ARTIFICIAL INTELLIGENCE AND BLOCKCHAIN

Insights and Actions for the Chemical Industry

CONTENTS

FOREWORD

Dear Reader,

New technologies are constantly on the horizon, including emerging technologies such as artificial intelligence (AI) and blockchain technology. Digitalization will be a source and driver of transformational change across all industries. The chemical industry strives to be a frontrunner in managing digital transformation. We therefore welcome Accenture's study on AI and blockchain technologies and the potential impact on the chemical industry.

The purpose of the study is to spark ideas on how the chemical industry can reap benefits from applying both technologies in their business models. AI can boost the industry toward a higher level of efficiency. New data analytics including artificial intelligence, machine learning, and deep learning are expected to impact all business processes as they will efficiently extract the value from data.

Where AI will reinvent the nature of our work, blockchain will impact how we interact across the value chain. Through blockchain, chemical companies can increase the transparency into how products are processed in each step down the value chain—allowing companies to tailor production to customers and proving the authenticity and circularity of their products.

Combined, both technologies present major opportunities for our chemical industry to contribute to long-term European policy goals, such as substantially increasing resource or energy efficiency and thus reducing carbon and other environmental footprints.

Value chains as we know them will change completely: products and related processes become more personalized, creating and delivering higher value for customers through the empowerment of local, more specialized value chains. The chemical industry will develop new data-based business models. Simultaneously, products will increasingly incorporate digital service components, enabled by the abundance and growing flow of data, to strengthen the competitiveness of the entire offer.

This study provokes new reactions to new technologies by giving valuable recommendations to our chemical industry. Let's get ready to create a (block)chain reaction.

Marco Mensink
Director General
Cefic

INTRODUCTION

On the surface, today's chemical industry looks solid, with peak cash and stable profits. Although some segments have performed better than others, in general, times have been good.

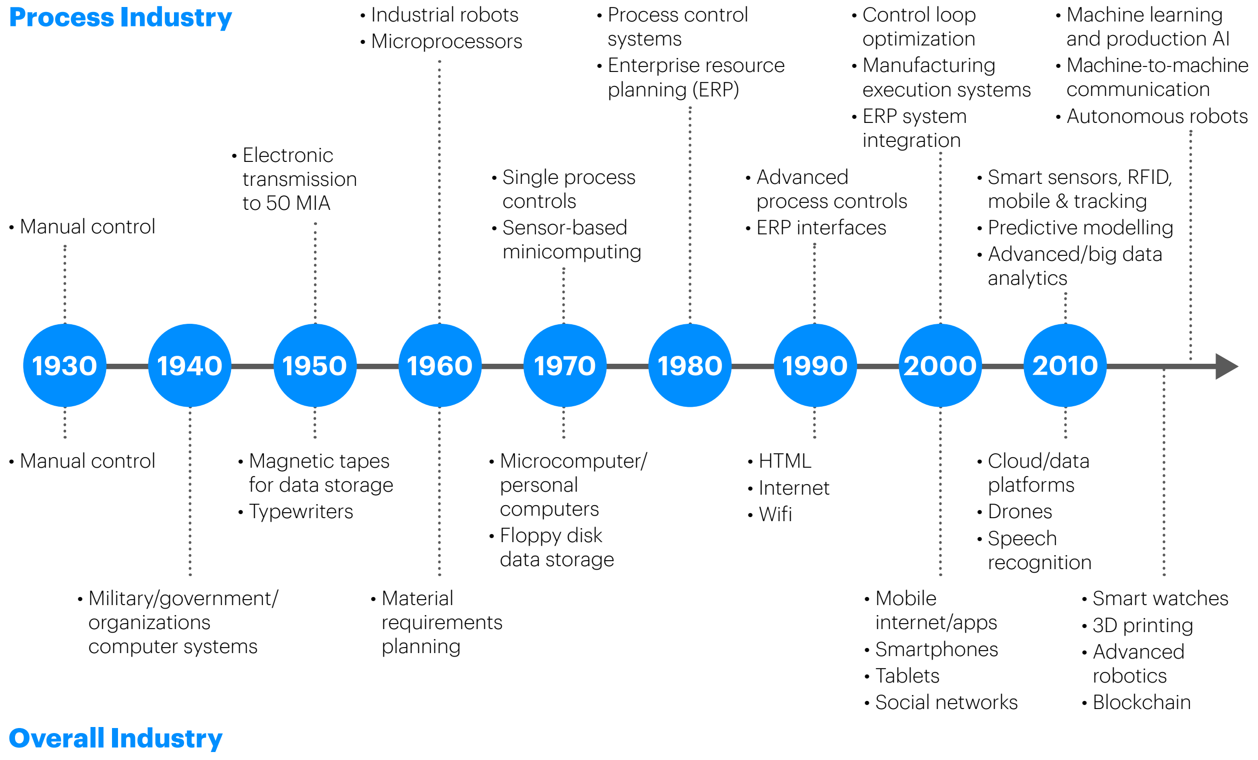
The industry's offerings continue to enable businesses around the world to optimize their performance, create new customer offerings and drive growth and profitability.

That said, the industry faces challenges on many fronts—from shifts in feedstock costs to changes in customer needs and competitive threats from new entrants. These challenges are especially significant in areas such as the customer interface, safe and sustainable operations, integrating new technologies, building the workforce to address demographic change and contending with ever-increasing regulatory requirements.

Chemical companies have long relied on advancing technology to address challenges, from the robots and microprocessors of the 1960s through the sensors, big data tools and cloud platforms of the last decade. (Figure 1)

Today, the industry's attention is turning to two emerging technologies: artificial intelligence (AI) and blockchain. Both have the potential to help chemical companies achieve step-change improvements in performance and value. (Figure 2) These technologies are likely to have an impact on the value chains and profit pools within those chains. But they could also have far-reaching implications for the structure of the entire industry and how it operates.

Figure 1: Technology evolution from mechanical to digital in process industries

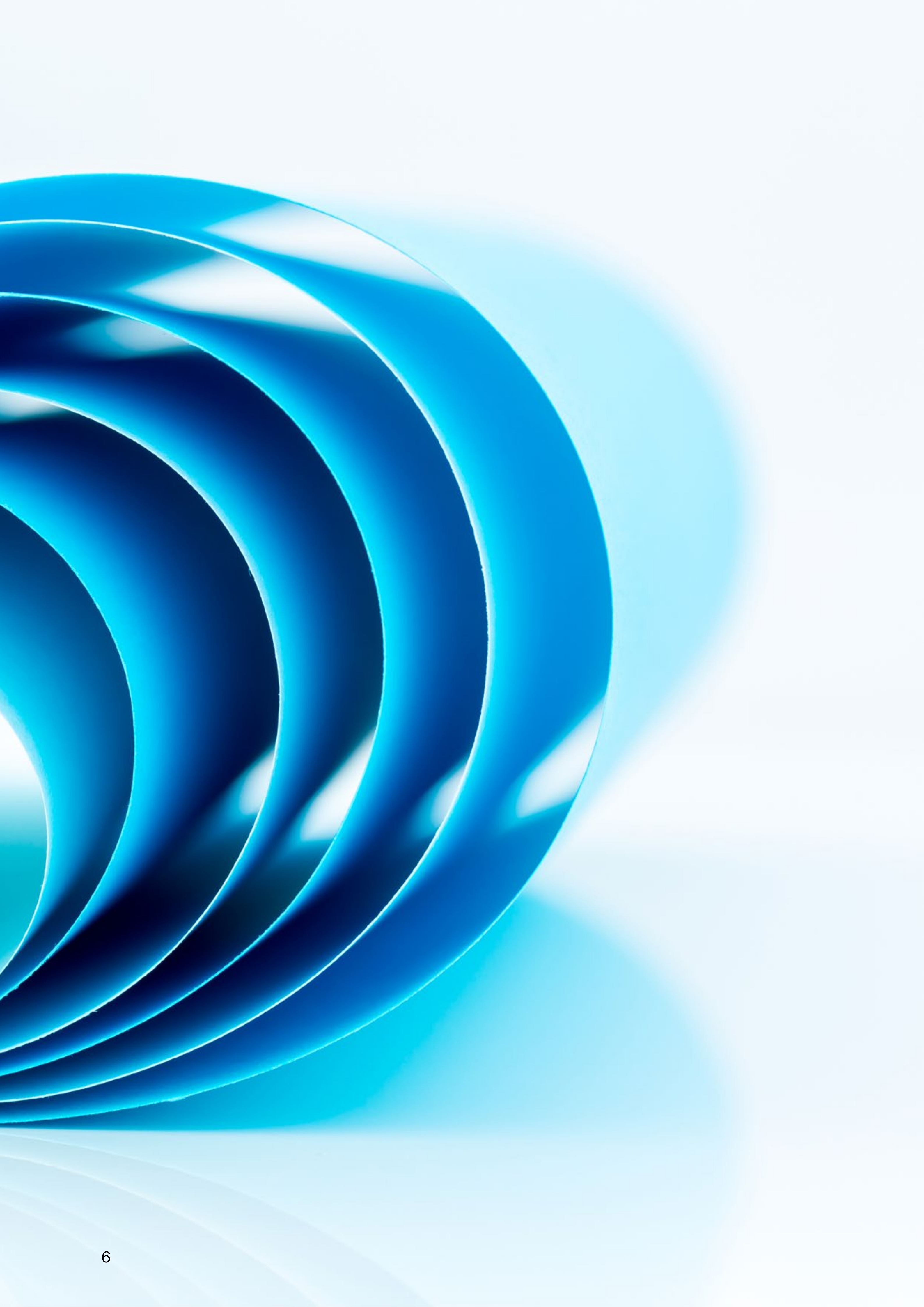


Drawing on an Accenture survey of 200 chemical industry executives from around the globe, this report explores the rapidly evolving application of these technologies in the industry.[1] It examines the economic benefits that they offer, and their broader impact on the way companies do business. The picture that emerges is one of disruption and shifting competitive advantage—and fundamental change that is coming soon.

Industry executives need to take steps to understand these technologies and their potential impact, and develop plans for incorporating them into their business and technology strategies. This report is designed to provide insights that can guide those actions and help chemical companies move ahead to take advantage of AI and blockchain—and avoid being left behind in this next stage of the digital revolution.

Figure 2: Key challenges in the chemical industry and potential applications of AI and blockchain

Key Challenges	Artificial Intelligence	Blockchain
Worker safety	Fewer injuries in production through early warning systems and generally fewer workers on site overall	–
Demographic change	Dynamic knowledge databases to ensure knowledge retention from an aging workforce	–
New market entrants/ competitors	Advanced insight on competitive activities for effective shielding strategies	Network structures creating an incentive to do business within an established network
Sustainability/ resource efficiency	Raw material or energy analytics for efficiency increase in production processes	Lifecycle management and traceability from end use back to raw material origin
Changing customer preferences	Sensing of market developments and customer demand pattern	Demand insight through value chain transparency, enabling more effective product and service development
Regulatory compliance	Intelligent document structuring, build-up of knowledge databases and systematic document analysis	Fraud resistant, tamper-evident transactions through network validations (e.g., instant data quality for REACH, product certificates, regulatory reporting)
New offerings to enhance growth	Pattern recognition in vast amounts of data (e.g., to uncover new formulations or applications for existing products)	Platform for product co-creation from different players across the value chain
Tracking value flows	–	Transparency on material transfers, finance flow and inventory levels across supply chain (e.g., improved planning and execution, near real-time tracking of delivery status)
Errors in routine tasks	Augmentation of human decision making (e.g., to increase first-time right in production)	Elimination of middle men, system breaks and human intervention in repetitive/transactional tasks
Manual effort	Automation in production, R&D and administration (e.g., chatbots in customer care centers)	Automation and elimination of transactions through near real-time validations (e.g., verifications of invoices, shipments, taxes)



DISRUPTION OF CHEMICAL BUSINESS MODELS THROUGH ARTIFICIAL INTELLIGENCE AND BLOCKCHAIN TECHNOLOGY

Chemical companies' business models are constructed around a common set of approximately 40 building blocks.

These support several organizational dimensions, which typically include product and service offerings, customer interactions, the management of assets and the supply chain and organizational enablers. (Figure 3)

Figure 3: AI and blockchain have the potential to disrupt business models substantially

Dimension	Building blocks	Configuration options					
OFFERING	Customer need addressed	Competitive price	Secured supply	High quality	Choice of configurations	Takeover of value creation	Product/process innovation
	Product offering	Catalog product	Product with configuration options	Product formulation			
	Service offering	None	Logistics services	Technical services	Co-development	Registration/ ESHQ service	
CUSTOMER INTERACTION	Pricing	Market-driven/index pricing	Cost-plus	Value-based			
	Sales	Fully automated inside sales	E-commerce	Bypassed distributors	No sales reps in field	Highly automated key account mgmt	
	Technical service	None	Remotely assisted and augmented field support	Solution co-development	Lab service		
R&D, ASSETS AND SUPPLY CHAIN MANAGEMENT	Research and development	None	Simulation of molecule modification/synthesis	Highly automated labs	Chemical process optimization/engineering		
	Production	Continuous	Campaign	Batch	Discrete		
	Order fulfillment	Make-to-stock	Make-to-forecast	Make-to-order	Make-to-project		
	Logistics & inventory	Direct to customer	Single echelon (Single-tier warehouse)	Multi-echelon (Multi-tier warehouse)	...		
	Maintenance	Predictive maintenance	Condition-oriented maintenance	Period-based maintenance	Run-to-failure maintenance		
ENABLERS	Procurement	Spot purchase	Contract agreements				
	Finance	No differentiating characteristics					
	HR	No differentiating characteristics					

Accenture believes that each of the building blocks will experience disruption from widespread adoption of AI and/or blockchain technology. Adoption of these technologies will fundamentally alter how chemical companies perform work and interact with customers. (Figure 4) In the near future, business models will focus on technology-based offerings, AI-enabled customer interactions, data-driven management of assets and the supply chain, and back-office processes that are automated as much as possible.

For example, today's cost-plus or target-price cost calculations will be replaced by contextual pricing based on foresight and market simulations driven by AI. Primary customer interactions will be based on virtual support, reducing the need for customer service centers and enabling companies to offer customers highly relevant products and services—and to do so more frequently. Chemical companies will be better able to predict process results based on more detailed specifications of input materials, or to bring their research and development (R&D) to new levels through AI-based result explorations. Logistics will be revolutionized through tamper-evident, near real-time tracking and freight settlement functionalities. And predictive maintenance will reach new heights through the processing of large volumes of data and AI-based simulations.

With these technologies, commodity and specialty chemical companies alike will experience disruptive change in their business models. They will have unprecedented visibility into the end uses of their products and will be able to operate plants with drastically reduced levels of lost-time incidents. They will also be able to offer 24/7 service at zero incremental cost and to extract insight and value from the massive amounts of data being generated continuously. At the same time, human employees will be able to focus on more creative tasks throughout the organization—allowing for more innovation and driving additional growth.

Figure 4: Key disruptions for chemical business model elements through AI and blockchain

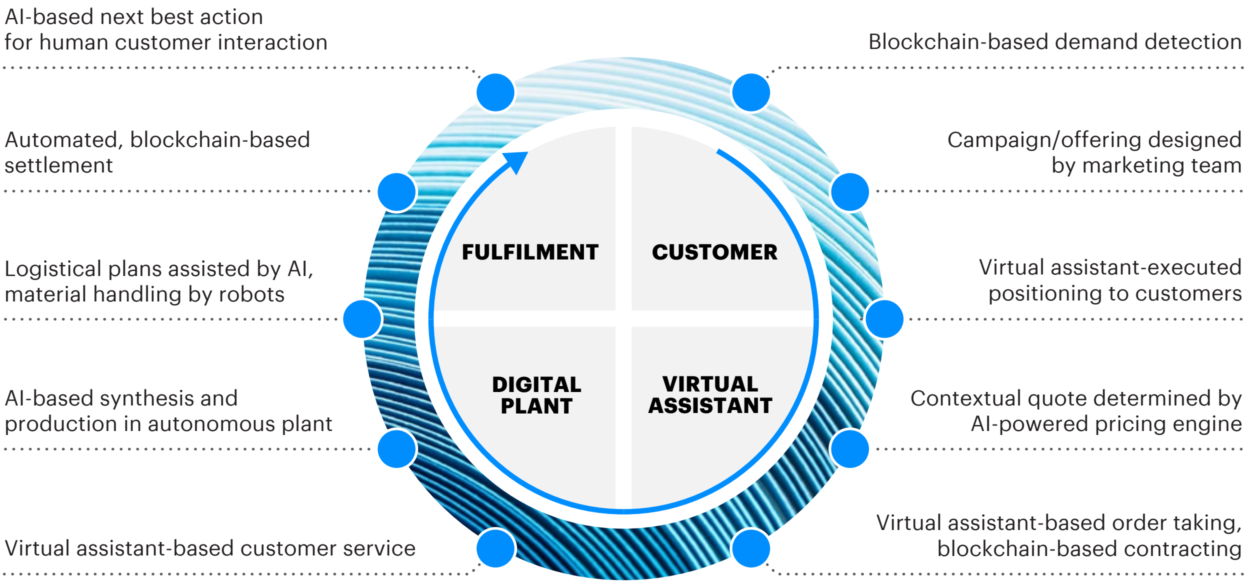
Dimension	Characteristics	Expected impact
OFFERING	Customer need addressed	• Reduction in churn rate through more scalable customer interaction, more frequent interaction, greater responsiveness
	Product offering	• Learning-based offering design: more tailored, differentiated offers, automated offering testing and campaigning • Greater insight into customer needs through blockchain-driven application transparency
	Service offering	• Greater scalability of services • More highly customized service offerings for each customer • Vendor-managed inventories, logistics, recycling and disposal • Performance-based optimization of circular services/business models—e.g., chemical leasing
CUSTOMER INTERACTION	Pricing	• AI-powered analysis of willingness to pay, price elasticity, switching thresholds, etc. • Reduced price leakage • Improved price synchronization vs. raw material cost and vs. players outside network
	Sales	• AI-based customer-specific demand sensing • Automated customer inquiries (virtual assistants) • Automated transactional tasks and simple interactions • Deeper insight through mining of overall ecosystem
	Technical service	• Wearable devices for field support with image recognition • Improved understanding of end customer needs

Dimension	Characteristics	Expected impact
R&D, ASSETS AND SUPPLY CHAIN MANAGEMENT	R&D	• Data-driven R&D, e.g., cross-BU experimentation, leverage of historic data, new applications for existing products, direct customer insights • In silico experimentation • Advanced lab automation
	Production	• Improved yield and throughput through AI-based optimization of production • Reduced off-spec, changeovers, slow-downs and downtime with AI-based demand planning and production scheduling • Reduced manual material handling through intelligent automation • Reduced energy consumption through machine learning-based optimization, improved spot vs. contracting mix for energy sourcing • Reduced effort for decision making—e.g., AI-assisted control room operations
	Order fulfillment	• Automation of administrative tasks • Machine learning-powered predictive models making make-to-stock obsolete • Improved demand visibility and supply capability • Track & trace, automated quality control, assured provenance • Reduced transaction cost (logistics, customs, quality, certificate handling, more automation, less paper)
	Logistics & inventory	• Improved network and inventory optimization • Pre-consolidations of transports • Reduced warehousing demand • Optimized loading/unloading slot management • Near-real time route optimization
	Maintenance	• Connected plants and 3-D modeling (digital twin) • Real-time, remote monitoring of equipment performance and condition • Causal analytics and advanced data visualization • Higher asset availability due to reduced unplanned downtime • Maximized hands-on-tool time through AI-powered work planning and scheduling • Reduced spare-part inventory and improved spare part availability • Reduced unplanned effort, improved prediction of high priority notifications
ENABLER	Procurement	• Lower raw material prices through higher forecast accuracy and AI-powered market intelligence and improved hedging of raw material prices • Optimized third-party spend through better scheduling and optimized procurement
	Finance	• Reduced invoice verification through automated settlement • Reduced foreign exchange risk if chemical token implemented
	HR	• Reduced employee data maintenance • Individualized, adaptive learning tools

As a result of all the technological disruption, the typical sequence of activities from sensing customer demand to fulfilling an order will soon look very different from today. (Figure 5)

The disruptive potential associated with these technologies is huge, and chemical companies need to rethink now how their organizations will operate in the near future.

Figure 5: Disruptive change in customer demand-to-fulfillment cycle



ARTIFICIAL INTELLIGENCE

Today, AI is already a part of daily life. For example, it is not at all unusual for someone to take Uber to the airport, using the time in the car to catch up on presorted e-mail and do some online shopping—arriving after a productive and seamless experience.

In the not-too-distant past, that experience would not have been possible. Today, it is, because it is largely based on AI technologies. AI helps the person and the Uber driver to connect, navigate around traffic jams and find the best route. It prioritizes e-mail and screens out fraudulent messages, provides shopping recommendations, and even offers a selection of music tailored to the rider's tastes. And AI-enabled autonomous vehicles are on the verge of being approved for widespread use on public roads—which means that the car soon may have no driver.

AI is a group of technologies that includes machine learning, computer vision and speech recognition, and it is at the core of tools such as predictive analytics, advanced process automation, robotics and mechanical automation, among many others. AI has quickly become relevant in private life and business-to-consumer (B2C) contexts, and it will soon have a tremendous impact on the chemical industry.

AI has the potential to disrupt business operations by helping companies to:

- Make more informed decisions.
- Make better use of existing data.
- Develop new insights from large amounts of data that would overwhelm humans.
- Accelerate learning.
- Automate repetitive, transactional and judgment-related tasks.
- Reduce human involvement in physical tasks.
- Create new services and offerings.

Two recent examples show just how far one type of AI—natural language recognition and generation—have evolved. In recent years, a university used IBM technology to create "Jill Watson," an AI-based teaching assistant that replied to students' e-mails,[2] and the Google Duplex AI system, which successfully reserved a restaurant table by phone.[3] In both cases, the people on the receiving end were unable to detect that they were conversing with a robot.

In a business context, AI is used to handle routine, rules-based and increasingly complex tasks, such as capital market investment management, even if there are multiple and varying factors and sentiments to consider. AI does this so well that 56 percent of hedge funds base their investment decisions on AI and machine learning, and more than a quarter use AI to execute transactions autonomously.[4]

In general, today's AI seemingly mimics the human brain to carry out simple tasks and make traditional digitization and automation more sophisticated, which in turn enables the human workforce to be more effective and efficient—as well as more creative. For example, by capturing and using existing knowledge in automated algorithms and creating new insights through machine learning, AI augments the human workforce. As a consequence, AI will play an important role in helping to sustain and accelerate productivity and growth in areas where there is a declining working population, such as the European Union.[5]

ARTIFICIAL INTELLIGENCE AS DISRUPTOR

AI has the potential to disrupt every aspect of today's chemical industry business model (customer interaction, operations, administration, etc.) and to open the door to new products and service offerings. For example, it could enable chemical companies to:

- Conduct highly targeted, proactive sales with AI-based customer-specific forecasting and demand sensing—which could make it possible to ship goods before the customer places an order.
- Reduce price leakage through superior product quality and faster innovation cycles, using data-driven R&D.
- Develop a much deeper understanding of customers and better identify new applications/markets for existing and new products.
- Increase production throughput by ensuring first-time-right production, and targeting reaction yield, optimized change-overs and advanced maintenance that reduces unplanned downtime.
- Reduce customer churn rates through 24/7 customer service, with higher levels of data-driven service quality.
- Use on-site natural language-enabled virtual technical sales agents that are always available to consult with customers in case of problems/inquiries, and to inform them about new offerings.

By enabling new levels of efficiency and effectiveness in all business functions, AI will have a significant impact on individual job profiles and the workforce overall. Many transactional and simple tasks will be performed by AI, thereby enabling people to focus on more value-added work involving complex judgment and creativity. Accenture has assessed tasks in 30 typical job families in the chemical industry and found that not only operational tasks (such as production or sales) will be disrupted, but also administrative, managerial and scientific tasks. All in all, AI is expected to reduce human effort across these job families by up to 45 percent. In the short- and medium-term, however, it will create a large demand for human workers who will develop, monitor and manage AI-based operations.[6]

VISION FOR THE INDUSTRY

Looking at AI's powerful and evolving capabilities, it's possible to imagine a future in which the chemical company never sleeps—where autonomous plants run 24/7 with maximized efficiency, yielding products in spec without waste and with minimal downtime. It's a future where:

- Tedious, routine manual work is obsolete, and safety and quality are at unprecedented high levels.
- Centralized teams of data scientists, chemical process engineers and production managers supervise autonomous plants and use real-time digital twin simulation to optimize operations constantly.
- Dedicated intervention teams of operators, pooled for larger plant clusters, are on standby to handle problems and unexpected events.
- AI augments supervision activities such as inspection rounds, helping to increase overall plant lifetime.
- Production data is fully available for R&D and customer service.

In this world, R&D will draw on a tremendous amount of knowledge and AI-powered robots will conduct experiments with such precision that a given experiment will never have to be performed twice. With an AI system continuously crawling the data ecosystem, new applications and potential fields of interest will be identified quickly, and their chances of success will be pre-assessed on the spot. Backed by fully automated chemical labs, further experimentation will be triggered without human interaction, results will be automatically assessed based on historic internal and external data, and workers will be given complete dossiers on potential actions to decide whether to engage further. Virtually no time will be spent on guessing value potentials, digging into previously conducted experiments to assess technical feasibility, or searching the internet for supporting information—which altogether will enable leaps in efficiency and effectiveness that will speed up product innovation cycles.

Meanwhile, customer service will use virtual agents to increase efficiency and serve the customer 24/7, online or by phone. Accessing all internal application, production and shipping data, as well as customer information, frontline AI systems will work with a complete set of data that makes it possible for the technology to handle most inquiries on its own. Only the more-complex questions will be passed to specialized AI systems or human experts. For example, with application-related questions, the AI lab system will conduct simulations based on historic and/or extrapolated R&D, application and customer data, and then will conduct preliminary trials overnight in a fully automated lab. The next morning, the human application expert will have an experimentally verified recommendation to review and forward to the customer.

In this AI-enabled future, chemical companies will proactively give customers tailored offers based on market information, R&D output, current product portfolio and their own process data. And with the greater efficiency involved such customized offers can be extended to a very broad range of customers, including lower-priority accounts. In addition, AI-based demand sensing will let chemical companies know exactly when a new shipment is required, meaning that customers will never run out of product. AI will simplify the customer ordering process and optimize warehousing, increasing customer retention and simplifying production planning. Altogether, such proactive, individualized interactions will make it possible to develop deeper win-win relationships with customers.

Overall, this vision paints a picture in which tomorrow's leading chemical companies will draw on AI to create an efficient and innovative enterprise where human intelligence is supported by an AI-enabled digital workforce.

REALITY CHECK: ARTIFICIAL INTELLIGENCE IN THE INDUSTRY TODAY

The chemical industry is already highly data-driven, with its core business generating large amounts of data. (Figure 6)

For example, a typical plant has 5,000 to 10,000 pieces of static and rotating equipment, each sending condition data such as pressure, temperature, flow rate and speed of rotation every few seconds—generating as much as 50–500 terabytes of information per year. In addition to asset data, chemical companies need to manage product data: Here, each business has hundreds (if not thousands) of stock-keeping units, including product variants, grades and packaging.

In R&D, researchers typically add to data volumes through multiple test series and measurements that yield insights into the complex structure-property relationships of chemical substances or the performance of chemical formulations in highly specific applications. In addition, companies also generate a large volume of structured and unstructured transactional data in customer and supplier interactions—information such as order sizes, prices, shipping addresses, raw material classification, visit reports, e-mails, application data, etc.

Figure 6: Large amounts of data are generated in the chemical industry

SUPPLY CHAIN	RESEARCH & DEVELOPMENT	PRODUCTION	PRODUCT PORTFOLIO	CUSTOMER INTERACTION
1-10TB per year	**1-20TB** per year	**50-500TB** per year	**1-10TB** per year	**1-2TB** per year
Offer **Order configuration** **Contract** **Customs** **Delivery notes**	**Recipes** **Experimental range** **Analysis results** **Research reports**	**Pressure** **Temperature** **Valves** **Speed** **Flowrate** **Quality**	**REACH** **MSDS** **Analysis protocol** **Stock levels** **Batch details** **Application performance data**	**Technical support** Order history Data sheets **Customer service** Call recordings CRM reports **Sales** Customer strategy
1,000-5,000 raw materials **2-5** suppliers per raw material **20-50** interactions per raw material **50-50,000** data points per raw material (MSDS, REACH, real-time shipment status, pricing data, etc.)	**250-1,000** lab technicians **2-5** test series per technician per day **10-100** samples per test **2-3** measurements per sample with 10-10,000 data points per test **10-100** relevant papers and patents per day with 10-100 relevant data points per source	**50-100** plants **5,000-10,000** pieces of equipment per plant **5-10** data points every 10 seconds **100-5,000** measurements per plant **1-1,000** data points every 1-10 seconds (pressure, temperature, flow rate, mixing, emissions, energy, performance, status, planning, etc.)	**10,000-20,000** stock keeping unites **100-1,000** data points per unit (documentation, stage-gate information, real-time pricing data, market information, competitor products, stock & shipment status, etc.)	**1,000-5,000** customers **50-150** data points per customer **4-5** interactions per month **10-20** data points per interaction (production information, market data, product performance, prices, R&D activities, etc.)

In recent decades, chemical companies have invested heavily in data capture and storage technology, such as operational intelligence systems for asset data or systems for customer-related data. So far, they have primarily applied standard analyses and human intelligence to extract insights from this data.

Consequently, it is no surprise that AI, which can help manage the industry's flood of data, has moved to the top of chemical leaders' digitization priorities. Accenture's research found that more than 95 percent of chemical companies have at least developed an AI strategy, while more than 50 percent of chemical companies are already in the pilot-program or early adoption stages.[7] Only four percent have yet to get started. Globally, two-thirds of companies plan to invest more than 20 percent of their digital budgets to AI in the next 12 months. A closer look at geographical distribution shows that North America and Europe are seeing the heaviest investment.

Several AI applications are already available for chemical companies, including:

- **Research & development.** Predictive analytics based on internal and external data can be used to help design experiments and interpret results. The design of chemical processes to synthesize target molecules is considered by many to be the epitome of what qualified chemists do. However, there are already examples of companies implementing solutions that use deep neural networks for this purpose. Recently, a research group presented such a network that had been trained on essentially all reactions ever published in organic chemistry. The network was able to derive retrosynthetic routes for almost twice as many molecules, and at 30 times the speed, compared with non-AI, computer-aided methods.[8]
- **Production.** AI can drive extra efficiency and effectiveness, even in production processes that have been optimized for decades. For example, steelmaking is as challenging an activity as chemical production. It traditionally requires highly experienced workers to constantly adjust furnace conditions, while carefully managing the addition of coal, iron ore and various alloying elements. The use of AI in a steel plant could increase output by five percent, while simultaneously reducing fuel expenses by four percent.[9] Furthermore, drones used in combination with AI technologies such as image recognition can dramatically improve efficiency in asset maintenance.[10, 11]
- **Customer service.** B2C businesses routinely deploy virtual agents that use natural language processing to handle customer inquiries. Business-to-business (B2B) companies need to do the same. As business models scale, product portfolios become broader and deeper, and more companies operate in foreign markets, customer service departments are swamped with inquiries and struggle to deliver best-in-class service. AI can help: For example, to counter rising costs, an oil and gas company started using AI-powered virtual assistants to handle requests by referring to more than 100,000 data sheets for more than 3,000 products in 21 different languages. Pilot-phase results showed that calls to human agents could be reduced by 40 percent, while customer expectations were met perfectly in 97 percent of all AI-managed requests.[12]
- **General and administrative functions.** AI can replace simple tasks requiring judgment, such as customer validation and the tracking of billings,[13] particularly in finance and accounting.

In general, AI initiatives and deployments in the chemical industry are being driven by individual business units, with a focus on automating simple tasks. In R&D, for example, chemical companies typically implement AI tools that support substance characterization; most are not yet engaged in creating fully autonomous development labs. Taking a broader perspective will enable each business, and the industry as a whole, to get much more value out of AI investments.

Employee training is also important in the adoption of AI into the organization. Here, there are three key rules for effective AI integration. Chemical companies need to ensure that employees:

1. Are informed about AI's capabilities and limits to reduce their fear of being replaced by machines.
2. Are trained on how to teach the machines to perform work and make the right choices.
3. Understand how to work most efficiently with their new digital colleagues in a day-to-day environment.

Across the organization, these AI-driven initiatives may represent a great deal of strategic planning and effort compared to the typical development of technology applications. However, this effort should be weighed against the significant benefits that AI promises—especially when cross-functional technologies can interact seamlessly with each other and naturally with human workers. In Accenture's view, chemical companies can generate considerable advantage over their competitors and guard against new entrants by combining their many decades of chemical expertise with AI to transform the entire enterprise into the chemical company of the future.

VALUE POTENTIAL

According to Accenture's models,[14] AI has immense value potential for the chemical industry, and it is likely to redefine competitiveness by reducing costs, introducing new product/services offerings and enabling innovative business models. Accenture estimates that a typical chemical enterprise with current annual revenues of €10 billion could increase its top line by more than €2.7 billion and reduce its operating expenses by up to €0.9 billion by taking full advantage of AI.

Figure 7 highlights the combined effect on a hypothetical chemical company's profit and loss structure that could result from increased AI-driven efficiency in all functions, along with related revenue growth.[15] The greatest impact is expected to be in production costs and sales.[16]

Figure 7: EBIT impact on a chemical company's profit and loss structure

Illustrative P&L structure with values in EUR billion

P&L Area	P&L Breakdown	Cost Impact	Growth Impact	New P&L
Sales	**10.0**		+2.7	**12.7**
Production	7.0	-0.5	+1.2	7.7
Maintenance & site logistics	0.3			0.3
Logistics	0.2		+0.1	0.3
Depreciation	0.3		+0.1	0.4
Sales, marketing, customer service	0.5	-0.2		0.3
Research & development	0.3	-0.1		0.2
Environment, health & safety	0.1			0.1
General administration	0.3	-0.1		0.2
EBIT	**1.0**			**3.2**

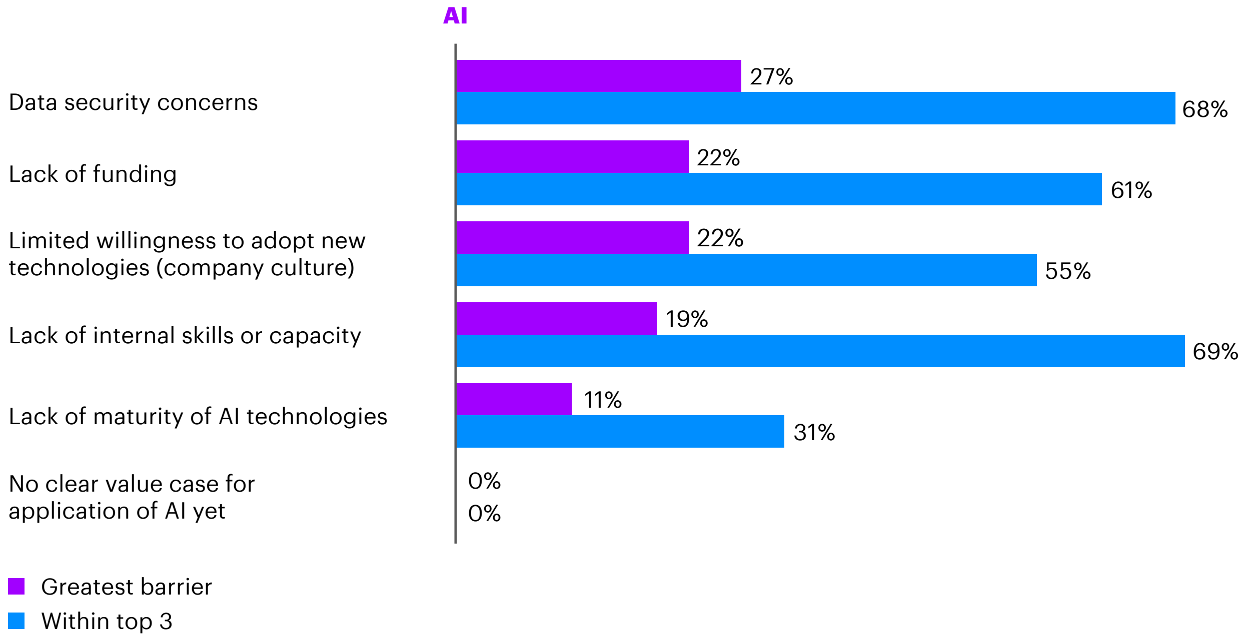
Source: Accenture analysis

CHALLENGES AND IMPLICATIONS

AI promises to transform the chemical industry and bring significant benefits in terms of safety, quality, productivity, cost efficiency and growth. Indeed, 100 percent of the industry executives in Accenture's survey agreed that the value case for AI is a given. The question, then, is what is preventing the industry from embracing AI more quickly and comprehensively? According to Accenture's research, data security concerns, lack of funding and personnel-related issues are the main hurdles to faster AI adoption. (Figure 8)

These findings point to three areas where chemical companies can focus their efforts and investments to enable the broader adoption of AI—IT architecture/data management, workforce capabilities and enterprise transformation.

Figure 8: Top barriers to AI adoption



Base: All respondents
Source: Artificial Intelligence and Blockchain in the Chemical Industry Survey, Accenture 2018

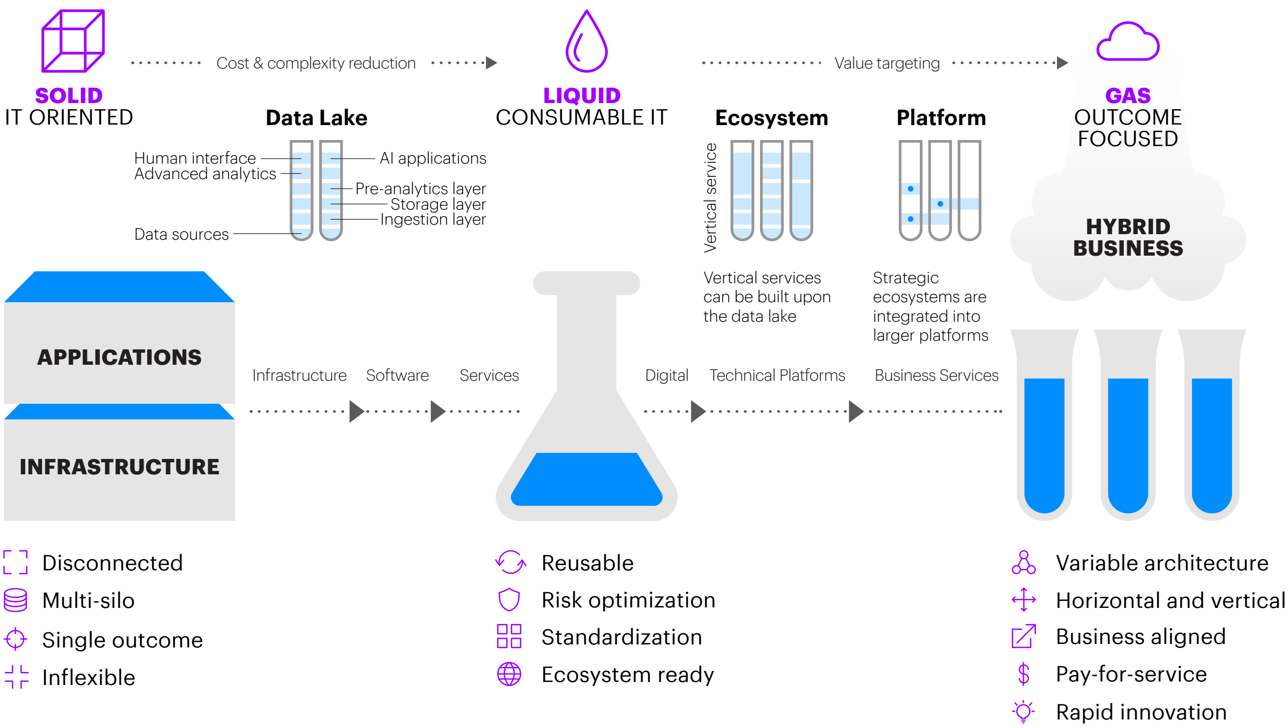
IT architecture/ data management

Chemical companies often operate with IT architectures that are not designed for a cloud-based, information-sharing AI environment. As Figure 9 shows, IT architectures can be categorized into three "states"—solid, liquid and gas. Traditional architectures fall into the solid state; that is, they have inflexible and isolated applications and infrastructures. In recent years, digitalization efforts have been directed toward liquefying these architectures to make them more flexible and scalable —e.g., by developing data lakes for core information. From there, the final step—the gas state—involves the development of strategic ecosystem networks with external partners, and eventually the full integration of platform-based services to provide new service offerings to a broad market.

Internal data lake architectures are at the heart of powerful AI and analytics applications, which leverage big data.[17] However, progressing to the gaseous state with such data lakes and integrating a company's IT systems with external networks opens new entry points for external intruders, thus becoming a security risk. Fortunately, AI-based security technologies are available to help protect intellectual property through real-time activity monitoring and probing.

Data quality is another ongoing challenge, but AI technologies also provide solutions for managing data governance and overseeing data cleansing. Human effort can be significantly reduced once a data validation algorithm has been trained on the ingested data structure to the point where it can operate autonomously.

Figure 9: The three states of IT architectures



Workforce capabilities

To integrate AI into business processes, operate the new systems and continuously increase their capabilities, chemical companies will need cross-functional expertise and various kinds of specialists. (Figure 10)

Take, for example, the role of "translator." These are experts who can work at the interface between business problems and data science solutions. Translators will capture and frame business problems, guide AI experts and understand clearly how to extract value.

Other roles will include data scientists and engineers with IT skills who will shape the business, as well as IT experts with chemical industry acumen. These people will be responsible primarily for data stewardship (including cleansing supervision) to ensure a solid foundation for AI activities. They also will be responsible for the continuous training of the AI system to enable consistent and reliable results—especially when there is a major task or process change or when complex, low-confidence issues arise.

Finally, a strong core of change agents will be required, especially upon AI system implementation. These agents can drive transformation by training colleagues and helping to ensure the effective integration of workers and technology. In an AI-enhanced enterprise, the change agents' roles will shift to technology screening, introduction and continuous development.

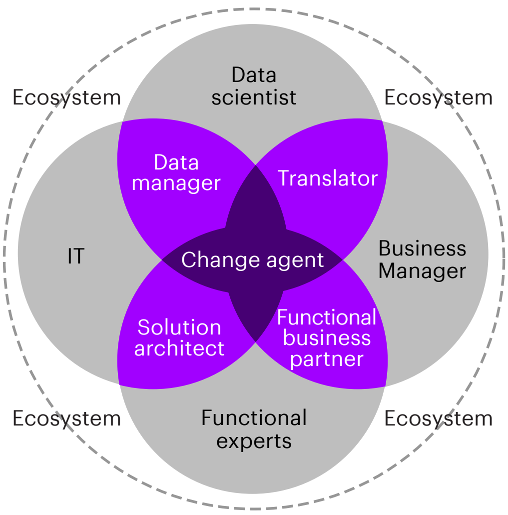
Accenture estimates that approximately 500 to 1,500 full-time employees with the described new skills will be required by the typical €10 billion-turnover, 15,000-employee chemical company. These skills are difficult to recruit today, and they will become even scarcer as demand increases. Developing them, therefore, will likely require structured capability building and training.[18]

Enterprise transformation

For an enterprise to effectively leverage AI, it will be vital to communicate the benefits for individual employees. Chemical companies can make it clear to employees that routine tasks will be covered by AI-based systems or machines, making the jobs of the human workforce more effective and interesting.[19] If introduced correctly, AI is more likely to increase the overall satisfaction and internal cross-collaboration of human employees, helping to drive sustainable business revenue.[20]

The chemical industry has excelled in implementing transformational change through dedicated, C-level run programs, such as production excellence, building marketing skills and the rollout of ERP or manufacturing execution systems. While Accenture's research found that the vast majority of chemical companies have at least some kind of AI strategy in place, many are still driving AI through isolated functional pilots, rather than large transformational programs.[21] This needs to change if the industry is to realize the full benefit of AI.

Figure 10: New ways of working



For 1000 employees (today)

5 translators
10 data scientists
20 data engineers
2-3 agile teams
1-2 solution architects
5 automation & robotic experts
All business managers with working knowledge
2 full-time change managers
50-100 change agents (part-time)

+ Ecosytem

BLOCKCHAIN

Blockchain records transactions between parties in a secure and tamper-evident way, thus creating a single source of trusted data.

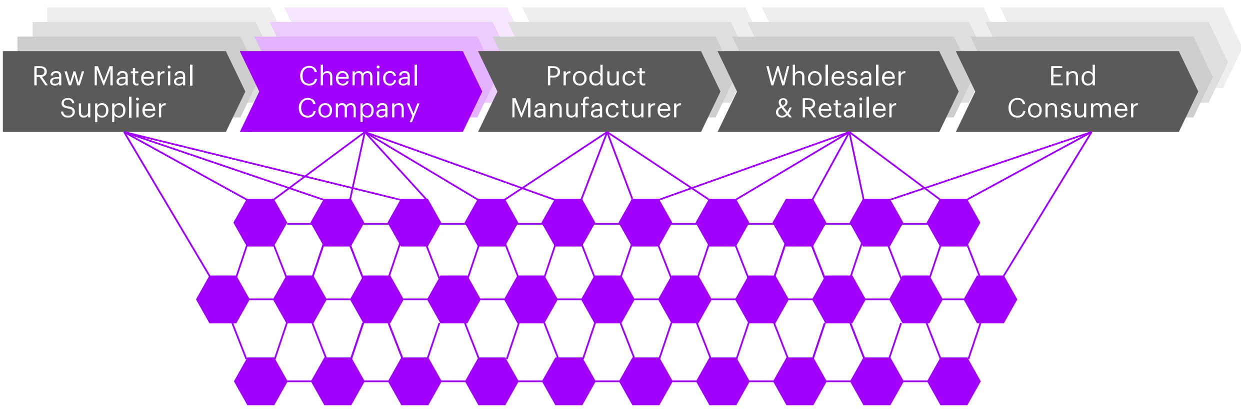
Transactions might include asset/material or financial transfers, contract completions or financial record updates. For chemical companies, product sales, shipments, payment flows, bank and intercompany reconciliations, and product property and quality certifications are areas that would lend themselves to the application of blockchain.

The technology lets participants trace transactions across multiple steps, leading to insights companies can use to better predict market changes and develop more customer-oriented products and services.

It can also lead to organizational planning and execution based on the near real-time observation of demand patterns in the value chain.

Today, each transaction includes at least one manual verification step. In contrast, blockchain technology maintains and records data so that multiple stakeholders can confidently and securely share access to the same data and information, thus eliminating the need to verify multiple times which streamlines the process while reducing credit risk. Blockchain could even make it possible to reduce the fees paid to institutions, and minimize foreign-exchange risks using direct and trusted payments between chemical companies.

Figure 11: Blockchain network across the chemical company value chain



BLOCKCHAIN AS DISRUPTOR

Blockchain promises to address several long-standing chemical-industry challenges. The technology can enable each chemical company in the network to see demand and consumption patterns in each step of the downstream value chain; understand how customers use products; improve quality and provenance assurance across the value chain; retrieve products at the end of their life cycles; and facilitate a trusted exchange of data about product properties, the EU's (REACH)[22] regulation or customs activities. These capabilities create a range of opportunities, such as:

Improved supply chain visibility

A better view of demand and consumption patterns could enable near real-time, optimized demand planning and production scheduling, virtually eliminating overstocks, rush orders, schedule breakers, etc.

New product innovations

A better understanding of how customers use products could enable more needs-based innovations and the development of tailored applications, potentially leading to a new wave of innovation and growth.

New revenue models

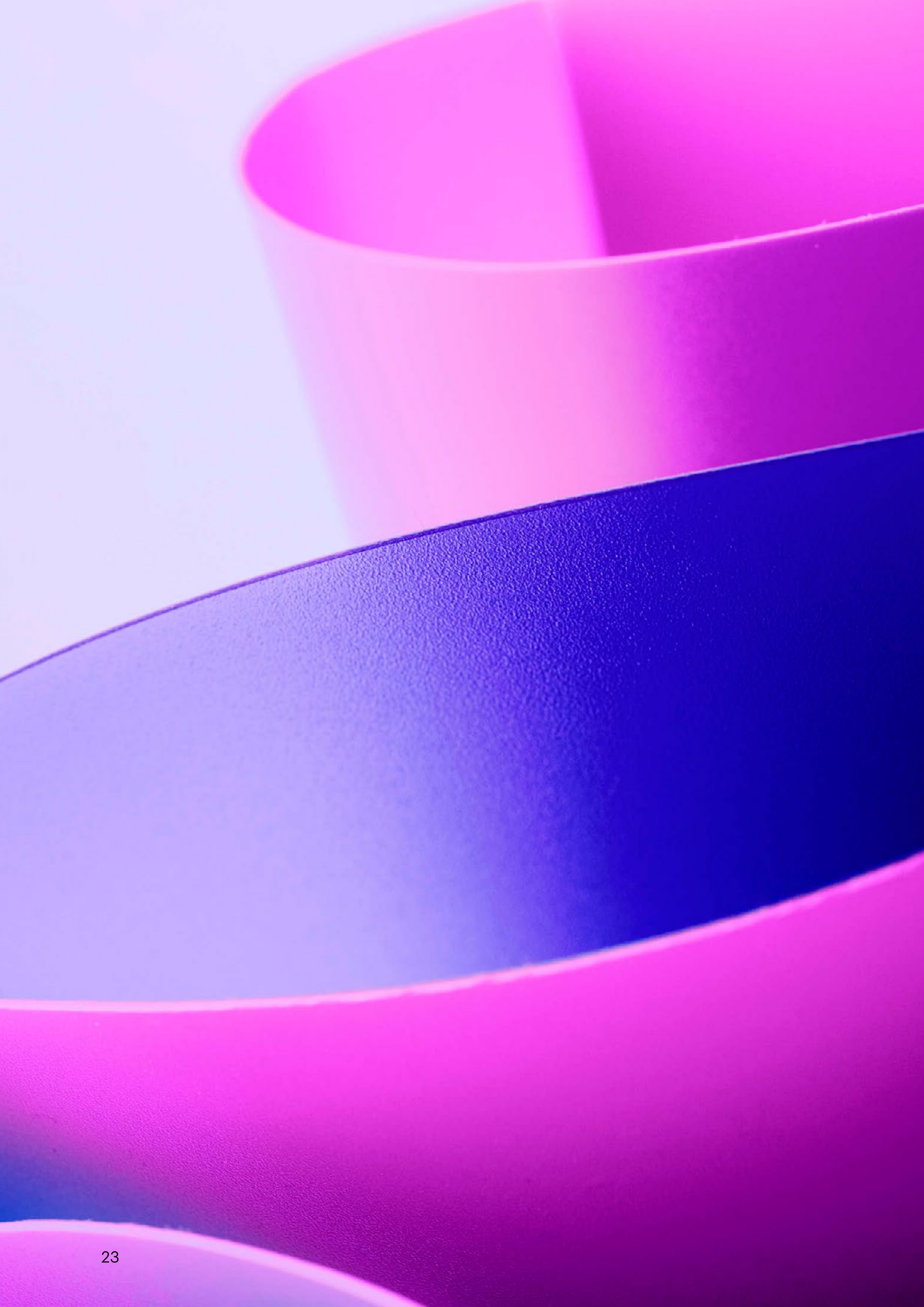
A deeper understanding of how chemical products add value in customer systems and offerings could enable value-based, performance-based or even chemical leasing-based revenue models.

Improved data integrity

Blockchain is tamper-evident, with consistent, validated transactions and data visible and usable by all participants.

Error reduction

Electronic data verification through smart contracts could enable new levels of automation in assurance and testing, and make paper-based documentation, inbound quality assurance and testing obsolete.



VISION FOR THE INDUSTRY

There are multiple blockchain use cases being discussed in the chemical industry. Accenture's survey of chemical industry executives shows especially high interest in the areas of supply chain, provenance tracking and financial payments. (Figure 12)

Those executive expectations are in line with the five top use cases that Accenture has identified as offering near-term business potential for the industry.

How might these stronger, blockchain-enabled capabilities play out in the future? Certainly, they have the potential to reshape several key industry activities, such as:

Near real-time tracking

Blockchain technology could provide much better transparency into how products are used in customer operations in each step down the value chain, helping companies to tailor offerings to customer needs.

Figure 12: Priority areas for blockchain investments within the next three years

Base: All respondents
Source: Artificial Intelligence and Blockchain in the Chemical Industry Survey, Accenture 2018

Companies could also gain a better understanding of production and delivery status to enable more precise inventory planning, warehouse management and production planning and scheduling. They could also apply analytics to tracking data to identify demand patterns for their products. And they could do all this with increased back-office efficiency, thanks to a reduction in verification steps for invoices, goods receipts and customs.

In addition, chemical companies could obtain downstream supply chain information through blockchain, infer the delivery status and share that insight with their customers—thereby catching up with companies such as Amazon or Alibaba who are able to provide such information to their customers easily. That could help chemical companies counter the efforts of these two online giants, which are working to enter the B2B market.

Payments

Instead of relying on global currencies, chemical companies could use blockchain-enabled platforms and the industry's own "currency." They could settle transactions via blockchain using a common chemical token and mutually agreed-to financial flows, eliminating the need for banks to act as trusted third parties for handling payments. Payments would be instant, reducing business, credit and foreign-exchange risks for the seller and the buyer. Local bank accounts could be consolidated into a single company-wide account, revolutionizing global cash flow management and enabling the greater use of analytics.

Intercompany reconciliations

Chemical companies often struggle with intercompany business reconciliations. In recent years, many have automated various reconciliation processes, but managing that activity across different ERP systems remains challenging. With blockchain, however, the need to validate and reconcile intercompany transactions could become obsolete, as there would be only one single source of truth across companies—eliminating manual effort for month-end account reconciliations and making financial closing far more efficient.

Global document management and intellectual property (IP) protection

Today, different systems and processes are used to manage IP, and there are varying standards across licensing organizations such as the European Chemicals Agency (ECHA) and the European Food Safety Authority (EFSA). Often, these processes are paper-based, and information is stored in separate systems. In the future, blockchain may enable a global IP protection-management regime. Through blockchain, lab results, certificates and product specifications could be stored securely in bar codes, enabling participating stakeholders to scan that information and log it into a blockchain system. Quality certificates could be sent and read for each shipment electronically via a blockchain, safeguarding product information while making it readily available for the whole value chain. Even end consumers and regulatory bodies could access the blockchain system for process and product specifications and to obtain accurate information about the content of final substances and production flow. Blockchain would enable the tracking of, for example, authenticity and the provenance of products—bringing end-to-end transparency as products move through the supply chain.

Circular provenance

The chemical industry is seeing increasing demand for sustainable, circular-economy products. Thus, companies have a growing need to confirm the provenance and the circularity of their products. Blockchain technology has the potential to deliver proof of authenticity, because it lets companies track a product's path from feedstock through production processes to delivery. All stakeholders can demonstrate the sources of raw materials and additives.

REALITY CHECK: BLOCKCHAIN IN THE INDUSTRY TODAY

Blockchain is still an emerging technology, and its use in the chemical industry is limited. But early proof-of-concept applications in other industries have already illustrated its benefits and are now moving to market adoption. These applications provide insight into how blockchain might be used in the chemical industry value chain.

For example, AB InBev (a global beverage manufacturer), APL (a large ocean carrier), Kuehne + Nagel (a large logistics company) and Accenture have formed a consortium to test blockchain technology with actual product shipments across different locations with the aim of rethinking the freight & logistics operating model. Approximately 20 types of documents were shared and validated using blockchain, and the tests showed that the solution offered a high level of data quality, visibility across all trades and instant financial-clearing possibilities. This application of blockchain helped reduce manual data entry by 80 percent, while simplifying data amendments, streamlining checks and reducing the burden of risk and penalties by customs. This type of approach is expected to save billions of dollars for international trade communities, and ultimately revolutionize the global exchange of goods.[23]

On the other hand, the Maersk shipping company and IBM have developed a blockchain platform called TradeLens[24] to digitalize a complex process. In its first year, the platform grew to have nearly 100 participants, including some of the world's largest shipping companies and ports. This consortium has leveraged blockchain technology to handle and track more than 430 million shipments around the globe as of April 2019, and it is currently adding 1.5 million shipments per day to that total. Savings are approximately 40 percent per transaction.[25]

VALUE POTENTIAL

Blockchain is likely to transform the industry's profit and loss structure through two key value levers: cost reduction (mainly in administration, supply chain and marketing and sales) and revenue growth (through improved product innovation and new business models).

Revenue growth

Blockchain provides a better understanding of customer demand and customer consumption patterns, making it a powerful driver of revenue growth. Through blockchain, chemical companies could observe how their products are processed along the downstream value chain. They could identify what applications are developed, what additives are added and what volumes are consumed by different stakeholders—all of which could help them tailor production and offer additional services to customers.

What's more, these insights could support the development of innovative applications tailored to ever-more precise specifications. Accenture's research indicates that companies with a good understanding of the downstream value chain of their products could expect potential revenue growth of 15 to 25 percent.[26] (Figure 13)

Figure 13: Profit and loss impact through blockchain deployment

Illustrative P&L structure with values in EUR billion

P&L Area	P&L Breakdown	Cost Impact	Growth Impact	New P&L
Sales	**10.0**		+2.0	**12.0**
Production	7.0	-0.4	+1.1	7.7
Maintenance & site logistics	0.3		+0.1	0.4
Logistics	0.2	-0.1	+0.1	0.2
Depreciation	0.3		+0.1	0.4
Sales, marketing, customer service	0.5			0.5
Research & development	0.3			0.3
Environment, health & safety	0.1			0.1
General administration	0.3	-0.2		0.1
EBIT	**1.0**			**2.3**

Source: Accenture analysis

For a €10 billion chemical company, this translates into a top line growth potential of about €2 billion. Considering the network effects and the total EU chemical industry sales of €507 billion,[27] blockchain could result in €75 to €125 billion in growth for the European chemical industry.[28]

Blockchain also has potential strategic implications that could easily exceed any of the above-mentioned benefits. For example, due to its network nature, blockchain could create a hurdle for new competitors. It also offers information transfer across the value chain, which could enable new business and sales models that deliver a more customer-centric experience, helping the industry to defend against these digital challengers.

Cost reduction

Accenture estimates efficiency gains and administrative cost reductions of up to 80 percent in function-specific blockchain applications. Blockchain would enable savings not only for a single organization, but also for companies across the entire network.

Based on Accenture's experience and research, a €10 billion chemical company could potentially realize cost savings of about €700 million. This includes:

- A 30 to 40 percent cost reduction in administration, thanks to:
  - Fewer verification steps (e.g., in the purchase-to-pay and record-to-report processes).
  - Fewer bank fees, due to direct platform-based payments.
  - Better forecasting capabilities.
- A 20 to 30 percent cost reduction in logistics, due to:
  - Lower transaction and handling costs.
  - Better inventory management.
  - Lower costs for customs and cross-border handling.
- A five to 15 percent cost reduction in marketing and sales, due to:
  - Lower order-handling costs.
  - Better customer service and fewer complaints.

CHALLENGES AND IMPLICATIONS

Blockchain technology has evolved beyond its first deployments in cryptocurrency, and it is now likely to have a significant impact across nearly all industries, including chemicals. But there are challenges. According to Accenture's research, industry executives see data security, lack of interest and lack of funding as the main hurdles to the adoption of blockchain in the chemical industry. (Figure 14)

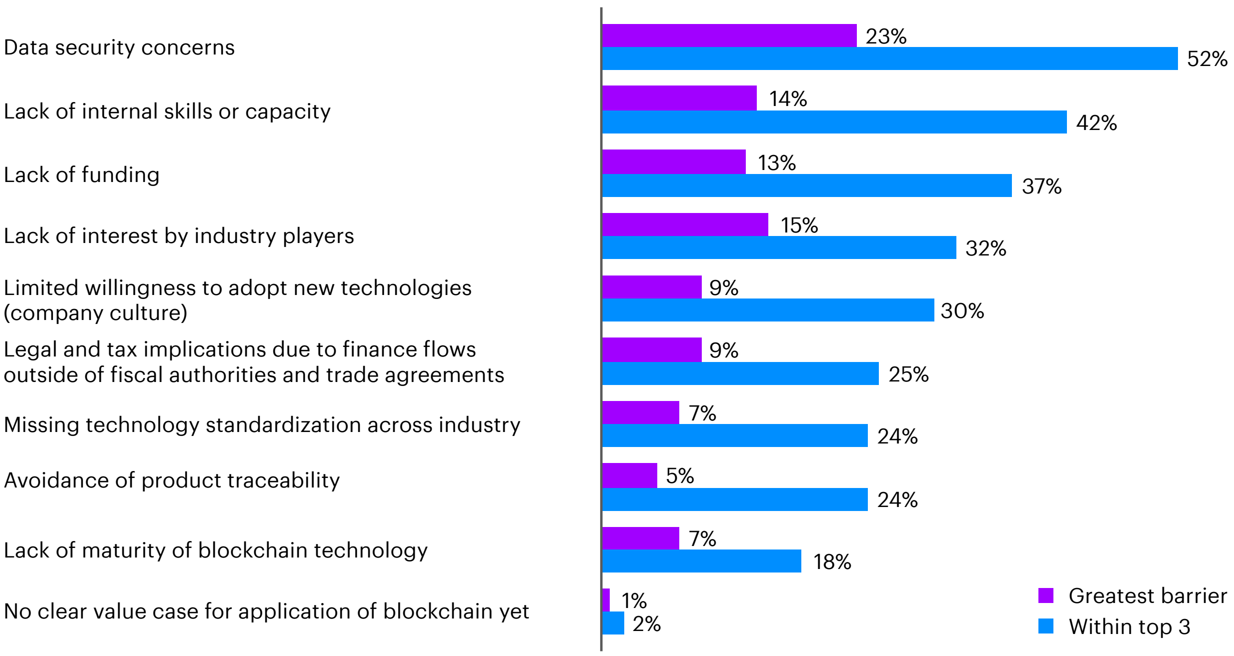
Moving from today's blockchain trials and pilots to the deployment of solutions at scale will require further technology development, organizational transformation and collaboration between all stakeholders. Success depends on numerous parties working together to use blockchain to transform legacy processes and to adopt jointly new ways of creating value. In the highly fragmented chemical industry, consortia that bring together stakeholders will play a key role in achieving blockchain's potential.

In exploring blockchain, chemical companies need to consider several factors:

- Blockchain is a collaborative technology, facilitating trusted transactions between multiple and often diverse companies, suppliers, customers, partners, government agencies, industrial organizations, regulators and even competitors. Information transparency up and down the value chain could provide a foundation for new approaches to business development that are very different from those in place today.
- Companies need to agree on certain standards, such as how blocks (the records in a blockchain) are designed, what information is included or how the verification mechanism works. Developing standards for the entire chemical industry and its upstream and downstream partners may present the biggest challenge.
- Meeting the needs of individual parties will require the development of a private technical architecture. Establishing a blockchain for the entire chemical industry will require agreement about and implementation of governance, validation and contract models—as well as accessibility to mature blockchain technology.

Blockchain technology and its usage are both evolving rapidly. Chemical companies should prepare for the future by acting now to investigate the use of blockchain technology in their organizations and their value chains.

Figure 14: Perceived hurdles to further blockchain adoption



Base: All respondents
Source: Artificial Intelligence and Blockchain in the Chemical Industry Survey, Accenture 2018

CONCLUSION

AI and blockchain have the potential to reshape both individual chemical companies and the industry overall.

AI will lead to the reinvention of the nature of work—augmenting human capability, improving productivity and allowing humans and machines to both focus on what they do best. Blockchain will revolutionize how companies interact across the value chain, creating a network that tightly integrates value chain partners, thereby enabling new business models and offerings while dramatically reducing transaction costs.

Each of these technologies is powerful in its own right, but their power is amplified when they are used together. For example, their combined use offers potential benefits such as:

IMPROVED DATA QUALITY

The combination of AI and blockchain does not make bad data into good data, but it does strengthen the ability to trust sound data that is being used in the business. For example, results obtained through machine learning can be captured on a blockchain, providing a tamper-evident record that partners can use to verify data integrity, and ultimately understand and trust how AI-based decisions are being made.

STRONGER SECURITY

Currently, it's extremely difficult to identify data that has been modified or poisoned by an attacker—but the combination of blockchain and AI makes it difficult to hack systems and steal sensitive data. Blockchain stores information in a tamper-evident way, while machine-learning algorithms can be used to automate near real-time threat and data breach detection—while continuously learning about the behavior of attackers.

ECOSYSTEM-WIDE SERVICES

With blockchain enabling the secure sharing of data with a network of partners, AI can screen the entire ecosystem to access data from additional sources. This can extend a supplier's capabilities, and enable it to work across end-to-end processes and, for example, provide a seamless experience for customers who are relying on several companies to provide the outcome they want.

Blockchain is still evolving into a practical business technology, but many AI applications are already mature enough for large-scale rollout and implementation. Accenture estimates that up to 80 percent of AI use cases are the same for all chemical companies, which opens the opportunity to benefit from standardized implementation programs. But both AI and blockchain will require new skills. The rate at which chemical companies can acquire those skills—or build internally through education and training—will determine their ability to capture value and secure competitive advantage with these technologies.

Based on experience, Accenture recommends a five-step plan to strategize and begin adopting AI and blockchain in the organization.

1. **Apply and prioritize AI and blockchain solutions** to focus on the company's greatest challenges.
2. **Be bold in developing a target vision** but understand that the technology will advance faster than the change readiness of the organization. That means it is important to map out a clear change journey to prepare and reskill the workforce for using these technologies.
3. **Be aggressive in recruiting required skills:** They are scarce today, and they will be even scarcer tomorrow.
4. **Define the required platforms and operating models.** Data models, data management and new ways of working with data will require moving away from legacy systems, learning how to use new systems, and exploring new partnering options.
5. **Set up a program to implement the technology.** The "mushrooming" approaches often used in digitalization initiatives—a small proof of concept here, a pilot there, lack of cross-business governance and scaling—are not suitable for transforming existing ways of working.

AI and blockchain are moving ahead quickly but adopting them will take time and effort. As a result, chemical companies should start now to understand the benefits and develop a plan to incorporate these technologies into the organization. Hesitating may allow competitors to bypass industry boundaries and gain an advantage with these new, powerful tools. By getting involved early, chemical companies can forge ahead to reshape the industry with AI and blockchain.

APPENDIX

ARTIFICIAL INTELLIGENCE

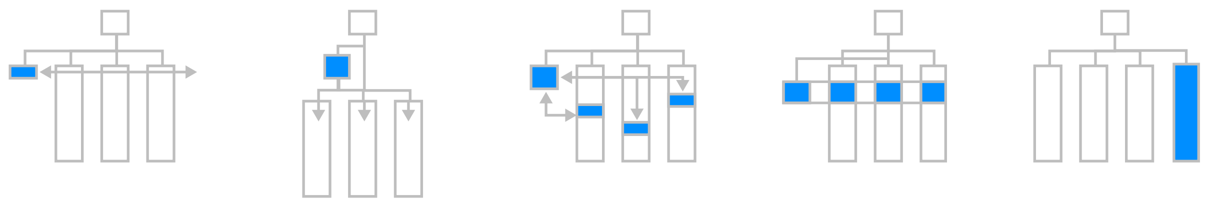
Governance

Accenture has found that companies can use one of five different governance models for AI implementations. (Figure 15) These offer a range of options, from a purely advisory function to a unit managing AI across the business. In any case, centralized AI coordination is a minimum requirement.

Accenture's research shows that 31 percent of chemical companies have already established an AI unit, either as a dedicated stand-alone unit or as part of a digital organization.[29] In the long run, AI governance should be integrated into the organization as a core function and perhaps even developed into an independent business function with its own revenues.

Figure 15: Organizational models for deploying the AI function in an enterprise

AI project coordination	Dedicated AI governance unit	AI center of excellence	Integrated AI service and business platform	Standalone AI business unit

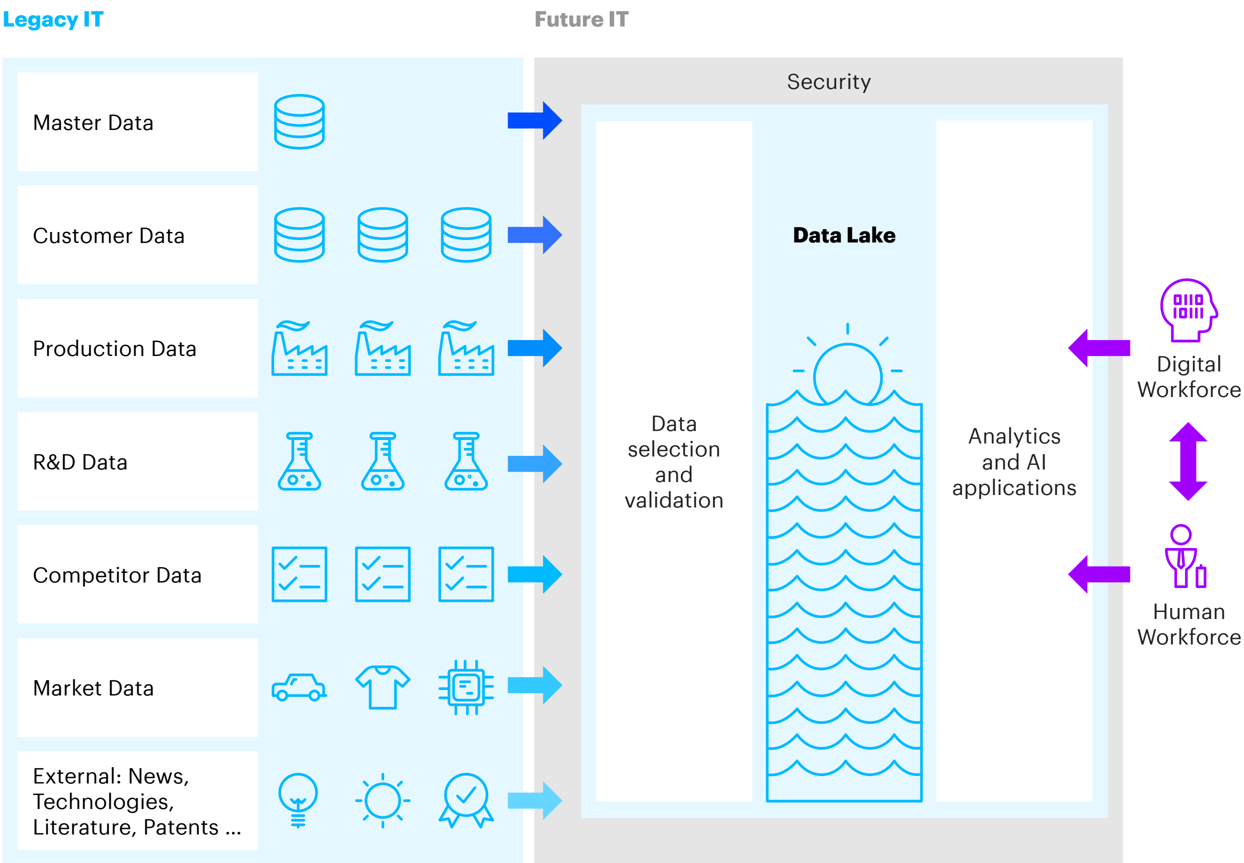


AI project coordination	Dedicated AI governance unit	AI center of excellence	Integrated AI service and business platform	Standalone AI business unit
Coordinating across businesses	**Setting impulses for digital excellence**	**Central excellence & BU-specific AI role**	**Harmonized set-up & central coordination**	**Central responsibility for AI business**
• Defining (minimum) AI standards • Sharing digital proven practices	• Reporting on standard AI KPIs • AI assessments and internal benchmarking	• Guiding BU specific digital teams • Providing digital expertise and rules • Supporting BUs selectively in AI projects	• Harmonizing AI activities across BUs • Coordinating and driving implementation of AI initiatives • Driving AI innovation and maturity of BUs continuously	• Developing and managing standalone AI function • Managing and driving digital activities as business with own (external) revenues

Data Lake Architecture

A first step to enterprise-wide AI adoption includes breaking down internal data silos to make big data accessible. Multiple cloud-based options are available to help with this, offering scalable storage and computing power for analytics. There are cloud-based, as well as on-premise, solutions—the optimal choice depends on multiple factors (e.g. whether all data already is available and accessible at adequate quality on premise or not). The data transformation needed to work across silos can be achieved gradually, allowing companies to keep familiar systems in place and minimizing the impact of change on users. Figure 16 shows a simplified, generic data lake[30] architecture that provides access to all relevant legacy internal and external data sources, along with security measures that guard against external threats. Access to the validated data takes place either through an AI application or humans.

Figure 16: Access to validated data is essential for autonomously operating AI systems, as well as for human workforce augmentation. A secure data lake architecture provides the required linkage between legacy IT, external data and new technologies.



Artificial Intelligence Glossary

Analytics

Analytics is a broad term that refers to the combination of technology and data science (that is, statistics applied to large amounts of structured data) to solve business problems. Generally speaking, the more mature the process, the more effective an analytics solution can be in driving process value. AI, and especially machine learning, are increasingly used with analytics to make predictions or prescribe actions. Various types of analytics include:

- Descriptive analytics—determining what has happened.
- Diagnostic analytics—determining why an event happened, using techniques such as drill-down, data discovery, data mining and correlations. Here, the line between analytics and AI is blurring as sensing technologies such as natural language processing or computer vision are employed, because these extend the analytical scope from pre-structured data to physical world input.
- Predictive analytics—projecting what will happen. Typically, this is done by using existing data to train predictive machine-learning models.
- Prescriptive analytics—providing recommendations on how a desired outcome can be achieved. Taking the concept further, AI can be used to manage the execution of the prescribed action, potentially creating broader opportunities for automation, such as the autonomous plant.

Artificial intelligence (AI)

AI systems perform actions that, if performed by humans, would be considered intelligent. There are two main types of AI: weak and strong.[31] Weak AI is designed and trained for a narrow purpose. Such systems don't "think," but they act as if they do by efficiently building upon what machines do best (e.g., remembering and finding information, carrying out probabilistic reasoning and discerning subtle patterns in data.)[32] The algorithms self-improve through machine learning. Virtually all of today's AI applications are based on weak AI. Strong AI differs from weak AI in that it continuously expands its capabilities by applying the patterns learned through experience to new problems, just as humans do. While strong AI has yet to be realized, machine-learning technologies are constantly moving closer to that goal.

Machine learning

Machine learning is a form of AI that analyzes and learns from data, and then uses what it learns to make decisions and/or take action. Rather than being coded with a specific set of instructions to perform a particular task, machine-learning algorithms are self-optimizing after having been trained on large amounts of data. Machine-learning algorithms use a variety of different approaches, including inductive logic programming, reinforcement learning, Bayesian networks, decision-tree learning and clustering.

Data mining

Data mining is the use of computers to explore and analyze large data sets to uncover trends and patterns. While data mining often involves some work by data scientists, AI can be used to automate more of the process.

Neural networks

A neural network[33] is a system of hardware and/or software designed to operate like the networks of neurons in the human brain to solve complex signal-processing or pattern-recognition problems. A neural network uses many processors—called nodes—that are structured in parallel and arranged in many layers. The first layer receives the raw input information, the next layers process the information, and the last layer delivers the output. The nodes are highly interwoven in their interactions, creating an "adaptive micro-environment," meaning that the nodes can refine and modify their individual processes and weighting within this closed environment until the desired outcome confidence level is reached. Natural language processing is a typical application of neural networks.

Deep learning

Deep learning is a specific machine-learning technique that uses algorithmic approaches and artificial neural networks. Neural networks consist of many discrete layers; the "deep" in deep learning refers to this depth of interconnected processing power. The key to effective deep learning is the use of large amounts of data to train the system.

Supervised/unsupervised learning

There are several techniques and methods used in data mining. They can be categorized as "supervised" and "unsupervised," which represent two different approaches to splitting data for information identification. Unsupervised learning involves finding hidden patterns without pre-defining or restricting the outcome. Common unsupervised methods are segmentation, clustering (self-organized maps) and link analysis (association rules, sequence detection). Supervised learning involves finding patterns relating to given outcomes and applying these patterns to classify the outcomes of new data sets (prediction). Common supervised methods are based on classification (decision trees, discriminant analysis, feed-forward back-propagation networks), regressions and time-series analysis.

Reinforcement learning

Reinforcement learning is when AI becomes its own teacher, with no need for human oversight.[34] It is a goal-oriented algorithm that learns how to reach a complex goal or how to optimize along a particular dimension. The algorithm learns only through sporadic positive/negative evaluations to reward/punish current behavior. These evaluations are conducted in a strong interaction feedback loop between a virtual agent and an environment.

Transfer learning

Transfer learning is a machine-learning technique in which a model trained on a specific task applies that learned knowledge to a second, related task. This transfer is designed to make AI perform better, train faster and require less labeled data than a new neural network trained from scratch to address that second, related task. This is one of the first steps toward developing a general artificial intelligence, and it can be highly effective for those areas in which only small amounts of "same" data is available.

Optical character recognition

Optical character recognition technology recognizes alphabetic characters and processes them into machine-encoded digital text. Images of text, such as scans of handwritten documents, can be digitized, making such data available for automatic analysis.

Natural language processing/understanding/generation

Natural language processing (NLP)[35] encompasses the sub-fields of natural language understanding (NLU) and natural language generation (NLG). This set of technologies enables machines to interact naturally with humans by understanding the semantic meaning of written or even spoken language, and to reply in a natural way. Chatbots are a prominent example of NLP.

Robotic process automation (RPA)

With robotic process automation (RPA), machines handle process steps traditionally done by humans, helping to reduce repetitive manual tasks such as transferring transactional order data from one enterprise system to another. Intelligent process automation (IPA) is the enhancement of RPA with AI technologies, such as machine learning, to enable the effective automation of tasks that are not always 100 percent identical. The use of AI brings flexibility and adaptability to RPA.

Value Model

The individual value levers for AI and their impact on cost reduction per business function and on sales/price increase are shown in Figure 17. The individual ranges provided are Accenture projections derived from benefit order of magnitudes observed in various proofs of concept, pilots and implemented solutions.

Figure 17: Normalized profit and loss potential of extensive AI deployment for a generic chemical company

Today				Value levers	Basis	Improvement/ Impact of Basis		Impact on EBIT (absolute)	
Illustrative P&L structure		Breakdown total cost				Min	Max	Min	Max
Sales	100.0%		100.0%	Less price leakage (average 2-4% today)	Sales price	2.0%	4.0%	2%	4%
				Additional volume					
				– Proactive sales; AI-based customer specific demand sensing, automated customer inquiries	Sales volume	1.0%	3.0%	0.37%	1.10%
				– Additional services (24x7, application support, customer support, etc)	Sales volume	1.0%	1.5%	0.37%	0.55%
				– Higher yield and throughput based on AI-based optimization of production	Sales volume	1.0%	2.0%	0.37%	0.73%
				– Reduction in churn rate (3-5% today), by more scalable customer interaction, more frequent interaction, higher responsiveness	Sales volume	0.5%	2.0%	0.18%	0.73%
				New products based on:					
				– Better understanding of customer needs (AI-based research): increase in sales from products younger than 5 yrs	Sales volume	1.0%	3.0%	0.37%	1.10%
				– More efficient R&D (automation of non-innovation tasks, better insights)	Sales volume	1.0%	1.5%	0.37%	0.55%
				New services like:					
				– Direct to customer	Sales volume	1.0%	2.0%	1.00%	2.00%
				– Vendor managed services	Sales volume	1.0%	2.0%	1.00%	2.00%
Production	69.7%	Raw materials	55.0%	Less off-spec & changeovers by AI-based demand planning and production scheduling					
				– Volume of off-spec - standard products sold at discounted prices	Sales volume	0.5%	1.0%	0.18%	0.37%
				– Change overs - availability loss	Sales volume	1.0%	3.0%	0.37%	1.10%
				– Additional output by reduction in yield losses, slow-downs and downtime by AI-based optimization	Sales volume	3.0%	4.0%	1.10%	1.47%
				– Lower raw material prices by higher forecast accuracy and procurement intelligence	Sales price	1.0%	1.0%	1.00%	1.00%
				– Improved hedging and trading of raw material prices, machine learning AI-based risk management	Sales price	1.0%	2.0%	1.00%	2.00%
		Energy	3.50%	Reduction in relative energy consumption by AI-based optimization	Logistic cost	5.0%	30.0%	0.09%	0.55%
				Improved spot vs. contracting mix for energy sourcing	Production/ energy cost	2.0%	3.0%	0.07%	0.11%
		Personnel	10.00%	Reduction in effort by automation of repetitive, transactional tasks as well as simple judgemental tasks - physical and administrative tasks	Production/ personnel cost	35.0%	55.0%	3.50%	5.50%
				New skills for AI-supported operations, e.g. data scientists in control rooms	Production/ personnel cost	-3.0%	-4.0%	-0.30%	-0.40%
				Reduction in effort by AI supported decisions, e.g. control room operations	Production/ personnel cost	12.0%	14.0%	1.20%	1.40%
				AI solution intensity based increased effort, e.g. more data gathering, storage, cleansing and analyses, design, deployment, monitoring and maintenance	Production/ personnel cost	-4.0%	-5.0%	-0.40%	-0.50%
		IT	1.20%	IT investment increase (e.g. AI technology, infrastructure, maintenance)	Production/IT cost	-100.0%	-150.0%	-1.20%	-1.80%

Today				Value levers	Basis	Improvement/ Impact of Basis		Impact on EBIT (absolute)	
Illustrative P&L structure		Breakdown total cost				Min	Max	Min	Max
Maintenance	2.0%	Personnel	0.66%	Less manual effort (physical and administrative) by intelligent automation	Maintenance cost	17.0%	22.0%	0.11%	0.15%
				Reduction of unplanned effort (volume, price, weekend/night premiums, better prioritization)	Maintenance cost	4.0%	7.0%	0.03%	0.05%
		Other	1.34%	Higher asset availability due to less unplanned downtime	Maintenance cost	2.0%	4.0%	0.03%	0.05%
				Lower spare part levels and better spare part availability by AI predictive maintenance	Maintenance cost	0.5%	1.0%	0.01%	0.01%
				Less maintenance cost by better work scheduling and planning	Maintenance cost	0.5%	1.0%	0.01%	0.01%
Site Services	1.0%	Personnel	0.35%	Less manual effort (physical and administrative) by intelligent automation	Site service cost	25.9%	25.9%	0.09%	0.09%
		Other	0.65%						
Logistics	2.0%	Personnel	0.17%	Less manual effort (physical and administrative) by intelligent automation	Logistics cost/ personnel cost	43.8%	43.8%	0.07%	0.07%
		Other	1.83%	Improved network & inventory optimization, pre-consolidations of transports, warehouse efficiency, OTIF, near-real time route optimization, 3rd party scheduling and procurement	Logistics cost	10.0%	20.0%	0.18%	0.37%
Sales, Marketing, CS	4.5%	Personnel	3.25%	Automation of transactional sales & marketing tasks; automation of simple interactions	Sales cost/ personnel cost	35.0%	50.0%	1.14%	1.63%
				Intelligent automation of customer & technical services by bots, AI based service assistants	Sales cost/ personnel cost	10.0%	20.0%	0.33%	0.65%
		Other	1.25%	Increase in service levels and offerings through deeper insights, learning and scalability (24x7 availability of AI service assistants; mining of overall ecosystem, machine and deep learning; more service offerings for each customer; more tailored, differentiating offers; automated offering testing and campaigning)	Sales cost/ personnel cost	-10.0%	-20.0%	-0.13%	-0.25%
				Higher prices/margins by AI-based elasticity analyses, value pricing, switching thresholds etc.	Sales cost/ personnel cost	-3.0%	-4.0%	-0.04%	-0.05%
R&D	3.0%	Personnel	1.83%	More insights by ecosystem and previous experiments data mining; Less effort by automation of transactional and simple judgemental tasks	R&D cost	22.1%	22.1%	0.40%	0.40%
		Other	1.18%	Less asset and chemical utilization, lower number of experiments	R&D cost	5.0%	10.0%	0.06%	0.12%
				Better understanding of customer systems and needs	Sales volume	1.0%	2.0%	0.37%	0.73%
				More innovations and new R&D offerings through deeper market insights	Sales Volume	1.0%	2.0%	0.37%	0.73%
EH&S	0.8%	Personnel	0.44%	Less effort by automation of transactional and simple judgemental tasks	EH&S cost	20.0%	20.0%	0.09%	0.09%
		Other	0.36%						
General & Administration	3.0%	Personnel	2.04%	Less effort by automation of transactional and simple judgemental tasks	G&A cost	35.0%	55.0%	0.71%	1.12%
		Other	0.96%	Better decisions by machine (structured) and deep learning (unstructured decision support)	G&A cost	2.0%	4.0%	0.02%	0.04%
				Better decisions by extracting insights from ecosystem	G&A cost	1.0%	2.0%	0.01%	0.02%
Depreciation	4.0%		4.0%	Increase of asset invest and depreciation as production volumes scale with increased sales	Depreciation	-12%	-25%	-0.48%	-1.0%
EBIT	**10.0%**					**Total EBIT of value levers (on top existing)**		**15.82%**	**27.50%**

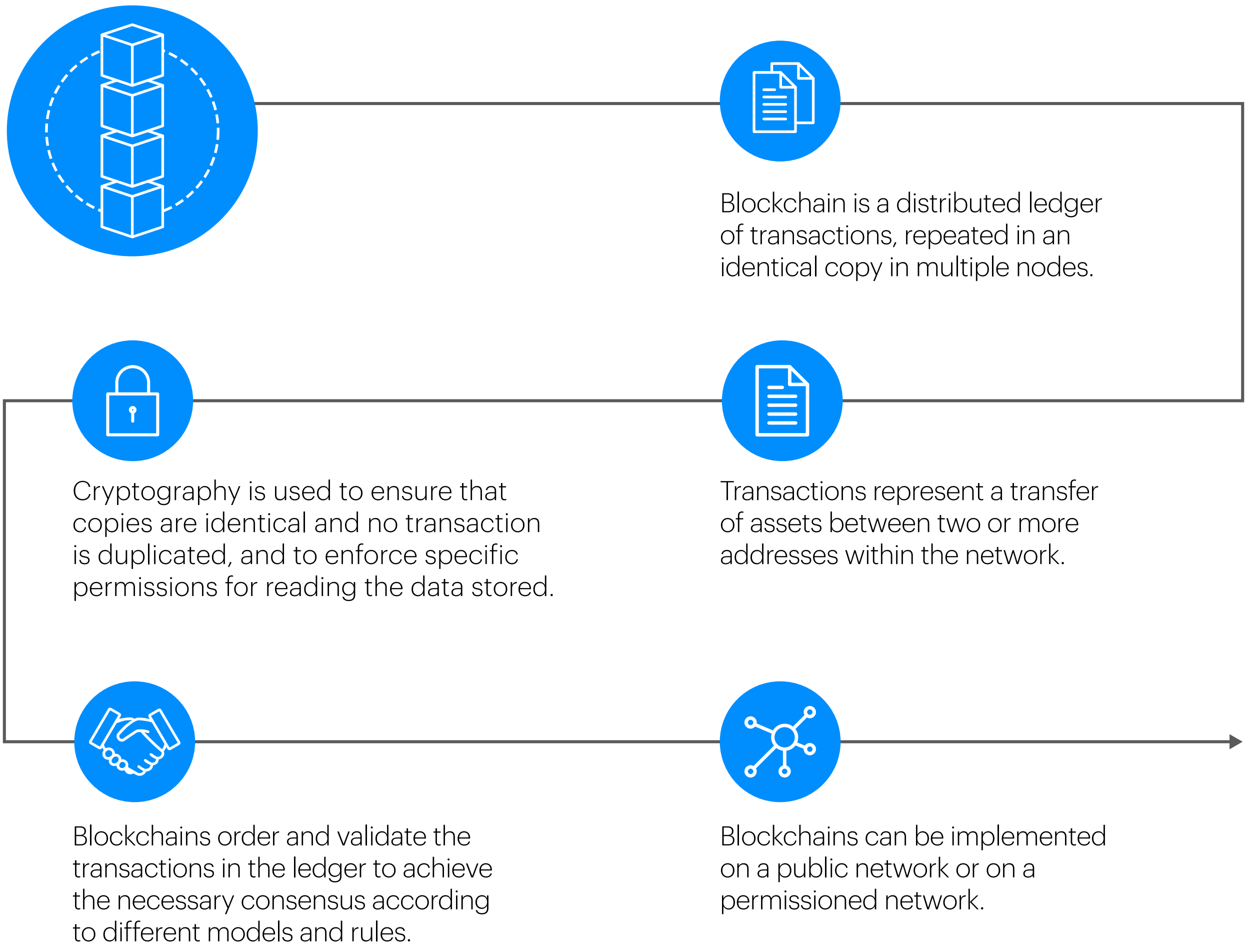
BLOCKCHAIN

Description

Blockchain is a type of distributed ledger that maintains exact copies of the ledger across multiple nodes without the need for a ledger master. (Figure 18) Cryptography is used to ensure that copies across the network are identical and enforce specific access permissions. Transactions represent a transfer of assets between two or more addresses within the network. There are different models for how transactions are validated and consensus between nodes is achieved. Blockchains can either be implemented as public, private or hybrid solutions. Smart contracts are computer protocols that facilitate, verify, execute and enforce the terms of an agreement with the ability to execute and move value.

Blockchain technology is not entirely new. It builds on standard bookkeeping registers/ledgers to log transactions over a certain period. But in contrast to a traditional ledger owned and controlled by one entity, blockchains are shared among a decentralized network of participants. Each block is validated by the network participants (nodes) via a jointly agreed proof protocol. Following network approval, the block can be appended only in a tamper-evident way to the existing chain. Any change that violates its integrity will be refused. This creates a high level of data resiliency.

Figure 18: How blockchain works



Value Model

The individual value levers for blockchain technology and their impact on cost reduction per business function and on sales/price increase are shown in Figure 19. The individual ranges provided are Accenture projections derived from benefit order of magnitudes observed in various proofs of concept, pilots and implemented solutions.

Figure 19: Normalized profit and loss potential of extensive blockchain deployment for a generic chemical company

Today				Value levers	Basis	Improvement/ Impact of Basis		Impact on EBIT (absolute)	
Illustrative P&L structure		Breakdown total cost				Min	Max	Min	Max
Sales	100.0%		100.0%	Network benefits (50% substitute):					
				– Better service offering, track & trace, automated quality control, assured provenance	Sales Volume	0.5%	1.0%	0.17%	0.23%
				– Price advantage due to lower transaction cost	Sales Volume	2.0%	2.0%	0.66%	0.46%
				– More tailored foreign exchange, cryptocurrency takes out volatility	Sales Price	1.5%	2.0%	1.50%	2.00%
				– Additional volume due to higher ease to deal with (contracts, verifications, etc.)	Sales Volume	1.0%	2.0%	0.33%	0.46%
				– Additional volume better supply capability, demand visibility, pro-active sales	Sales Volume	1.0%	1.0%	0.33%	0.23%
				– New applications tailored to specific customer needs	Sales Price	2.0%	3.0%	1.00%	4.00%
				– Better customerization and fit-of-product to specific customer needs	Sales Price	2.0%	3.0%	2.00%	3.00%
				– Better contribution to customer innovation through improved understanding of end customer needs	Sales Volume	2.0%	3.0%	0.46%	0.69%
				– Option for new business models, e.g. taking over non-value add activities of customers / customers customers (e.g. Inventories, disposal, circularity)	New Sales Category	1.0%	2.0%	0.33%	0.46%
Production	69.7%	Raw Materials	55.0%	Better planning and less inventories	Production/ Logistic cost	2.0%	5.0%	0.04%	0.10%
				Better price synchronization (product demand and pricing vs. raw material pricing), esp. versus players outside network	Sales Volume	1.0%	1.0%	0.33%	0.92%
				Less transaction cost (logistics, customs, quality, certificate handling)	Production/ Logistic cost	4.0%	6.0%	0.08%	0.12%
		Energy	3.50%						
		Personnel	10.0%	Reduced production cost due to faster processing of tasks	Production/ personnel cost	25.0%	50.0%	2.50%	5.00%
		IT	1.20%	More effort through new systems	Production/IT Cost	-10.0%	-30.0%	-0.12%	-3.36%
				Replacement of old and introduction of new systems	Production/IT Cost	-10.0%	-30.0%	-0.12%	-3.36%
Maintenance	2.0%	Personnel	0.66%						
		Other	1.34%	Option for equipment suppliers to contribute to better total cost of ownership, reliability and reduced maintenance cost	Maintenance cost	1.0%	2.0%	0.02%	0.04%
				Less transaction cost from notification to repair process	Maintenance cost	1.0%	2.0%	0.02%	0.04%
Site Services	1.0%	Personnel	0.35%						
		Other	0.65%						
Logistics	2.0%	Personnel	0.17%	Efficiency gains through automation through less admin and transaction cost	Logistic/ Personnel cost	10.0%	20.0%	0.20%	0.40%
		Other	1.83%	Less cost through efficient warehouse inventory management	Logistic cost	1.0%	3.0%	0.02%	0.06%
				Efficiency through better slot management and loading/ unloading across network	Logistic cost	1.0%	2.0%	0.02%	0.04%
				Less handling cost for shipments through more automation and less paper handling	Logistic cost	3.0%	4.0%	0.06%	0.08%
				Less custom cost through direct data exchange with custom authorities	Logistic cost	3.0%	5.0%	0.06%	0.10%
				Faster international delivery times through faster shipment and custom clearance	Logistic cost	4.0%	5.0%	0.08%	0.10%

Today				Value levers	Basis	Improvement/ Impact of Basis		Impact on EBIT (absolute)	
Illustrative P&L structure		Breakdown total cost				Min	Max	Min	Max
Sales, Marketing, CS	4.5%	Personnel	3.25%	Less customer inquiries	Sales/Personnel cost	3.0%	5.0%	0.14%	0.23%
				Less effort for order taking and management	Sales/Personnel cost	3.0%	5.0%	0.14%	0.23%
		Other	1.25%	Margin increase through less transaction cost	Sales cost	1.0%	2.0%	1.0%	2.0%
R&D	3.0%	Personnel	1.83%						
		Other	1.18%	Faster time to market through data exchange	New sales category	1.0%	2.0%	0.37%	0.53%
EH&S	0.8%	Personnel	0.44%						
		Other	0.36%						
General & Administration	3.0%	Personnel	2.04%						
		Other	0.96%	Reduction of verification steps incl. invoices, goods receipt, intercompany, business	G&A cost	10.0%	20.0%	0.30%	0.60%
				Less bank fees and transaction through direct payments	G&A cost	10.0%	20.0%	0.30%	0.60%
				Improved cash flow forecasting through near real-time payments	G&A cost	10.0%	20.0%	0.30%	0.60%
				Higher efficiencies through less transaction and admin cost	G&A cost	10.0%	20.0%	0.30%	0.60%
Depreciation	4.0%		4.0%	Increase of depreciation as sales volume increase	Depreciation	-7.50%	-10.0%	-0.30%	-0.40%
EBIT	**10.0%**		**10.0%**			**Total EBIT of value levers**		**12.5%**	**16.8%**

REFERENCES

1 Artificial Intelligence and Blockchain in the Chemical Industry Survey. Accenture, 2018.

2 Wall Street Journal, “Imagine Discovering That Your Teaching Assistant Really Is a Robot,” May 6, 2016. Retrieved September 19, 2018 from https://www.wsj.com/articles/if-your-teacher-sounds-like-a-robot-you-might-be-on-to-something-1462546621

3 Forbes, “Google Introduces Lifelike AI Experience with Google Duplex,” May 13, 2018. Retrieved September 19, 2018 from https://www.forbes.com/sites/shephyken/2018/05/13/google-introduces-lifelike-ai-experience-with-google-duplex/#351778c04dcf

4 https://www.thetradenews.com/half-hedge-funds-now-using-ai-technology, accessed September 18, 2018

5 European Commission News (02.12.2015); “Demographics and the economy: how a declining working-age population may change Europe’s growth prospects”; http://ec.europa.eu/social/main.jsp?langId=en&catId=1196&newsId=2402&furtherNews=yes (accessed on December 10, 2018)

6 See Appendix for details

7 Artificial Intelligence and Blockchain in the Chemical Industry Survey. Accenture, 2018.

8 Nature, “Planning chemical syntheses with deep neural networks and symbolic AI,” March 28, 2018. Retrieved September 19, 2018 from http://www.nature.com/articles/nature25978

9 The Korea Times, “POSCO revamps productivity through AI steel mill,” May 29, 2018. Retrieved September 19, 2018 from http://www.k oreatimes.co.kr/www/tech/2018/06/693_249781.html

10 AkzoNobel. Retrieved September 19, 2018 from https://www.akzonobel.com/en/for-media/media-releases-and-features/akzonobel-and-partners-developing-drone-technology-make-marine

11 The Advocate, “Corporations turn to drones to help reduce accidents; Dow Chemical lists Baton Rouge with its chief pilot,” May 23, 2015. Retrieved September 19, 2018 from https://www.theadvocate.com/baton_rouge/news/business/article_8e3c1230-858d-5593-a355-4c0f2d3f33b0.html

12 Emerj, “Artificial Intelligence in Oil and Gas – Comparing the Applications of 5 Oil Giants,” December 12, 2018. Retrieved September 19, 2018 from https://emerj.com/ai-sector-overviews/artificial-intelligence-in-oil-and-gas

13 Forbes, “How AI is Reshaping the Accounting Industry,” July 20, 2017. Retrieved September 19, 2018 from https://www.forbes.com/sites/forbestechcouncil/2017/07/20/how-ai-is-reshaping-the-accounting-industry/#126eb33537f3

14 For details on the model, see Appendix.

15 Top-line growth also drives variable effort across business functions. However, the cost growth will be much flatter or even close to zero due to the advantageous impact of AI on operational expenses.

16 The increase of production costs associated with sales increase is a result of increased production activity, including raw material, energy and personnel costs.

17 For a more detailed description of a generic data lake architecture, see Appendix for details.

18 For a more in-depth description of essential new job profiles required in the chemicals industry, see Appendix for details.

19 Why Artificial Intelligence is the future of growth. Accenture, 2016.

20 Ibid

21 Artificial Intelligence and Blockchain in the Chemical Industry Survey. Accenture, 2018.

22 Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH). REACH addresses production and use of chemical substances, and their potential impacts on human health and environment.

23 Accenture. https://newsroom.accenture.com/news/industry-consortium-successfully-tests-blockchain-solution-developed-by-accenture-that-could-revolutionize-ocean-shipping.htm

24 Tradelens. https://www.tradelens.com

25 Forbes, “IBM-Maersk Blockchain Platform Adds 92 Clients As Part Of Global Launch,” August 9, 2018. Retrieved September 19, 2018 from https://www.forbes.com/sites/michaeldelcastillo/2018/08/09/ibm-maersk-blockchain-platform-adds-92-clients-as-part-of-global-launch-1/#436c934a68a4

26 For details on how the value potential was modeled, see Appendix for details.

27 Cefic. http://www.cefic.org/Facts-and-Figures

28 The model in the Appendix details the impact of the individual levers on an individual chemical company.

29 Artificial Intelligence and Blockchain in the Chemical Industry Survey. Accenture, 2018.

30 The data lake covers only validated data. This validation step is accomplished by humans and AI itself, side-by-side.

31 Stuart J. Russell and Peter Norvig. Artificial Intelligence: A Modern Approach (2nd edition). Prentice Hall, 2003.

32 Brad Smith and Harry Shum. The Future Computed: Artificial intelligence and its role in society. Microsoft, 2018.

32 Accenture Technology Vision 2018. Accenture, 2018.

34 Ibid

35 Mohamed Zakaria Kurdi. Natural Language Processing and Computational Linguistics: Speech, Morphology and Syntax, Volume 1. Wiley, 2016.

ABOUT THE RESEARCH

Accenture carried out a proprietary online survey in 2018 to research the use of, and investment in, AI and blockchain technologies in the chemical industry.

The survey targeted chemical-industry executives from companies with global annual revenues of more than $500 million. These companies operate primarily in basic and intermediate chemicals, fertilizers, pesticides and/or seeds, industrial gases, petrochemicals, plastics and fibers, and paints and coatings.

The 200 executives who participated in the survey hold positions such as Board of Management/C-Suite (31 percent), Executive/Senior Vice President (43 percent), Vice President (22 percent), and Plant/Site/Commercial Manager (4 percent). They represented companies headquartered in Canada, China, France, Germany, Japan, Netherlands, Saudi Arabia, Singapore, Switzerland, UAE, UK and US.

The geographic split of respondents' locations was Europe (40 percent), Asia Pacific (26 percent), North America (18 percent) and Middle East (17 percent).

Findings Summary

About half of the organizations involved in the study have started early adoption or launched pilot programs in AI and/or blockchain, with more than 60 percent planning to allocate more than one-fifth of their total global digital technology budget to AI and blockchain technologies within the next 12 months. Companies in North America and Europe are planning to invest more aggressively in AI and blockchain, compared to their competitors from the Asia-Pacific (APAC) region and the Middle East.

Investments in these technologies are expected to grow in the next three years. North American companies expect the greatest growth of overall investment in AI, with 43 percent of executives saying that investments in this technology will be significantly more than current levels. APAC companies expect the greatest growth in blockchain investments, with 45 percent saying that investments will be significantly more than current levels.

More than half of the surveyed executives ranked improving production among the most promising focus areas for AI investment in the next three years. Real-time optimization of supply chain/procurement was also ranked high for AI investment by more than half of the executives. More than one in three ranked real-time tracking and chemical currency within the platform economy among the most promising focus areas for blockchain. Tracking of product specifications and qualities within production and delivery networks was also ranked among the most promising focus areas for blockchain investment.

In terms of value potential for these technologies, more than one-third of the organizations in the study expect a minimum annual cost saving of more than 10 percent, and 40 percent or more expect at least a 10 percent annual revenue improvement.

With both AI and blockchain, the greatest barriers to achieving business value stem from data security concerns and a lack of internal skills or capacity. For AI, a limited willingness for technology adoption in the organization was also raised as a significant barrier.

The majority of companies (more than 60 percent) have organized their AI and/or blockchain capabilities as part of a dedicated digital organization or have even created a dedicated AI/blockchain unit that works separately from the traditional IT organization, further supporting a significant and lasting commitment to these technologies within the organization.

ABOUT THE AUTHORS

Dr. Bernd Elser

Bernd Elser is a Managing Director who leads Accenture Strategy's Resources and Chemicals practice in Europe. He works with clients to address their most challenging and vital business issues, drive growth, optimize business operations and extract value at the intersection of business and technology. His functional expertise covers strategy development and commercial, operational and functional excellence. Bernd is based in Frankfurt, Germany.

Michael Ulbrich

Michael Ulbrich is a Managing Director in Accenture Strategy's Resources and Chemicals practice. He specializes in business strategy and operational and commercial excellence, focusing on deploying analytics and AI in enterprise functions such as R&D, the transition of the chemical industry into the circular economy, and marketing and sales strategy and capability building. Michael is based in Frankfurt, Germany.

Patrice Fasshauer

Patrice Fasshauer is a Senior Manager in Accenture Strategy's Resources and Chemicals practice in Austria, Germany and Switzerland. He works with international chemicals and oil & gas companies. His areas of expertise are organizational transformation, operational and maintenance excellence, global business service optimization and digital performance management. Patrice is based in Berlin, Germany.

Dr. Vikas Aggarwal

Vikas Aggarwal is a Manager in Accenture Strategy's Resources and Chemicals practice in Austria, Germany and Switzerland. He is a chemist with working experience in the chemicals industry and specializes in cross-functional digital and chemical innovation and market strategy. He focuses on enabling AI deployment and driving the transition of the chemicals industry toward a circular economy. Vikas is based in Frankfurt, Germany.

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