. This project combines internal skill sets and many</td>
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<td></td>
<td>possibilities offered by digital technologies: connected eyewear, tablets, 3D</td>
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<tr>
<td></td>
<td>modeling, etc. Connected eyewear, integrated into a safety helmet to pass on vital</td>
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<td></td>
<td>real-time information while keeping the wearer’s hands free, is undergoing feasibility</td>
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<tr>
<td></td>
<td>tests at Air Liquide. It conveys sounds and images to remote support teams, who can</td>
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<tr>
<td></td>
<td>then deliver immediate technical assessments or adjustments. Instructions are passed</td>
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<tr>
<td></td>
<td>on visually – and instantly – on the screen of the field worker’s glasses.</td>
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<tr>
<td><strong>Clariant:</strong></td>
<td><strong>Helping Oil and Gas Operators Improve Efficiency and Customer Service</strong></td>
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<tr>
<td></td>
<td>Clariant Oil Services’ VeriTrax Delivery is an integrated chemical delivery and data</td>
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<td></td>
<td>management system to help oil and gas operators obtain more frequent and accurate</td>
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<td></td>
<td>information about their chemical usage, product spend and tank levels. It integrates</td>
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<td>a GPS capability with a computer tablet, and a pump system with a smart meter,</td>
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<td></td>
<td>adding value to the oil and gas sector by driving down costs (through fewer site</td>
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<tr>
<td></td>
<td>visits), boosting efficiency and accelerating business processes, such as budgeting</td>
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<tr>
<td></td>
<td>procedures. When a chemical delivery is made, GPS immediately identifies the well</td>
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<tr>
<td></td>
<td>or dispatch location, and smart meters capture the amount of product dispensed and</td>
</tr>
<tr>
<td></td>
<td>upload the information to an enterprise resource planning system.</td>
</tr>
<tr>
<td><strong>BASF:</strong></td>
<td><strong>Connecting People to Tackle Urban Living, Energy and Food Challenges</strong></td>
</tr>
<tr>
<td></td>
<td>BASF’s co-creation programme, “Creator Space”, is designed to encourage collaboration</td>
</tr>
<tr>
<td></td>
<td>with customers and partners, and to build a deeper understanding of the challenges</td>
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<tr>
<td></td>
<td>relating to urban living, energy and food. Topics addressed in 2015 include Mumbai’s</td>
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<tr>
<td></td>
<td>water supply problems and smart energy. Concepts are tested during a period of rapid</td>
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<tr>
<td></td>
<td>assumption-based experimentation, both in the lab and with customers, influencers</td>
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<tr>
<td></td>
<td>and potential delivery partners. Seed funding for promising ideas increases the</td>
</tr>
<tr>
<td></td>
<td>likelihood of success and the reach of the entire system’s innovation capability.</td>
</tr>
</tbody>
</table>
Seizing the $550-billion opportunity that digitalization in chemicals and advanced materials potentially represents will depend on the industry’s success in overcoming the following 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.

**Cybersecurity**
The management of an increasingly complex cybersecurity space is considered an imperative – and a 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**
Creating new digital business models is one of the more challenging initiatives. Identifying the right ideas, managing internal competition for resources, establishing a partner system and commercializing offerings are all seen as issues to be tackled. The integration and interoperability of enterprise systems (IT / OT integration) is not only a technical challenge but includes organizational alignment efforts, too.

**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 their existing internal procedures and policies to effectively collaborate in digital ecosystems.
Digitalization is a huge opportunity for Chemistry and Advanced Materials companies, but unlocking its full potential requires resourcefulness, creativity and a willingness to embrace constant and rapid change.

**Imperatives for industry**

**Set the right digital strategy**
- Have a digital strategy and roadmap in place – driven by the CEO or at least with direct attention from the board.

**Manage cultural change and bring your workforce into the digital age**
- Promote an open and agile culture to cope with constant change across all levels of the organization.
- Leverage and train employees with digital technologies. Apply advanced knowledge-management tools to support changes in working style and the transfer of knowledge from an ageing, soon-to-retire workforce to younger colleagues.

**Ensure cybersecurity**
- To protect against cyberattacks, assign appropriate attention, investment and capabilities to managing cybersecurity.

**Collaborate in digital ecosystems and accelerate partnerships**
- Identify and understand network partners and dynamics in the network, and the role your company wants to play within the relevant R&D, offering and distribution ecosystems.

**Identify, develop and launch new business models**
- Imagine what your business models would look like if the core businesses were complemented with digital services or even digital business models.

**Imperatives for policy-makers**

**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.
- 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**
- Develop harmonized data structures would support the interoperability of Industrial Internet of Things (IIoT) devices and systems.
- Ensure that current concerns on data privacy and usage, security and interoperability can be resolved.
- 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.
Over the past two years, DTI research has focused on understanding the impact of digital transformation in 13 industries and drawing insights from the cross-industry themes that came out of that analysis.

We have covered five cross-industry themes. Digital Consumption explains how the rapidly changing expectations of digital customers are forcing enterprises to reinvent themselves. Digital Enterprise looks at how companies can respond by rethinking every aspect of their business. Platform Economy focuses on the immense impact of one type of digitally enabled business model – B2B platforms. The adoption of new digital business and operating models is having a profound impact on society, a theme we analyse in Societal Implications. We then introduce our quantitative analysis of the impact of digitalization on business and wider society in our final cross-industry theme, Societal Value and Policy Imperatives.

Our industry deep dives have covered 13 industries: Automotive; Aviation, Travel and Tourism; Chemistry and Advanced Materials; Consumer; Electricity; Logistics; Media; Mining and Metals; Oil and Gas; Professional Services; Retail and Telecommunications.

White papers, SlideShares, articles, an overall executive summary for the DTI project, and a library of video interviews can be found on our website.
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Project Team Contributors

World Economic Forum

- Mark Spelman, Co-Head, System Initiative on Shaping the Future of Digital Economy and Society
- Bruce Weinelt, Head of Digital Transformation
- Fernando Gomez, Head of Chemistry and Advanced Materials Industry
- Nour Chaabane, Community Lead, Chemistry and Advanced Materials Industry
- Reema Siyam, Project Lead, Digital Transformation Initiative

Accenture

- Bernd Kreutzer, Accenture Strategy, Global Lead Chemicals & Natural Resources
- Mario Galovac, Accenture Strategy, Chemicals & Natural Resources
- Wolfgang Popp, Accenture Strategy, Project Lead and World Economic Forum Secondee
- Anand Shah, Accenture Strategy, Digital Transformation Initiative Engagement Partner
- Tim Beckmann, Accenture Strategy
- Shishir Shroff, Accenture Strategy, Value Expert