MIT Technology Review Insights

Produced in partnership with

revvity signals

Focus on accelerated digitalization helps decarbonization and emissions efforts, and drives innovation.

Creative chemistry: Adapting to the 21st century

Preface

“Creative chemistry: Adapting to the 21st century” is an MIT Technology Review Insights report sponsored by Revvity Signals. To produce this report, MIT Technology Review Insights conducted interviews with nine executives, professors, and industry leaders. Adam Green was the author of the report, Michelle Brosnahan was the editor, and Nicola Crepaldi was the publisher. The research is editorially independent, and the views expressed are those of MIT Technology Review Insights.

We would like to thank the following executives for providing their time and insights:

Michel Claassens, Global Head of Digital Solutions, AkzoNobel

Rui Cruz, Vice President of Core R&D, Dow

Bernd Elser, Senior Managing Director, Global Lead for Chemicals, Accenture

Arne Kätelhön, Co-founder and CEO, Carbon Minds

Jerker Ligthart, Senior Chemicals Advisor, ChemSec

Bastian E. Rapp, Professor of Process Technology at the Department of Microsystems Engineering, University of Freiburg

Patrick Ryan, General Manager, Surface Digital Platform, Chevron

A. N. Sreeram, Senior Vice President, Research and Development, Chief Technology Officer, Dow

David Williams, Chief Innovation Officer, AksoNobel

Daniel Witthaut, Executive Director Innovation, Cefic

Foreword

As the chemicals industry heads into the 21st century, it remains the backbone of all of the industries that power our global economy. That continuity can be depended on, as can the current pace of change in the digital economy, the hunger for clean energy, and the need to protect our planet. Transformational change is part of our journey at Revvity Signals as specialists in life sciences and diagnostics.

The name “Revvity” comes from the word “revolution,” signifying vast change, and “vita,” the word for “life” in Latin. Our company serves customers at the heart of both: across the pharmaceutical, biotech, and material science sectors, with a mission of expanding the boundaries of human potential through science. Revvity generated more than $3 billion in revenue in 2022, and our more than 11,000 employees see the challenges faced by our customers as a call to action.

The chemicals industry faces some of the new economy’s toughest challenges. Much of the industry relies on legacy infrastructure and processes. Consumers and investors are looking for companies with advanced environmental, social, and governance (ESG) standards. Tightening government regulations are demanding fine-tuned accountability. The Earth demands our attention as well, as we strive to transition to renewable energy sources and stop damage to our environment: Chemicals is the third largest industrial sector for direct CO2 emissions. No net-zero emissions goals are possible without the chemicals industry’s full commitment.

The key to achieving these goals is digitization. These forward-thinking technologies will help create cyclical supply chains that minimize waste and maximize energy sources; produce the ability to trace carbon throughout the economy; accelerate research productivity, improve operational efficiency, and enhance safety in the workplace; and help talented people with the precise planning and leadership necessary to make the digital transition.

We hope to leverage our heritage of success and our expertise to help the chemicals industry forge new pathways faster, to meet the exciting challenges of the 21st century.

Revvity Signals

CONTENTS

01 Executive summary

The chemicals industry helped build the 20th century, and is urgently adapting to the 21st. Almost all daily goods rely on output from the chemicals sector, from clothes and home insulation to fertilizer and medicine. But this energy-hungry industry needs innovation to find safer, more sustainable products. With tightening regulation and growing pressure from consumers and investors, the industry is embracing digital capabilities. Digitization is key to achieving a toxin-free environment, climate neutrality, and a circular economy.

As an industry with significant regulation and legacy IT infrastructure, chemical companies face hurdles scaling digital projects. Among key strategic practices are starting small, creating central nodes to coordinate initiatives, and investing in digital literacy.

The following are the key findings for this research:

- **Demand for decarbonization and emissions reduction is accelerating.** The chemicals industry is the most energy-hungry of all in terms of carbon dioxide (CO2) emissions: If growth continues at current rates without decarbonization solutions, the sector's greenhouse gas (GHG) emissions will double within 30 years. And the global push for greener industry means governments are stepping up regulation. This means tackling "forever chemicals" that do not biodegrade, and reducing the scale of chemical pollution. Due to its reach into many industries, the sector is a lynchpin for sustainability. This will require partnerships and data standards. No net-zero industries are possible without a net-zero chemicals industry.

> "If we can't achieve net-zero chemicals, there won't be any net-zero products in almost every sector."
>
> Arne Kätelhön, Co-founder and CEO, Carbon Minds

- **AI, digital twins, robotics, and lab automation are accelerating research productivity, improving operational efficiency, and enhancing safety.** Chemical companies increasingly see digital transformation as a way to improve safety, optimize production, and advance R&D. AI is booming in analytical chemistry and biochemistry. AI, machine learning (ML) and digitization of research are enabling high-throughput research, allowing scientists to build on past efforts efficiently, identify promising ideas, and forecast product performance. Robotics and automation reduce human error and minimize the need for human contact with hazards, and the Internet of Things (IoT) allow visibility into everything from chemical transport to environmental, social, and governance (ESG) reporting.

- **Transforming to scale requires strategic oversight and coordination, a talent and capabilities plan, a focus on data standards and interoperability – and leadership.** As chemical companies digitalize, some struggle to transition from pilot projects to companywide transformation. As digitalization increases the surface area for cyberattacks, security protocols must grow alongside. Companies that succeed often have a team dedicated to innovation and R&D, with organizational and strategic factors carefully mapped out. Without precise planning, digitization can result in inefficiency and confusion. High-level leadership is required to steer the effort and manage momentum.

02 Transforming chemistry

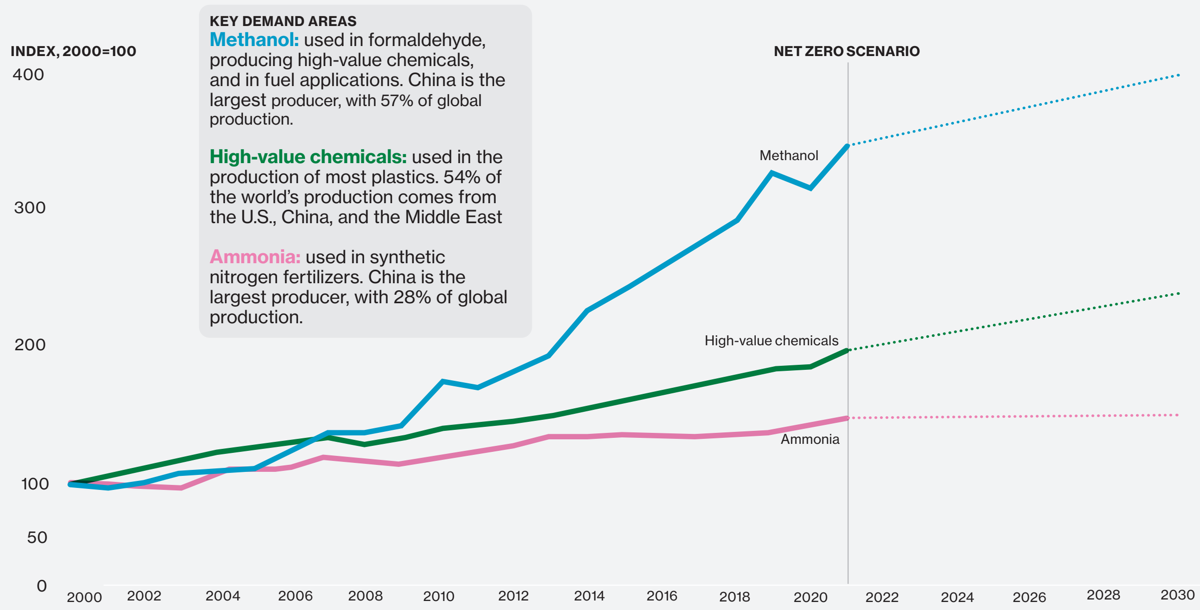
The chemicals industry accounts for 5% of global GDP and supports the production of 96% of manufactured goods.[1] From plastics to pharmaceuticals, rubber to fertilizer, there is little in the modern world that does not owe its existence in part to breakthroughs in chemistry.[2]

Chemicals is the most energy-hungry industry – and the third largest industrial subsector in terms of direct CO2 emissions. Half of its energy input is consumed as feedstock, as fuel is a raw material input and not just an energy source.[3] Industry growth, without abatement, could double the sector's GHG emissions in the next 30 years.[4]

Because of how many goods rely on the chemicals industry, it is a lynchpin for the global sustainability transition. "If we can't achieve net-zero chemicals, there won't be any net-zero products in almost every sector," says Arne Kätelhön, co-founder and CEO of Carbon Minds, a startup that provides lifecycle emissions data and assessment tools for the industry.

Alongside decarbonization, the industry must transition from products that contain hazardous substances, such as per- and polyfluoroalkyl substances (PFAS). "Forever chemicals," which do not biodegrade, can be found in the blood of 97% of people in the U.S.[5] Bisphenol A (BPA) can seep into food and beverages from plastic

Figure 1: Demand for chemical products needs to decrease to achieve the Net Zero Emissions by 2050 Scenario Private and public sectors need technological innovation, efficiency gains, and to increase recycling rates.



Source: Compiled by MIT Technology Review Insights with data from the International Energy Agency, 2023.[6]

containers, with potential ramifications on reproductive and cardiovascular health.[7]

A step up in regulations

Governments are increasing regulations for the chemical industry. As part of the European Green Deal, the EU is reviewing its Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) framework that applies to all chemical substances.[8,9]

"The EU is really the front runner when it comes to chemical regulation," says Jerker Ligthart, senior chemicals advisor at ChemSec, a non-governmental organization. "It has proliferated in the chemical regulation arena globally." South Korea created a version of REACH, adapted to local conditions, Ligthart says, and Europe's Restriction of Hazardous Substances (RoHS) in Electrical and Electronic Equipment directive spawned similar directives in China, Korea, Singapore, and Japan.[10]

The U.S. created the 2016 Frank R. Lautenberg Chemical Safety for the 21st Century Act, which requires the U.S. Environmental Protection Agency (EPA) to evaluate existing chemicals under clear and enforceable timeframes, risk-based assessments of chemicals, improved transparency of public information, and mandated funding to carry out the law.[11,12] The EPA required utilities to remove PFAS chemicals from

> "The demand for innovative products is bigger than ever considering net-zero commitments, the need to operate with higher safety and efficiency, and the customer interface – which requires a better understanding of customer needs."
>
> Bernd Elser, Senior Managing Director, Global Lead for Chemicals and Natural Resources, Accenture

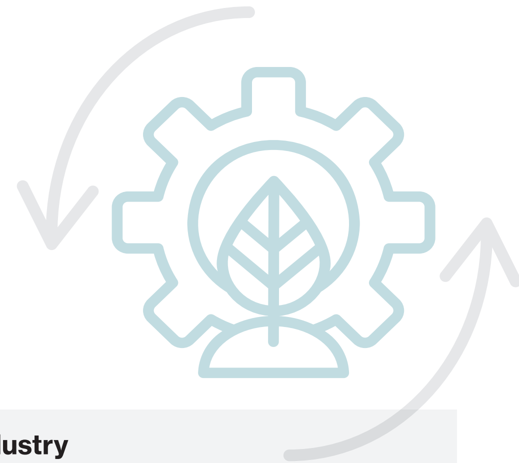
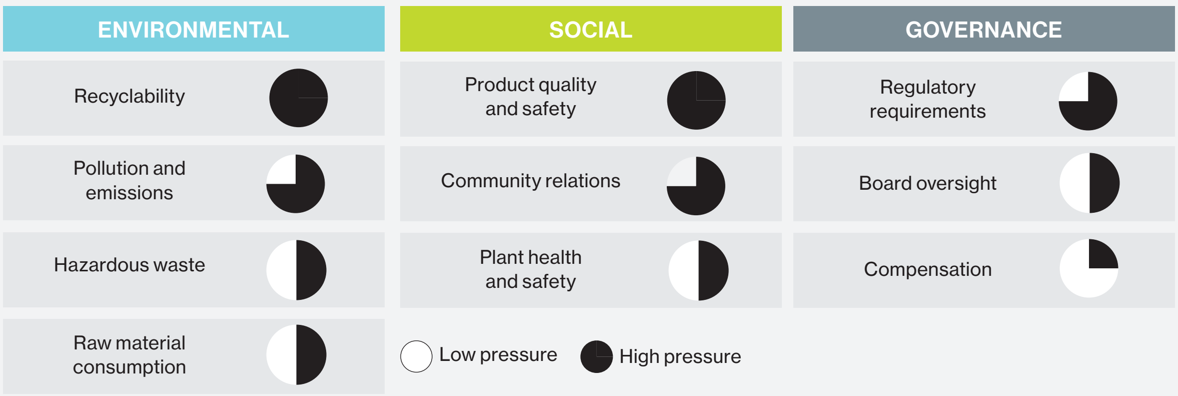


Figure 2: Pressure to improve ESG practices in the chemicals industry



Source: Compiled by MIT Technology Review Insights with data from ADI Analytics, 2023[13] drinking water for the first time in 2023, a landmark move that came earlier than many anticipated.[14] In 2022, UN member states agreed to forge an international, legally binding treaty to end plastic pollution by 2024.[15] While recycling is crucial, reducing the scale of plastic production and waste will mean significant innovation by the industry, such as development of biodegradable and alternative plastics.

Investors are following suit. “If the big investors are demanding something, the chemical companies have to listen to it,” says Ligthart. The Investor Initiative on Hazardous Chemicals (IIHC), a consortium of 50 institutional investors with more than $10 trillion in assets, is pushing for an increase in transparency and to phase out forever chemicals. Kätelhön says good environmental performance will mean access to capital and positive brand reputation.

Geopolitics echoes around the globe

Geopolitics is also a pressure for the chemicals industry. The Russian war against Ukraine has taken a toll on the industry, increasing feedstock and energy costs, leading to safety concerns and increased costs for land and air transport routes in Ukraine and Russia.[16] The cost of benzene, used to make rubber, nylon, and pharmaceuticals, surged to a record-high of $1,900 per ton in June 2022.[17] Chemicals toluene and xylene, used in plastic packaging and textiles, also spiked to the highest prices since records began in the 1980s.[18] While price dynamics normalized during 2023, volatility in 2022 was a reminder that the industry needs to reduce reliance on fossil fuels and derivatives, which are highly effected by geopolitical instability. The war in Ukraine could still limit flexibility or appetite to embark in new and untested waters.

> “The EU is really the front runner when it comes to chemical regulation.”
>
> Jerker Ligthart, Senior Chemicals Advisor, ChemSec

03 The digital imperative

The chemicals industry increasingly sees digital transformation as a means to improve safety, optimize production, and spark breakthroughs in R&D for the challenges and opportunities of the 21st century. Digitization is one of four focus areas in the EU Transition Pathway for the Chemical Industry, alongside a toxin-free environment, climate neutrality, and circularity.[19]

Renewable energy, sustainable transport, and the circular economy requires innovations in chemistry; from the resins, coatings, and adhesives needed in renewable technology to viable and scalable alternative energy sources and feedstocks like biofuels, algae, and lignocellulose.[20]

Green chemistry, the design of chemical products and processes that reduce the use of hazardous inputs,[21] requires best-in-class digital R&D and data management to foster collaborative research. An example is AlphaFold, the AI-powered protein prediction tool developed by DeepMind and the European Molecular Biology Laboratory. Predictions are based on a protein databank of 200,000 samples. AlphaFold illustrates the benefits of bringing shared data and tools to life sciences research.[22]

"The demand for innovative products is bigger than ever considering net-zero commitments, the need to operate with higher safety and efficiency, and the customer interface, which requires a better understanding of customer needs," says Bernd Elser, a senior managing director and global lead for chemicals and natural resources at Accenture. Elser says the industry is currently at less than 20% of its digitization potential.

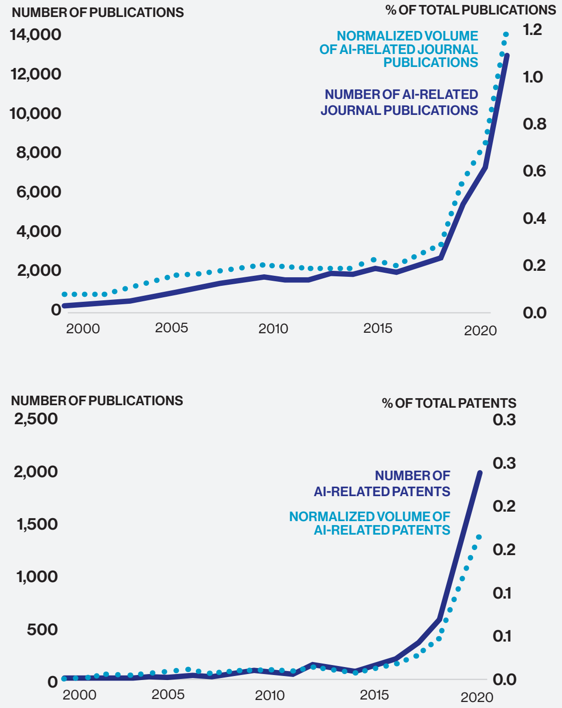
Technology boosts R&D productivity

R&D is fundamental to safe and sustainable chemistry, and digital technology will be key for productivity and efficiency. This is illustrated by the boom in journal and patent publications since 2015, as analytical chemistry and biochemistry integrate AI.

Accenture identifies six building blocks to digitalized R&D: search and content analytics, lab automation, AI, quantum computing, intelligent knowledge management, and co-creation platforms.[23] Accenture found a typical €10 billion (US$ 10.8 billion) revenue company could increase operating profits by €40 million to €70 million (US$ 43.2 million to US$ 75.6 million) through a combination of revenue and cost improvements using technology currently available.[24]

> "Looking for chemistry with the same function but less toxicity is best done by computing, because you can train datasets with thousands of substances."
>
> Jerker Ligthart, Senior Chemicals Advisor, ChemSec

Figure 3: AI-related publications and patents in the chemicals industry from 2000 to 2020



Source: Compiled by MIT Technology Review Insights with data from the Journal of Chemical Information and Modeling, 2023[25]

Daniel Witthaut, executive director of innovation at the European Chemical Industry Council (Cefic), says AI and ML speeds the search for molecular designs or structures, enabling replacement of hazardous materials. "The more machine power you have, the more you can simulate how a new chemical will behave," says Ligthart. He expects significant gains in the premanufacture stage, as companies replace hazardous or persistent chemicals. "Looking for chemistry with the same function but less toxicity is best done by computing, because you can train datasets with thousands of substances. Instead of trying out 100 different substances, you can try out 10 instead because the algorithm has already sorted out the 90% which carry toxic properties," says Ligthart.

Elser says integrated data systems that combine multiple years of data history improve R&D efficiency, drawing more knowledge from past efforts and ensuring work is not needlessly repeated. Dow digitized every research report ever written by its R&D into Adobe, for efficient deep searching. Such large data sets can then generate predictive analytics on issues like performance of new chemical compounds, such as heat resistance or adhesion.

Efficient data management systems can shorten discovery time, improve planning and experiment logistics, and facilitate collaboration. Dark data, described by Gartner as information assets stored but unutilized, could aid R&D teams when made visible, shareable, and interoperable. An estimated 55% of data stored by organizations is reportedly in the shadows. By curating, connecting, and analyzing internal data, R&D teams can search once-hidden documents to harness past efforts, and errors, to guide discovery.[26] Developing best practices in the findability, accessibility, interoperability, and reusability (FAIR) data agenda also requires well-organized data management systems, controls, and protocols, including metadata.[27]

Bastian Rapp, professor of process technology at the Department of Microsystems Engineering (IMTE) at the University of Freiburg, says AI is particularly good at finding the best parameter space for chemical reactions. AI samples data iteratively so deep neural networks can learn and optimize best-reaction conditions, he says. Rapp expects industry to embrace this AI, since increasing yield from a chemical reaction by even "a couple of percent makes a huge difference," he says.

Dow uses high-performance computing, AI, and ML as part of its high-throughput research, says A. N. Sreeram, its senior vice president of research and development and chief technology officer. This significantly increases the "probability of success in product development," he says. In plastic packaging, he says, it used to take eight to 11 years to come up with a new polymer and scale it. Today it takes about one year. Sreeram estimates digital transformation has accelerated product development by two to three times.

Adopting automation and robots for the lab

Mordor Intelligence predicts global lab automation in analytical chemistry is forecast to grow 4.31% from 2020 to 2025.[28] Offerings include IBM's RoboRXN, a fully automated synthesis system, which programs itself, planning details such as temperature changes, and whether to shake, swirl, or inject.[29] It performs up to five steps without human assistance. Researchers at the Materials Innovation Factory (MIF) at the University of

Is quantum computing a 'huge hammer looking for a huge nail'?

With classical computing for simulation chemistry, accuracy decreases as complexity – and time – increases. New systems can quickly handle large computations previously impossible. They can also look more deeply at molecular structure and bonding, aiding drug discovery. IBM is exploring quantum in chemical and petroleum companies, developing catalysts and surfactants, optimized feedstock routing, refining, marketing, and reservoir production.[30,31]

A. N. Sreeram, senior vice president of R&D and CTO at Dow, cautions that quantum computing will not solve every problem, but when combined with other technologies, it could make substantial progress within the decade.

Bayer AG and Google Cloud are collaborating on drug discovery with accelerators for ML models and computational workloads, to advance and scale quantum chemistry calculations.[32]

Dow began collaborating on quantum computing with 1QB Information Technologies (1QBit) in 2017, to speed deployment of quantum computing for discovery of new chemicals and materials.[33]

Elser cautions that quantum computing can be "a huge hammer that is looking for a huge nail. It is fantastic for individual use cases, but the challenge is to scale it."

Quantum computing in the chemicals industry value chain

	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5
	DESIGN OF CHEMICALS[1]	DESIGN OF PRODUCTS	SUPPLY CHAIN	PRODUCTION	MARKETING
IMPACT POTENTIAL	Early killer application	Early killer application	Mature quantum computing	Potential early application	Mature quantum computing
QUANTUM TOOL USED	• Quantum simulation • Optimization • Quantum AI[3]	• Quantum simulation • Optimization • Quantum AI[3]	• Optimization • Quantum AI[3]	• Quantum simulation • Optimization • Quantum AI[3]	• Optimization
EXAMPLES OF FUTURE APPLICATION	Design molecules and solid materials with required properties, reducing lab work Use computers to define shape of proteins to make better active ingredients	Discover more effective formulations by modeling how ingredients affect processes or how complex mixtures behave	Use quantum computing to optimize supply chains and logistics and to reduce costs	Improve yields and suppress by-product generation through better understanding of reactions and finding new catalysts	Use quantum AI[3] to help handle B2B and B2C customer relations

[1] New molecules.
[2] Formulations and complex assemblies.
[3] Artificial intelligence

Source: Compiled by MIT Technology Review Insights with data from McKinsey & Company, 2023[34]

> "Any time a Dow employee enters a lab, our database says what chemicals are there, what reactions are ongoing."
>
> A. N. Sreeram, Senior Vice President, Research and Development, Chief Technology Officer, Dow

Liverpool built a mobile robot chemist, which can make decisions and do all experiment tasks, from weighing solids and dispensing liquids to quantifying reaction products.[35] Designed with human-like dimensions, it works easily with equipment designed for human use.[36]

Digitalization and integrated data paired with Dow's robotics and automation targets both efficiency and safety compliance. Maintenance and online monitoring inside a reactor are now done by robots and sensors, says Sreeram. Unmanned aerial vehicles (UAVs) use sensors to monitor inside chimney stacks hundreds of feet high. "You can imagine how harsh conditions are," he says.

"Any time a Dow employee enters a lab, our database says what chemicals are there, what reactions are ongoing," says Sreeram. "Everything is recorded, barring jurisdictional privacy laws. We also record near-miss [injury] cases so that we can learn from them digitally, and it is updated monthly. Our injury and illness rate as a company is one of the best, not just in the chemical industry."

Chevron uses digital technology to reduce risk, incidents, and human error, and also track physical proximity to safety risks. "Our industry has risk, and being able to decrease that is a virtuous cycle," says Patrick Ryan, general manager of surface digital platform at Chevron. "When we do have failures, if we can reduce the likelihood that humans are in close proximity to what occurred, we limit potential injuries and fatalities," he says.

Embracing smarter supply chains

The chemical industry is embracing digital supply chain management solutions that use AI, ML, IoT, blockchain, and process automation. A 2022 Allied Market Research report valued the global IoT chemical industry market at $57.4 billion, and predicted it will reach $193.9 billion by 2031.[37]

IoT systems provide visibility into the supply chain, reducing risk. With AI's advanced analytics, enterprises can predict demand patterns to align supply chain and manufacturing. Tools like Ovinto satellite monitoring devices use GPS and sensors to monitor chemicals in transit.[38] The device sends an alert when it nears a destination, at any impact or collision, or when conditions surpass set ranges.[39]

Dow does IoT order tracing for up to 20,000 customers. Rui Cruz, vice president of Core R&D at Dow, says this improves sustainability. "It has allowed us to minimize the transportation lag between the warehouse and our customers," Cruz says. Digital technology also supports sustainability by reducing physical travel needed by field assets, Ryan of Chevron says.

Digital twins – virtual representations of physical assets – help boost efficiency. Ryan says it creates "symbiotic relationships" between technologies like AI, advanced simulating modeling, and data analytics. "The digital twin is providing a portal to access engineering information that is beyond one function," Ryan says.

This is in contrast, he says, with an engineer manually searching a metric, such as vessel operating pressure.

Looking to green and sustainable chemistry

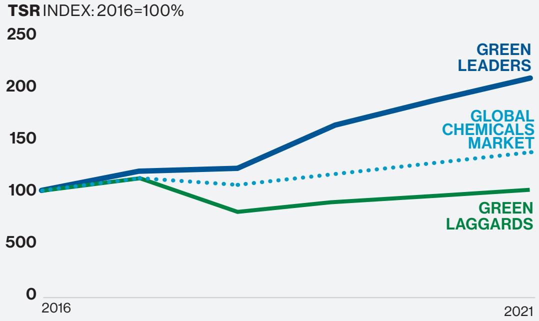
A focus on ESG factors is critical for the chemicals industry. Companies want to preserve functional advantages of current products without environmental downsides: both goals are equally important. "If a new product is sustainable but its performance is not as good or worse, it only has a very niche market," says Sreeram. "The products need to be performing at least as well if not better, and at the same time be sustainable and profitable." Research by McKinsey in 2022 indicates chemical companies with more sustainable product portfolios perform better.

There are also operational challenges, as companies invest in supply chain visibility. In complex global supply chains, one product can be produced several different ways, which presents a data challenge. "We need data on the production steps, which involve suppliers of different tiers from many different countries, so data availability is a massive problem," says Kätelhön.

Production variables multiply within categories such as feedstocks, technologies, regions, and more. A carbon footprint depends on all of these variables. "You need the granularity of data to fully understand your supply chain, and also to be able to find emission-reduction opportunities," says Kätelhön. Methodological consistency also matters. Some standard calculation methods, like ISO for carbon footprints, allow for choices and human discretion. "If two people were doing the same assessment, it's not guaranteed that they will get the same result," he says.

Figure 4: Sustainability-focus shows better capital returns

McKinsey's technological social responsibility (TSR) index measures "conscious alignment between short- and medium-term business goals and longer-term societal ones." Green leaders in all markets, with high TSR scores, were rewarded by capital markets from 2016 to 2021. Green laggards were not. Global chemical markets are shown, near the center.



Source: Compiled by MIT Technology Review Insights with data from McKinsey, 2023.[40]

Europe's Cefic anticipates innovations to address both data and circularity, such as digital product passports and external data sharing in the value chain, to enhance traceability of finished products and components.

Building an enhanced customer experience

For Dutch multinational paint and coatings company AkzoNobel, digital transformation improves customer experience through personalization and augmented reality. The company uses customer photos to demonstrate how different paint will look, and also uses VR to detect defects, says David Williams, chief innovation officer at AkzoNobel. "Similar technology helps business customers make informed choices about the properties of the coatings they select," he says.

> "You need the granularity of data to fully understand your supply chain, and also to be able to find emission-reduction opportunities."
>
> Arne Kätelhön, Co-founder and CEO, Carbon Minds

04

A focus on digital transformation

Organizations typically struggle to achieve companywide digital transformation. Chief digital officers or heads of R&D often have hundreds of pilots and use cases, Elser says. But only a handful of transformative companies have years-worth of experimental data in an accessible data lake, he says. Instead, companies typically "are struggling to scale their transformation efforts and put the right platforms and skills in place," he says.

Scaling requires data governance, institutional architecture, and talent in equal measure to new technology. Elser calls out three signs that companies are succeeding at digital transformation. "Firstly, within the IT department of the company, they will have a dedicated team looking after R&D and innovation," he says. "Secondly, they tend to think big in terms of data platforms, but not just editing one pilot after another. It starts with data integration and data contextualization. Finally, they usually have a team of data scientists who can work with the researchers to develop models and scale them up."

Favoring coordination and support over individual projects

Uncoordinated digital transformations can mean duplicated effort, confusion, and complication. Ryan says that around 2018 at Chevron, to accelerate digital innovation, different functions developed solutions, then business units could choose to adopt them, or not. This federated approach had unforeseen results. "Three people would solve the same problem three different ways," says Ryan. "We wound up paying for three solutions when one would do." Later, around 2020, Chevron took a centralized approach, pairing business and IT leads to consider scalable solutions, with more control and cost visibility.

High-level leadership support and tight business coordination is also key for Dow, where digital corporate efforts are managed by a steering team. "With the high-level support from our senior leaders and a balance between corporate and grassroots strategies, we are able to accelerate our R&D progress," says Cruz.

> "It's best to have a demand-pull approach, where people come with a problem, and we craft the digital enablement."
>
> Patrick Ryan, General Manager, Surface Digital Platform, Chevron

Large industry may strain to move away from vertical thinking. Michel Claassens, AkzoNobel's global head of digital solutions, says AkzoNobel shifted to a horizontal digital organizational interface. Its governance plan addressed transformation strategically and operationally, creating a protected, dedicated resource. This deflected internal stress and "connected everything underneath the surface of digital transformation," he says.

Starting small and proving value

Ryan advises companies to prioritize costs and technical efficiency, and avoid having too many projects. "You end up with a proliferation of solutions, technical debt, and cost, which you have to unravel later," he says. Focus on a few high-value technologies and lead with demand, and don't push solutions just because one manager wants it, Ryan says. "It's best to have a demand-pull approach, where people come with a problem and we craft the digital enablement," he says.

AkzoNobel emphasizes a holistic model allied with strategic business objectives all the way to execution, says Claassens. "We try to avoid the trap of going too big all at once," he says. "We focus on strategic sales where we can make the most impact."

The digital environment must also be simple and navigable. Overzealousness can leave staff struggling to navigate too many interfaces. A 2022 study by Forrester Consulting and Airtable found organizations with more than 20,000 employees are on average using 367 software apps and systems. These data and workflow silos mean employees spend 2.4 hours every day searching for information. The study found these processes lower productivity by 24%.[41] Knowledge management and mobilization, often harnessing AI, can help avoid balkanized data repositories.

Minding the cyber threat

The chemicals sector is highly exposed to cyberattacks, given its strategic importance. An attack in 2017 at a petrochemical facility in Saudi Arabia used malicious software to control the memory of devices, and accessed unauthorized programs.[42,43]

A 2022 report by cybersecurity company Skybox Research Lab found an 88% increase in vulnerabilities in operational technology that could be used to attack critical infrastructure.[44] SonicWall, using data from the U.S. National Vulnerability Database and Cybersecurity and Infrastructure Agency, found malware attacks for control of devices rose 77% in the first half of 2022.[45]

"The more you digitize and the more you put on the cloud, the more vulnerable you are to hacking," says Sreeram. Dow's most sensitive data is never on the cloud, he says, but only on internal servers not connected to any network, and cybersecurity protocols are reviewed six times a year.

Capability planning for upskilling, hiring, and partnering

The most advanced digital innovations do not replace human ingenuity. Sreeram describes four stages of learning: data, information generated from data, advanced knowledge, and wisdom. "None of the AI and machine learning techniques are anywhere near advanced knowledge and wisdom," he says. "It is the best engineers and scientists who bring that."

Chemical companies are closing the digital skills gap. Only 37% of chemical companies reported a lack of qualified personnel for digitalization in EY's 2022 survey, down from 47% in 2020.[46] "We've done a lot of technology and capability mapping to understand where we want to go in the future," says Williams of AkzoNobel. "We've mapped where the technologies are, what technologies and innovations we need in the future, what capabilities we need to develop, and where we need to develop them."

Dow's most sensitive data is never on the cloud, only on internal servers not connected to any network, and cybersecurity protocols are reviewed six time a year.

"We've done a lot of technology and capability mapping to understand where we want to go in the future."

David Williams, Chief Innovation Officer, AkzoNobel

A good capability plan covers both advanced digital expertise and the entire workforce. Dow's R&D data citizenship program will ensure staff are fluent in current tools, understand how data is curated and why, and can manage data for safety, quality, and storage. Dow's "extremely critical" investment helps employees make the most educated decisions, Cruz says.

Chemical companies often partner with universities, startups, and big tech firms. Dow works with universities to digitize information and apply advanced computation for research, operations, and logistics.[47] It also works with Nvidia on generative variational autoencoders (VAEs) for chemical discovery.[48] AkzoNobel works with startups like Hyperreality Technologies, which specializes in the metaverse, and Fluid AI, which creates multichannel customer conversations using AI. These joint opportunities help both parties innovate and solve problems, says Williams. "It's not always easy to bridge the gap between adjacent technology areas."

One critical partnership challenge is pursuit of common data standards. Witthaut expects a sector-based approach to emerge to ensure the chemical industry tackles sustainability across the entire value chain. "By leveraging digital technologies to share information and create transparency across the supply chain, the chemical industry can promote circularity, reduce waste, and replace hazardous materials with safer alternatives," a spokesperson from he says.

But sharing is not yet the norm. Reaching common data standards across the array of industry tools is challenging, says Ryan. "Companies that provide digital and data services also serve competitors, and each company handles data differently and wants different standards," he says. "There is a need for industry-driven data standards and consistent architecture around a common data standard within a slate of tools."

Endnotes

1. David Yankovitz, Robert Kumpf & Aijaz Hussain, "Reducing carbon, fueling growth: Lowering emissions in the chemical industry report," Deloitte, 2022
2. Science Museum, "Green chemistry: Cleaning up the chemical industry," August 2, 2021, https://www.sciencemuseum.org.uk/objects-and-stories/our-environment/green-chemistry.
3. International Energy Agency, "Chemicals - Analysis and key findings," September 2022
4. David Yankovitz, Robert Kumpf & Aijaz Hussain, "Reducing carbon, fueling growth: Lowering emissions in the chemical industry article," Deloitte, June 2, 2022
5. National Institute of Environmental Health Sciences, "Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS)," https://www.niehs.nih.gov/health/topics/agents/pfc/index.cfm.
6. International Energy Agency, "Direct CO2 emissions from primary chemical production and CO2 intensity in the Net Zero Scenario, 2000-2030," October 26, 2022
7. Brent A. Bauer, "What is BPA, and what are the concerns about BPA?," Mayo Clinic, March 8, 2022
8. European Chemicals Agency, "Understanding REACH," https://echa.europa.eu/regulations/reach/understanding-reach.
9. European Commission, "Chemicals legislation – revision of REACH Regulation to help achieve a toxic-free environment," https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12959-Chemicals-legislation-revision-of-REACH-Regulation-to-help-achieve-a-toxic-free-environment_en.
10. European Commission, "Restriction of Hazardous Substances in Electrical and Electronic Equipment (RoHS)," https://environment.ec.europa.eu/topics/waste-and-recycling/rohs-directive_en.
11. United States Environmental Protection Agency, "Summary of the Toxic Substances Control Act,"
12. United States Environmental Protection Agency, "The Frank R. Lautenberg Chemical Safety for the 21st Century Act,"
13. ADI Analytics, "Top 10 ESG Trends in Chemicals," https://adi-analytics.com/2020/07/24/top-10-esg-trends-in-chemicals/.
14. United States Environmental Protection Agency, "Proposed PFAS National Primary Drinking Water Regulation," March 14, 2023
15. UN Environment Programme "Historic day in the campaign to beat plastic pollution: Nations commit to develop a legally binding agreement," March 2, 2022, https://www.unep.org/news-and-stories/press-release/historic-day-campaign-beat-plastic-pollution-nations-commit-develop.
16. TechSci Research, "Impact of Russia-Ukraine War on the Chemical Industry, "December 2022, https://www.techsciresearch.com/blog/impact-of-russia-ukrainewar-on-the-chemical-industry/1335.html.
17. Harry Dempsey & Yasemin Craggs Mersinoglu, "Gasoline surge pushes up costs for chemicals used in essential goods," Financial Times, July 13, 2022, https://www.ft.com/content/3f2297ee-6130-4c73-90c7-67645985b7e3.
18. Ibid.
19. European Commission, "Transition pathway for the chemical industry," March 6, 2023, https://ec.europa.eu/docsroom/documents/53754.
20. Peter Fantke, et al., "Transition to sustainable chemistry through digitalization, "Science Direct, November 11, 2021, https://www.sciencedirect.com/science/article/pii/S2451929421004745.
21. United States Environmental Protection Agency, "Definition of Green Chemistry,"
22. Ruth Nussinov, et al., "AlphaFold, Artificial Intelligence (AI), and Allostery," The Journal of Physical Chemistry, August 17, 2022, https://pubs.acs.org/doi/full/10.1021/acs.jpcb.2c04346.
23. Michael Ulbrich & Philipp Sommerhuber, "From disruption to maturity: The evolution of digital R&D in chemicals," Accenture, 2021, https://www.accenture.com/_acnmedia/PDF-158/Accenture-Digital-Research-And-Development-Chemicals.pdf.
24. Ibid.
25. Zachary J. Baum et al., "Artificial Intelligence in Chemistry: Current Trends and Future Directions," Journal of Chemical Information and Modeling, 2021, https://pubs.acs.org/doi/10.1021/acs.jcim.1c00619.
26. Jennifer Sexton, "Dark data in R&D: How knowledge management can uncover hidden value," The American Chemical Society, October 25, 2022, https://www.cas.org/resources/cas-insights/digital/dark-data-knowledge-management.
27. Hendrik Gossler et al., "A new approach to research data management with a focus on traceability: Adacta," Chemie Ingenieur Technik, September 2, 2022, https://onlinelibrary.wiley.com/doi/full/10.1002/cite.202200064#:~:text=Adacta%20is%20a%20new%20research,used%20to%20measure%20catalyst%20performance.
28. Mordor Intelligence, "Lab automation in analytical chemistry market - Growth, trends,COVID-19 impact, and forecasts (2023-2028)," https://www.mordorintelligence. com/industry-reports/global-lab-automation-in-analytical-chemistry-market-industry#:~:text=The%20benefits%20of%20laboratory%20automation,collection%20to%20 test%20result%20reporting.
29. Craig Bettenhausen, "IBM debuts chemical synthesis robot," Chemical &Engineering News, September 2, 2020, https://cen.acs.org/business/informatics/IBM-debuts-chemical-synthesis-robot/98/i34.
30. IBM, "Exploring quantum use cases for chemicals and petroleum: Changing how chemicals are designed and petroleum is refined," November 2019, https://www.ibm.com/downloads/cas/BDGQRXOZ.
31. Florian Budde & Daniel Volz, "The next big thing? Quantum computing's potential impact on chemicals," McKinsey & Company, July 12, 2019 the-next-big-thing-quantum-computings-potential-impact-on-chemicals.
32. Bayer, "Bayer to Accelerate Drug Discovery with Google Cloud's High-Performance Compute Power," January 11, 2023, https://www.bayer.com/media/en-us/bayer-toaccelerate-drug-discovery-with-google-clouds-high-performance-compute-power/.
33. Bloomberg, "Dow and 1QBit Announce Collaboration Agreement on Quantum Computing," June 21, 2017, https://www.bloomberg.com/press-releases/2017-06-21/dow-and-1qbit-announce-collaboration-agreement-on-quantum-computing.
34. Florian Budde & Daniel Volz, "The next big thing? Quantum computing's potential impact on chemicals," McKinsey & Company, July 12, 2019
35. Laura Thompson, "How Robotics and Lab Automation Unlock Chemistry and Advanced Materials Research and Innovation," Azo Robotics, August 20, 2021,https://www.azorobotics.com/Article.aspx?ArticleID=398.
36. Laura Thompson, "How Robotics and Lab Automation Unlock Chemistry and Advanced Materials Research and Innovation," Azo Robotics, August 20, 2021, https://www.azorobotics.com/Article.aspx?ArticleID=398.
37. Arpita K & Yerukola P, "IoT In Chemical Industry Market Research, 2031," Allied Market Research, August 2022, https://www.alliedmarketresearch.com/iot-in-chemical-industry-market-A17266.
38. Stefan Van Thienen, et al., "Industry 4.0 and the chemicals industry: Catalyzing transformation through operations improvement and business growth," Deloitte, 2016,
39. Ibid.
40. Obi Ezekoye, et al., "Chemicals and capital markets: Growing sustainably," McKinsey& Company, April 22, 2022
41. Forrester Consulting & Airtable, "The Crisis of Fractured Organizations, "December 2022, https://www.airtable.com/lp/resources/reports/crisis-of-the-fractured-organization.
42. Nicole Perlroth & Clifford Krauss, "A cyberattack in Saudi Arabia failed to cause carnage, but the next attempt could be deadly," Independent, March 20, 2018, https://www.independent.co.uk/news/long_reads/cyber-warfare-saudi-arabia-petrochemical-security-america-a8258636.html.
43. Chemical Industry Journal, "Chemical-processing industry responds to increasing cyber security threat," https://www.chemicalindustryjournal.co.uk/chemical-processing-industry-responds-to-increasing-cyber-security-threat.
44. "Vulnerability and threat trends report 2022," Skybox Security, 2022, https://www.skyboxsecurity.com/wp-content/uploads/2022/04/skyboxsecurity-vulnerability-threat-trends-report-2022_041122.pdf.
45. Nikolaos Boumpoulis, "Chemical companies face increasing cyber risk on the road to digitization," S&P Global, October 31, 2022, https://www.spglobal.com/ratings/en/research/articles/221031-chemical-companies-face-increasing-cyber-risk-on-the-road-to-digitization-12517764.
46. Frank Jenner, "Why the chemical industry is prioritizing digitalization," EY, August 22, 2022, https://www.ey.com/en_gl/advanced-manufacturing/why-the-chemical-industry-is-prioritizing-digitalization.
47. Dow, "Partnerships and collaborations with universities," https://corporate.dow.com/en-us/science-and-sustainability/working-together/universities.html.
48. Nvidia, "GTC Silicon Valley-2019 ID:S9417:Molecular Generative VAEs: Parallelization, Optimization, and Latent Space Analysis on the DGX-1," https://developer.nvidia.com/gtc/2019/video/s9417.

About MIT Technology Review Insights

MIT Technology Review Insights is the custom publishing division of *MIT Technology Review,* the world's longest-running technology magazine, backed by the world's foremost technology institution—producing live events and research on the leading technology and business challenges of the day. Insights conducts qualitative and quantitative research and analysis in the U.S. and abroad and publishes a wide variety of content, including articles, reports, infographics, videos, and podcasts. And through its growing MIT Technology Review Global Insights Panel, Insights has unparalleled access to senior-level executives, innovators, and thought leaders worldwide for surveys and in-depth interviews.

About Revvity Signals

Revvity Signals enables scientists, researchers and clinicians to address their most critical challenges across science and health care. With a mission focused on innovating for a healthier world, we deliver unique solutions to serve the diagnostics, life sciences, food and applied markets. We strategically collaborate with customers to enable earlier and more accurate insights supported by deep market knowledge and technical expertise. Our dedicated team of about 14,000 employees worldwide is passionate about helping customers work to create healthier families, improve the quality of life, and sustain the well-being and longevity of people globally.

revvity signals

Illustrations
All illustrations assembled by Chandra Tallman Design. All icons provided by The Noun Project. Background pattern by Adobe Stock.

While every effort has been taken to verify the accuracy of this information, MIT Technology Review Insights cannot accept any responsibility or liability for reliance by any person in this report or any of the information, opinions, or conclusions set out in this report.

© Copyright MIT Technology Review Insights, 2023. All rights reserved.

MIT Technology Review Insights

www.technologyreview.com

insights@technologyreview.com