Capgemini
RESEARCH INSTITUTE

Conversations for tomorrow

Quarterly review
N°3 — 2021

Intelligent Industry: The Next Era of Transformation

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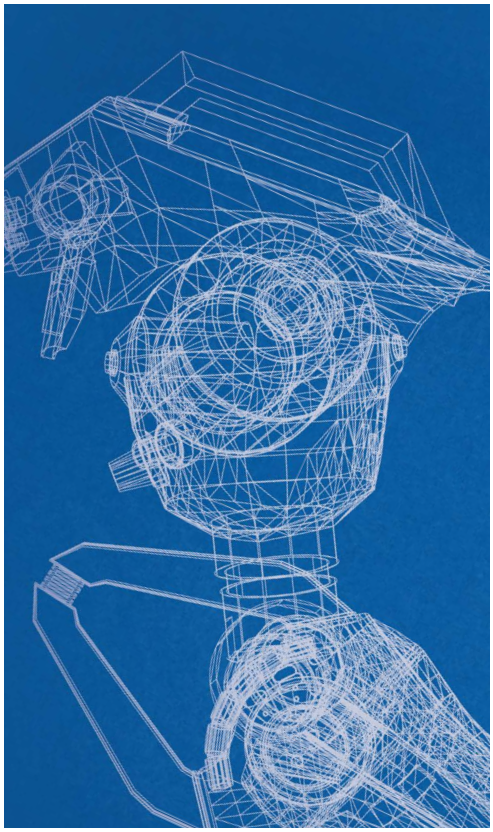
Conversations for tomorrow

Quarterly review



A representation of a robotic arm — a symbol of the convergence between the physical and virtual worlds. For us, this picture is also a reminder that our sustainable and intelligent future can only be achieved with the right combination of human and machine.

Foreword

Developments in three pivotal areas – software, connectivity, and semiconductors – are redefining traditional industries. Software is driving paradigm shifts for industries such as automotive; technologies such as 5G and edge are transforming operations and enabling the emergence of connected products; and digital twins are bridging the gap between virtual systems and the physical world via real-time models that can be continually updated and optimized. Connected products and platforms are enabling organizations to propose a new set of data-driven services, and thereby transform both the customer experience and business and operating models. Capgemini calls this new era of transformation *"Intelligent Industry."*

At Capgemini, we believe that bringing together key stakeholders and compiling their disparate views, makes us better prepared to seize the new opportunities and face the rising challenges of our volatile world. Through our journal, Conversations for Tomorrow, the Capgemini Research Institute endeavors to help leaders and experts identify strategic imperatives that shape the future of business and society as a whole. In this edition, we look at how the tech-driven convergence of the physical and virtual worlds will transform industries – from automotive to energy and utilities, to life sciences and to high-tech.

This edition contains perspectives from an array of business leaders, entrepreneurs, technologists, academics, and our own subject-matter experts, including:

- Frédéric Vincent, chief information officer, Renault Group
- Catherine Kniker, chief strategy officer, PTC
- Norihiro Suzuki, CTO and Head of the Research & Development Group, Hitachi, Ltd.
- Torbjørn Folgerø, senior vice president, Enterprise Digital, Equinor

We are grateful to all the leaders and experts who shared their thoughts and insights with us to enrich this journal. Through collaboration and the opportunities provided by Intelligent Industry, we aspire to unveil new possibilities and innovate our way to a more sustainable, efficient, and technologically advanced future.

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Executive Summary

Based on our discussions with global leaders and experts, as well as our own research, this edition examines a range of key themes.

Intelligent Industry is the new era of digital transformation

While digital transformation is not a new concept, a variety of factors – such as growth in ecommerce; the global semiconductor shortage; mass personalization of products; changing customer preferences; and growing concerns around sustainability – are compelling organizations to accelerate their transformations. Our research shows that 68% of organizations plan to boost investment

into the transformation process, with technology-led initiatives at their core.[1] Börje Ekholm, president and CEO of Ericsson, sees a fundamental shift in organizational focus, from "traditional operational efficiencies" to using emerging technologies to "transform business and operating models" across all facets of customer interaction, operations, manufacturing, and supply chains.

At Capgemini, we call this new era of transformation "Intelligent Industry:" *Intelligent Industry is about fostering synergies between the digital and engineering worlds to help companies build intelligent products, operations, and services, at scale. Intelligent Industry brings together engineering, IT, and digital and thereby allows a convergence of the physical and virtual worlds.*

Software holds the key to the next big opportunity

Products are no longer standalone pieces of hardware that operate in isolation; more often than not, they consist of a complex set of software layers. A large part of the value in the products now lies in the services embedded within or associated with the product, often bringing together contributions from various industries. Over the coming decade, the share of revenue among automotive original equipment manufacturers (OEMs) that is derived from software-based features and services is expected to almost triple, from 8% to 22%.[2]

Frédéric Vincent, CIO of Renault Group, believes that software is changing the paradigm of the automotive industry — delivering numerous new services to customers, ranging from predictive maintenance, insurance, and mobility services to suggested features a customer can install in their own car to improve their user experience. He comments, *"This [software] revolution will be comparable to that of the smartphone. The use cases associated with smartphones skyrocketed when they were connected to the cloud. In the same way, the connected car will lead to the invention of new services."*

5G and connectivity technologies already deliver significant improvements in operational efficiency

5G is a key catalyst in driving Intelligent Industry – allowing organizations to accelerate the digitalization of their core processes, at scale. Hitachi CTO Norihiro Suzuki sees 5G enabling a number of use cases, such as remote monitoring, video-based inspection, predictive maintenance, automated guided vehicles (AGVs), and remote collaboration using AR/VR-based applications.

Our research also shows that, among industrial organizations, early adopters of 5G have already achieved greater operational efficiencies. Despite these positive outcomes,

1 Capgemini Research Institute, "Fast-forward to the future defining and winning the post-COVID new normal," July 2020.

2 Capgemini Research Institute, "Next Destination: Software: How automotive OEMs can harness the potential of software-driven transformation," July 2021.

however, industrial 5G adoption is still taking off, with just 30% having reached the pilot and implementation stages.[3] Monika Gupta, vice president, Group 5G & Edge lead for Industries & Partnerships at Capgemini, says, *"To accelerate 5G adoption, industrial organizations should begin experimenting with or testing the new technologies and applying them to address business challenges, while progressively fine-tuning their approach as new features become available. For this, collective innovation and experimentation are key."*

Digital twins unlock new benefits across the value chain

Digital twins are enabling organizations to connect virtual systems with the physical world via real-time models that can be continually updated and optimized. The benefits this offers to organizations range from increased efficiency and lifecycle environmental impact to greater reliability and cost savings. For instance, public authorities everywhere from Singapore and Shanghai to Stockholm and Brooklyn are turning to digital twins to help them evolve their urban planning, infrastructure management, traffic monitoring, and even disaster management.

Data brings together products, software, and services

Harnessing the power of data fosters innovation, resulting in new and differentiated "smart" products, more streamlined, efficient supply chains, and new, enhanced customer experiences. All this, in turn, delivers new sources of value. Organizations that are proven data leaders realize a significant performance advantage; for instance, they see 22% higher profitability than the average among their peers.[4]

In the life sciences sector, data-driven transformation is enabling R&D teams to take novel approaches to drug discovery; understanding pathologies; identifying the therapies with the greatest potential; digitally optimizing clinical trials; and compressing the time to market for new medicines and medical products. Anastasia Christianson, vice president, R&D Business Technology at Janssen, Pharmaceutical companies of Johnson and Johnson, agrees that AI-based drug discovery can be "250 times more efficient" than traditional methods.

3 Capgemini Research Institute, "Accelerating the 5G Industrial Revolution: State of 5G and edge in industrial operations," June 2021.

4 Capgemini Research Institute, "The data-powered enterprise: Why organizations must strengthen their data mastery," November 2020.

As the demand for new, data-driven skills grows, the talent gap is widening

The skillset required for an operator in the "new working environment" is very different from that of a factory worker a few years ago. CXOs agree that there is a big skills gap in the market today, specifically in skills related to AI, machine learning (ML), and software engineering. Upskilling initiatives not only boost employee morale and enable workers to move on to more value-added activities and opportunities, but also allow organizations to make the most of their AI and automation initiatives. Yet few organizations have a mature upskilling program in place today – with three-quarters (73%) yet to begin their upskilling pilots.[5] Capgemini's CEO, Aiman Ezzat, adds, *"[Organizations] need to look at their technology investments and assess their impact on the workforce, identify the skillset that's going to be in demand, and develop a learning plan to meet that demand."*

Technologies will extend sustainability across the value chain.

While organizations today are focused on reducing carbon emissions in their operations, only when they address the issue across their entire value chain, including their customers and suppliers, will they begin to make a significant difference. Technologies such as AI, ML, data analytics, and digital twins can play an important role here, as they allow organizations to better utilize their resources, simulate emissions, and optimize their supply and transportation networks. Our research on sustainability in manufacturing operations shows that scaled use of these technologies has resulted in a 15% reduction in waste, on average, over the past two years.[6]

By being able to shape the virtual world, we can make ongoing improvements and refinements to the physical world it simulates, anticipating urgent market needs and gaining a clear view of the business horizon in the era of Intelligent Industry.

5 Capgemini Research Institute, "Upskilling your people for the age of the machine," June 2018.
6 Capgemini Research Institute, "Sustainable operations: A comprehensive guide for manufacturers," June 2021.

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The CEO Corner

Börje Ekholm
President and
Chief Executive Officer,
Ericsson

ERICSSON

In discussion with

Aiman Ezzat
Chief Executive Officer,
Capgemini

Capgemini

Conversations for tomorrow

Börje Ekholm
President and Chief Executive Officer,
Ericsson

Börje Ekholm has been president and CEO of the Ericsson Group since January 16, 2017. Prior to this, he was CEO of Patricia Industries, a division of Investor AB and his previous positions include president and CEO of Investor AB between 2005 and 2015. He is a board member of Telefonaktiebolaget LM Ericsson, Alibaba Group, and Trimble Inc.

Aiman Ezzat
Chief Executive Officer,
Capgemini

With more than 20 years' experience at Capgemini, Aiman Ezzat has a deep knowledge of the Group's main businesses. He has experience working in many countries, notably the UK and the US, where he lived for more than 15 years. Aiman was appointed CEO in May 2020. Before that, he served as the Group's COO, from 2018 to 2020, and CFO from 2012 to 2018. Aiman is also on the Air Liquide Board of Directors and is a member of the Business Council.

The Capgemini Research Institute spoke to Börje and Aiman to understand how the new era of digital transformation will look like, the role of connectivity technologies in shaping this next phase of transformation, and the new business models likely to emerge in the coming years.

ACCELERATING THE TRANSFORMATION

What will the next phase of digital transformation look like and how do you think it will impact global industry?

— **Börje:** Over the last few decades, organizations have focused on incremental changes and driving traditional operational efficiencies. I think that initiative has run its course. A much more fundamental transformation is going to be needed, where we use emerging technologies in a completely new way. That will involve digitalizing production and re-engineering whole processes.

It used to be that enterprises had to make a choice between more reliable but restrictive fixed connectivity and lower-performing wireless connectivity. Today, we don't need to make that trade-off of agility versus performance. High-performance, energy-efficient wireless connectivity will be instrumental in digitalizing enterprises and is going to have a similar impact to that which wireless connectivity had in digitalizing the consumer experience.

> **"A much more fundamental transformation is going to be needed, where we use emerging technologies in a completely new way."**
>
> Börje Ekholm

— **Aiman:** We coined the term "Intelligent Industry" to describe the next generation of digital transformation. Intelligent Industry is about fostering synergies between the digital and engineering worlds to help companies build intelligent products, operations, and services, at scale. Intelligent Industry brings together engineering, IT, and digital and thereby allows a convergence of the physical and virtual worlds.

We can, for example, now integrate a physical factory with its digital twin and use sensor data, machine learning, virtual reality, and cloud-based technologies to improve production efficiency and to imagine new products and services.[7]

> **Intelligent Industry is about fostering synergies between the digital and engineering worlds to help companies build intelligent products, operations, and services, at scale."**
>
> Aiman Ezzat

The unprecedented developments in and demand for a number of technologies is helping industries redefine themselves. They are now creating intelligent value chains and developing new ecosystems, such as mobility, smart cities, and connected healthcare. This, in turn, will allow organizations to transform their products and the processes they use to deliver those products. On top of that, they will be able to surround these products with an array of new, data-driven services.

ROLE OF 5G

What is the role of 5G in transitioning to this next phase of transformation?

— Börje: I think 5G is critical, but it is not only 5G; it's the convergence of cloud technologies, big data, artificial intelligence (AI), IoT, and 5G at a critical juncture in time. 5G is like a horizontal platform that allows enterprises to innovate on top of it. The fiber-fast speeds and performance characteristics of 5G form the basis of this next era of transformation. This transformation would not happen if you removed 5G connectivity; equally, it wouldn't happen if you removed cloud, so there is more than one vital element.

7 Capgemini, "See benefits of building digital twin of your factory with Capgemini," August 2021.

"The convergence of cloud technologies, big data, AI, IoT, and 5G is critical to the next phase of transformation"

Börje Ekholm

— Aiman: 5G is a key catalyst in driving Intelligent Industry. The massive machine-type communications and the ultra-reliability that 5G provides allow industries to accelerate the digitalization of their core processes, at scale. Today, 5G is enabling diverse applications, such as remote monitoring, video-based inspection, predictive maintenance, AGVs (automated guided vehicles), and cobots (collaborative robots designed for direct human interaction). It also allows organizations to learn from its data, thus maximizing performance and creating real business value.

What are the most promising use cases of 5G in the industrial world?

— Börje: In manufacturing, for example, the seamless, ubiquitous connectivity provided by 5G allows a different level of automation, improving productivity. We are starting to see completely remotely managed factories, for instance. Drones are another area where I see significant potential. Wireless connectivity is changing the way we conduct inspections and manage security. Mines are utilizing wireless networks to connect all the machinery they use, not just for increased productivity, but also to improve safety. There are significant improvements in drilling capacity and a reduction in fatalities and injuries. In ports, it is now possible to track every container. We also have AGVs that move the containers and goods around the ports, leading to significant efficiency gains.

Conversations for tomorrow

What needs to change to accelerate 5G adoption within industrial organizations?

— Börje: Telecom companies need to take an active role in demonstrating the benefits of 5G within the customer environment. They should also develop and make available a portfolio of solutions to address each of the various network-deployment scenarios. Professional-services companies also have a role to play here in providing manufacturing and industry-specific expertise, and in driving connectivity solutions based on customers' needs. We work together to bring this power of connectivity to enterprises.

— Aiman: Among industrial organizations, early adopters of 5G say they have already achieved greater operational efficiencies. Despite these positive outcomes, our research shows that industrial 5G adoption is still developing, with just 30% having reached the pilot and implementation stages.[8] Challenges such as the lack of 5G devices and difficulties in identifying the most appropriate use cases and in accessing vertical-specific solutions are obstacles to 5G adoption. If they want to fully leverage these opportunities, industrial organizations should get a clear understanding of 5G's capabilities and build a business case for its adoption as soon as possible. This business case should be followed by a multi-year roadmap that incorporates a network roll-out plan, the launch of new applications, and migration of existing applications. They can also actively work with other players in the ecosystem, including telecom companies, service providers, and startups.

"Among industrial organizations, early adopters of 5G say they have already achieved greater operational efficiencies."

Aiman Ezzat

8 Capgemini Research Institute, "Accelerating the 5G Industrial Revolution: State of 5G and edge in industrial operations," June 2021.

Could you share some best practices and lessons learned from Ericsson's manufacturing facility in Tallinn, Estonia or the 5G smart factory in Lewisville, Texas?

> **By bringing in new technologies, we can manufacture closer to the end consumer, thus driving efficiency; it is much easier to transport components than to ship finished goods."**
>
> Börje Ekholm

— **Börje:** We live in a world where manufacturing is done offshore and then the products are shipped to consumers. But, by bringing in new technologies, we can manufacture closer to the end consumer, thus driving efficiency; it is much easier to transport components than to ship finished goods. When we announced the plan for our factory at Lewisville in 2019, the idea was to be closer to our end consumers, the operators in the US. This factory is now recognized as a "global lighthouse" by the World Economic Forum, based on the technologies deployed and the impact they have had.[9]

What have we done there? We employ all the latest communication technologies. We have invested in AGVs, digital twins, and augmented reality (AR) to improve operations. The lessons learned from this factory operation have a broader significance for manufacturing companies, too: they ought to rethink their manufacturing footprints.

What are the new service or business models that you see emerging in the coming years?

— **Börje:** I think this is yet to be defined. But just as sharing and renting models are becoming prevalent in the B2C world, we may start to see more "as-a-Service" models in the B2B space. Cloud is already delivered this way but other products, be they machinery or parts, will also be sold more through a service model. This is already happening for jet engines, air

9 Ericsson, "Ericsson USA 5G Smart Factory recognized as 'Global Lighthouse' by the World Economic Forum," March 2021.

compressors, and smart lighting systems. This model benefits customers, as they can use a product for a fraction of the upfront investment required to purchase it. Manufacturers can continue to offer enhancements to the product by offering the customer software updates. But the sustainability of these business models is only driven by the benefits generated, and it all comes back to the question of how you create value for the end consumer. However, I do think sharing models are going to be more prominent going forward.

— Aiman: With the rapid development of IoT, cloud, AI, and 5G, "servitization" is definitely in the cards. The vast amounts of data that organizations are able to collect and analyze, supplemented by the data they are sharing with their ecosystem partners, means they are better positioned to offer data-driven services associated with their products. This shift from "product" to "product + services" will open up new revenue opportunities for organizations. At the same time, organizations will have an even greater need to ensure that customers' expectations are met. For instance, if an organization is using Robotics-as-a-Service for their warehouse operations, it will expect the service to deliver higher productivity, since the manufacturer of these robots has the means to monitor these robots and proactively address potential maintenance and performance issues.

BRIDGING THE TALENT GAP

How is this new phase of transformation redefining the skills that employees need, and will organizations be able to bridge the skills gap?

— Börje: This is a crucial aspect of the digital transformation and there is a big skills gap. The consensus in our company is to take investment to the level required to ensure we have the right skills for the future. The skillset required for an operator in the new working environment will be

very different from that of someone working in a factory a few years ago. We have to ensure that skill shift is a part of our OKRs (objectives and key results), and we should have clear plans to execute them by understanding the value they bring to us, individuals, leaders, and company. There is also a need to invest in the education system to provide the market with new capabilities in the long term.

— Aiman: As Börje mentioned, there definitely is a talent gap in the market today. Organizations are turning to upskilling initiatives that not only boost employee morale but also result in long-term savings. They need to look at their technology investments and assess their impact on the workforce; identify the skillset that's going to be in demand; and develop a learning plan to meet that demand. There is lot more work that needs to be done across sectors on upskilling, however. At Capgemini, we reskill people every 18 months on average and we are increasing the number of training days per person.

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SUSTAINABILITY THROUGH TECHNOLOGY

How can technology aid an organization's sustainability efforts? Can you share some of the best practices from your organization regarding sustainability programs?

— Börje: The biggest issue the world faces is the climate crisis. At Ericsson, we have said that we, as a company, should be carbon-neutral in our own operations by 2030. But, I am challenging us to beat that. We have reduced our own carbon footprint by 70% over the last decade, since 2012. But, given what we know today, we can do more, faster.

Our 5G factory in Lewisville is now powered by 100% renewable electricity, partly from onsite solar energy, but we're also buying certified renewable electricity from the utility grid. It's all about using as much renewable power as you can and thinking about the efficiencies we can produce. Secondly, we use 25% less energy here than in our other factories. It's clear that new technologies are not only driving labor productivity, but also energy productivity. We have reduced indoor water usage by 75%. These things are important in driving sustainability.

We also invest a lot in making our own products more energy efficient. We call that "breaking the energy curve." Every mobile generation in the past has increased energy consumption. With 5G, we think we're at the point where we can accommodate the likely increase in data demand without using more energy.

100%

Ericsson's 5G factory in Lewisville is now powered by 100% renewable electricity, partly from onsite solar energy.

— Aiman: At Capgemini we are committed to becoming a net zero business, and will be carbon neutral by 2025. And as an organization connected to so many large players, we can have a really strong impact well beyond our company. To achieve a sustainable future, collaboration with clients, suppliers, and other stakeholders is a must. We have among the most ambitious offerings of the market that can help our clients reduce their carbon emissions. For example, we built a platform using cloud and AI for European scientists, public authorities, and industry representatives to better explore information from the European Space Agency (ESA). This platform looks at indicators such as air quality and spread of deforestation, and facilitates decision making in near-real time. It has multiple applications, from analyzing rice crops to predicting clean-energy production or monitoring natural disasters such as floods.[10] Today, organizations are definitely aware of the need to be sustainable, and technology is a key enabler.

> **"To achieve a sustainable future, collaboration with clients, suppliers, and other stakeholders is a must."**
>
> Aiman Ezzat

OUTLOOK

What does the evolution to 6G look like and what further technological innovations will 6G enable?

— Börje: We think there are a couple of demands that 6G is trying to fulfill. We call the first one the "internet of senses," where we will see a very tight synchronization between the physical world and its digital representation, leading to an immersive physical experience. Telepresence, for instance, is one such application where you can experience the physical world remotely with lifelike fidelity. This means users can interact with digital replicas of

10 Capgemini, "Capgemini takes a stance against climate change by developing tools to better understand our planet," January 2020.

other users or objects using multi-sensory interactions, extending the audio-visual experience with haptic [transmitting information through touch] or olfactory experiences. You can think of this as the ability to feel the fabric while you buy clothes. You could also see this being extended to immersive sports experiences.

The second demand 6G serves is connecting intelligent machines, allowing close interaction between the virtual and real machines; for example, interactive robots that you can configure as well as interact with. E-health is going to be big, too. We're going to see the emergence of completely new ways to track our health.

6G will allow us to build a sustainably connected world. While 5G allows us to do some of these things already, 6G will make these things monumentally better.

Conversations for tomorrow

Börje Ekholm
President and
Chief Executive Officer,
Ericsson

Aiman Ezzat
Chief Executive Officer,
Capgemini

“Just as sharing and renting models are becoming prevalent in the B2C world, we may start to see more “as-a-Service” models in the B2B space"

"The shift from “product” to “product + services” will open up new revenue opportunities for organizations."

Discussions with...

Leaders from industry.

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HITACHI

Norihiro Suzuki

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JANSSEN, PHARMACEUTICAL COMPANIES OF JOHNSON AND JOHNSON

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SIEMENS

Gunter Beitinger

SVP Manufacturing & Head of Factory Digitalization, Siemens

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KIMBERLY-CLARK

Kim Kirkconnell

Vice President, IT Global Digital Supply Chain, Kimberly-Clark

and

Amy Sausen

Global Director, Digital Technology, Kimberly-Clark

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EQUINOR

Torbjørn Folgerø

Senior Vice President, Enterprise Digital, Equinor

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FRÉDÉRIC VINCENT

Member, Renault Group Board of Management, CIO
Renault Group

ENABLING THE AUTOMOTIVE SOFTWARE TRANSFORMATION

Renault Group

Frédéric Vincent joined Renault Group in 2016 as Chief Information Officer, drawing on his experience in the media industry, a leader in the digital transformation. He is also Chairman of the Renault Digital subsidiary and leads Renault Group's digital transformation. On April 1, 2019, Frédéric Vincent was appointed EVP, Group IS IT/Digital and EVP, Renault Brand, IS/IT.

The Capgemini Research Institute spoke to Frédéric about the digital transformation of the automotive industry and what the future of mobility will look like.

When we started our digital transformation, we realized that the IT department had to be modernized to capture the full value of digital. "

ALIGNED BUSINESS AND IT STRATEGIES

Frédéric Vincent
Member, Renault Group Board of Management, CIO Renault Group

How has Renault's combined digital and IT structure helped accelerate digital transformation?

— When we started our digital transformation, we realized that the IT department had to be modernized to capture the full value of digital. Our teams were mainly focused on managing contracts with suppliers, or delivering products based on cost, quality, and planning. We were not focused on delivering benefits from technology, working in short cycles, or understanding the needs of the different businesses within the group.

Such a change would usually be a very long journey. To move fast, in 2017, we decided to create a subsidiary dedicated to our digital transformation, called Renault Digital. We were able to hire several hundred people with the right skills. They could immediately deliver digital products for the company. Bringing in the correct skillset also afforded more time for the existing teams to transform themselves.

Meanwhile, Renault Digital could play the role of incubator for IT teams and projects. To enable this, Renault Digital had to be close to the IS/IT teams, and we therefore allocated the same management to both teams. This ensured Renault Digital had sufficient autonomy to make key decisions while being closely connected to the rest of IS/IT, which meant they could embark on this transformation as a unified team.

How well prepared is the automotive industry for the data-driven digital era?

— The automotive industry is not particularly advanced in the efficient and innovative use of data. We are working hard, firstly to create usable data; secondly, to collect it; and lastly, to make it consistent and transversal within the company.

We have a lot of data today but were not able to share it across the industry or even across different business units in the organization as there was no standard or common referential. In the plants, for instance, we have many different robots coming from different providers that don't speak the same language. We needed to define standards for our industrial data to make it interoperable. Then, we had to put all curated data in a common space to create meaningful links. To achieve this, we created a data lake hosted in the cloud. Cloud technologies and capacities are essential to manage a large volume of data and scale very quickly to follow the evolution of our needs. Additionally, we need to share all this data and since the cost of uploading to the cloud is high, we use edge computing to analyze the data closer to the point of collection, reducing latency [delay] in transferring data across a network. After initial computation near the data source, we only upload relevant data to the cloud that we need for large scale or cross-domain calculations. This optimizes costs and makes data available to other parts of the organization for cross-functional usage. Thanks to the cloud, we created transversal integration of data between functions. This allowed us to start using the data from Industry 4.0 in sales, data from after-sales in engineering, etc., to generate value.

"Thanks to the cloud, we created transversal integration of data between functions. This allowed us to start using the data from Industry 4.0 in sales, data from after-sales in engineering, etc., to generate value."

On the consumer front, we also need to be cognizant of complying with the General Data Protection Regulation (GDPR) and similar standards. We need to gather all the data from inside a vehicle, since it is vital for maintenance, security, and understanding usage patterns. We have 80 ECUs in a car, which can generate up to 25 GB of data each hour.[11] But, as most of it is considered personal data, we need to maintain transparency about how we access it, for customer assurance.

25 GB

We have 80 ECUs in a car, which can generate up to 25 GB of data each hour.

11 Venture Beat, "Vehicle telematics data could unlock $1.5 trillion in future revenue for automakers," December 2018.

SOFTWARE AND SERVICES AT THE CORE

How do you see software driving change within the automotive industry?

— Software-driven transformation is redefining the automotive industry in terms of how vehicles are conceived, designed, and manufactured. On the product front, the heart of a vehicle is now the software, rather than a collection of specialized hardware.

Over time, cars will become more intelligent and have the ability to learn. When a customer buys a car, it won't stagnate as a product during its lifetime. It will improve, learn, and will bring more value to the owner of the car with the help of emerging technologies such as AI, edge, and Cloud computing. This revolution will be comparable to that of the smartphone. The use cases associated with a smartphone skyrocketed when it was connected to the cloud. In the same way, the connected car will lead to the invention of new services. It will create new business models and new revenue opportunities for auto manufacturers.

"This software revolution will be comparable to that of the smartphone. The use cases associated with a smartphone skyrocketed when it was connected to the cloud. In the same way, the connected car will lead to the invention of new services."

How is Renault integrating software into manufacturing operations – specifically, digital twins?

— We use digital twins extensively to save time and money and achieve optimization and greater efficiency. For instance, in car design, we used to test car-crash safety by throwing the car into a wall. To achieve the desired results, we had to repeat this process multiple times. Today, we can do this using digital simulation, where we create a digital twin of the car in the cloud and simulate the crash to update, upgrade, and change required parameters. We still do a physical test with a real car to verify the final results, but digital simulation of crash tests brings significant savings.

Digital twins help us make rapid changes in our manufacturing line. When we have a new car to produce, we can use digital twins to check and configure the manufacturing line in a matter of seconds. We can simulate all possible manufacturing chains to optimize the final configuration before building a single piece. Once the plant is in operation, a digital twin helps us anticipate breakdowns, optimize energy consumption, and achieve higher efficiency.

"With digital simulation, we create a digital twin of the car in the cloud and simulate the crash to update, upgrade, and change required parameters. We still do a physical test with a real car to verify the final results, but digital simulation of crash tests brings significant savings."

What role will IT play in Renault's fulfilling its commitment to become more software-driven?

— The IS/IT and Digital teams have a crucial role to play in enabling Renault's software-driven transformation, in terms of defining the car-software strategy and designing the organizational structure required to deal with this software evolution. We work closely with the engineering teams to realize various applications of software inside the car.

When you put software in the car, the first thing that must be done is connecting the car to the cloud, to get information used in maintenance, security, understanding customer usage, and for software updates. The IS/IT team provides the tools to enable this crucial connectivity to the cloud. We have created a car-data platform that is dedicated to handling this connectivity.

> **"Software [in automotive] is enabling new services opportunities, ranging from maintenance to insurance."**

Many operations can also be undertaken outside the car. For instance, we have a camera in front of the car that is able to take pictures of tires when a turn is taken. By uploading these pictures to the cloud, wear and tear on the tire is detected. We can go back to our customer saying, "You have an issue with your tire." This is enabling new services opportunities, ranging from maintenance to insurance. IT has the responsibility to put the framework in place to enable these services – in terms of cloud, connectivity, and artificial intelligence (AI).

LOOKING AHEAD: FROM OWNERSHIP TO "USERSHIP"

How do you see mobility evolving in the next 5–10 years?

— There are three main axes. The first major evolution is due to CO2 regulations and the move to electrification. Although we are still at the beginning of this, the market share of electric cars is increasing day by day.

The second axis is the increasing use of software inside a car. By 2030, we anticipate 20% of our turnover to come from services, data, and energy trading. These services could include updates on quality and maintenance, insurance, or suggested features a customer can install in their car to improve user experience.

The third axis focuses on changing customer behavior: moving from "ownership" to "usership" in order to optimize the cost of cars. We view this as an emerging trend, since, especially in big cities, owning a car can be a hassle, but people still want to be able to use one. This is creating new businesses, including car-sharing and -hailing, which we call "mobility."

Conversations for tomorrow

Frédéric Vincent
Member, Renault Group Board of Management, CIO Renault Group

"Changing customer behavior: moving from "ownership" to "usership" in order to optimize the cost of cars is one of the key axis of mobility's evolution."

CATHERINE KNIKER

Chief Strategy Officer, PTC

BRIDGING GAPS THROUGH DIGITAL CONTINUITY

DIGITAL TRANSFORMS PHYSICAL

Catherine Kniker leads the corporate strategy, corporate development, and corporate marketing functions at PTC. She has more than 20 years of experience across internet, telecommunications, medical devices, and the healthcare sector. At PTC, she focuses on evaluating business problems that they should address for clients and strengthening the position of the organization within its markets.

PTC has a portfolio of digital solutions that work together to transform how physical products are engineered, manufactured, and serviced. The Capgemini Research Institute spoke to Catherine about how connected products are transforming various parts of the value chain and ways to establish digital continuity.

POTENTIAL OF CONNECTED PRODUCTS

How do you see the potential of smart, connected products for transforming design, manufacturing, operations, and services in industrial organizations?

Catherine Kniker
Chief Strategy Officer, PTC

— Connected products is a significant focus point in the digital transformations of many companies. One of the more interesting trends is the growing applicability of product data across the business. We're moving well past the days of computer-aided design (CAD) and product lifecycle management (PLM) data only being applicable to a design or management function. Now, we're seeing it deployed in other areas of the value chain, such as the application of PLM data to produce digital work instructions for a factory work cell, or original CAD data being utilized for an augmented reality (AR)-based digital inspection and quality-assurance exercise. This is an example of the 'digital thread:' the connection of digital product data across a company's engineering, manufacturing, and service departments, as well as their supply-chain partners.

"We're moving well past the days of computer-aided design (CAD) and product lifecycle management (PLM) data only being applicable to a design or management function. Now, we're seeing it deployed in other areas of the value chain, such as the application of PLM data to produce digital work instructions for a factory work cell…"

An emerging symbiotic link that's still largely untapped is the one between connected products operating in the field and the design team that could incorporate real-world product performance insights into new designs. The tools are there; it's only happening in pockets to begin with, but we think there's more potential to be unlocked.

The connection that now exists between the design, manufacturing, operations, and service departments is changing the way that work gets done. This opens the door for products to get to market faster, because these processes are happening concurrently. Engineers in R&D are working directly with planners on the factory floor, and they're collaborating with the service department to identify likely challenges when a product is taken to market.

Could you share some interesting success stories from your clients?

— One of our customers, Lanzhou Electric Co., Ltd (Landian), a China-based motor manufacturer, is a good example of a company that has embraced digital to transform its product-development process. It faced dual challenges: growing market demand and, in parallel, an intensifying need to shorten its new-product development cycles. Its engineering department was still operating primarily paper-based processes, which limited design-reuse options and hindered visibility across departments.

30%

In terms of bottom-line business impact, the shift to a digital-first approach resulted in a 30% increase in the design-reuse rate [for Lanzhou Electric Co., Ltd].

Landian embraced CAD and PLM to digitize and manage its product data. Immediately, these systems offered an accurate record of all this information, giving other departments visibility of the product-development process. In terms of bottom-line business impact, the shift to a digital-first approach resulted in a 30% increase in the design-reuse rate.

We see this type of change in customers across a variety of industries, including medical-device manufacturers, automotive suppliers, and heavy-equipment manufacturers.

ESTABLISHING DIGITAL CONTINUITY

Our research has found that around 60% of manufacturers are struggling to ensure "digital continuity"[12] throughout product lifecycles. Why do you think businesses are struggling here?

"Businesses that are struggling [in digital continuity] often lack a modern PLM system and may still be relying on antiquated processes like managing product data in Excel spreadsheets."

— Your research validates one of the more prominent pain points that we see in the industrial companies we work with, which has led us to cite the digital thread concept. We consistently see manufacturers and other industrial companies struggling to solve problems that could be addressed with the correct level of access, and the correct utilization of product data. I would point to a few reasons why businesses could be finding digital continuity a challenge:

Firstly, over the last few years, we've seen a significant spike in interest in PLM systems. As organizations realize how central PLM is to digital continuity across a product's lifecycle, it is becoming a strategic, enterprise-

12 Digital continuity is the ability for everyone working on a given product or design to view current versions of data and models simultaneously.

wide solution. It's the primary system for managing product data and it allows the entire enterprise an invaluable lens through which to view product development in a context and domain they recognize. Businesses that are struggling here often lack a modern PLM system and may still be relying on antiquated processes like managing product data in Excel spreadsheets.

Secondly, PLM and the product data that it manages serve to secure the digital thread for a company. We need to make the concept of the digital thread more actionable for businesses, and this is a key aspect. What's interesting about the digital thread is the way that it blends longstanding technologies, such as CAD and PLM, with newer technologies, such as the industrial internet of things (IIoT) and AR. Manufacturers and industrial companies need to understand the benefits of these newer technologies, and see examples of how they work with more familiar ones, such as CAD and PLM. The way PLM manages and orchestrates the digital thread helps to unlock significant value for customers, including enterprise visualization, digital product traceability, closed-loop quality, and more.

Finally, a third reason could be the fact that industrial companies have been laggards in embracing the benefits of the cloud and other digital-first tools. Far more managerial leadership and hands-on work is required in traditional on-premises processes – whether it's checking design files in and out or evaluating the benefits of installing personnel at a specific site to monitor a process versus the ability to do so remotely. It's no secret that most software markets have moved to a cloud-first model and we're pushing for the industrial space to do the same, so that these companies can realize similar convenience, collaboration, and efficiency benefits.

" It's no secret that most software markets have moved to a cloud-first model and we're pushing for the industrial space to do the same, so that these companies can realize similar convenience, collaboration, and efficiency benefits."

Which steps should organizations take to bridge the various data discontinuities within engineering disciplines (hardware, software, electronics, etc.) and functions (design, production, service)?

"Engineers in R&D must collaborate concurrently with planners in the factory and the service department, or there is a significant risk of falling behind."

— Traditional ways of working must change, so that we see more effective collaboration between disciplines, across geographically distributed projects, within and across divisions, and with external partners. There needs to be closed-loop quality and processes to achieve compliance with regulatory requirements and quality standards. Lead times must get shorter; engineers in R&D must collaborate concurrently with planners in the factory and the service department, or there is a significant risk of falling behind.

I have mentioned the value of the digital thread and how it can be fueled by data created in engineering, manufacturing, and service. You can employ requirements, systems models, functional models, x-BOMs (such as engineering bill of materials (EBOM), manufacturing bill of materials (MBOM), service bill of materials (SBOM)), CAD and eCAD models, and software that is created by engineers to drive downstream "derivative works" in manufacturing and in service.

At PTC, we have a strong focus on applications that are used in product development, production, and quality (CAD, PLM, application lifecycle management (ALM), service lifecycle management (SLM)). In the IIoT space, we are focusing on two things that are tied to the digital thread. First, we have solutions and a platform that can address factory and service-use cases, generating data that can inform the digital thread. Second, IIoT technology helps to orchestrate data between important enterprise systems, clouds, assets in the factory, and products once they're out in the market.

Conversations for tomorrow

Catherine Kniker
Chief Strategy Officer, PTC

“IIoT technology helps to orchestrate data between important enterprise systems, clouds, assets in the factory, and products once they’re out in the market."

DR. NORIHIRO SUZUKI

CTO and Head of the Research & Development Group, Hitachi, Ltd.

A JOURNEY TO INTELLIGENT MANUFACTURING

HITACHI
Inspire the Next

Dr. Suzuki received his PhD from the University of Tokyo and began his career in research in digital-image signal processing and embedded software systems, later leading research projects in Japan and the Americas. He is a member of the Institute of Electronics, Information and Communication Engineers (IEICE), the Institute of Image Information and Television Engineers, and a Senior member of the Institute of Electrical and Electronic Engineers (IEEE).

The Capgemini Research Institute spoke to Dr. Suzuki about Hitachi's journey to adopting intelligent operations, using emerging technologies and its determination to use these technologies for social good.

IT-OT CONVERGENCE

What are the best practices that you want to share with manufacturing organizations with regards to integrating cutting-edge technologies into production processes?

— At Hitachi, we focus on our strengths: information technology (IT), operational technology (OT), and product. Omika Works, a factory of ours in Japan, manufactures information-control systems for societal infrastructure such as railway systems, electricity grids, and water-supply and sewerage networks. In 2020, this factory was recognized as

Dr. Norihiro Suzuki
CTO and Head of the Research & Development Group, Hitachi, Ltd.

"Omika Works [one of our factories recognized by the WEF] uses the internet of things (IoT) for designing and manufacturing hardware to reduce production lead times; a decentralized autonomous framework for the design and development of software, and digital twins for quality control."

a "lighthouse factory" by the World Economic Forum (WEF) owing to its use of advanced digital technologies in all aspects of its operations. The factory uses the internet of things (IoT) for designing and manufacturing hardware to reduce production lead times; a decentralized autonomous framework for the design and development of software, and digital twins for quality control. We are now working on automation and unmanned operations using 5G, robotics, and artificial intelligence (AI). This integration of IT and OT systems helps us to find solutions to various issues and create new products. Our Lumada platform focuses on analyzing the combined data from our customers' IT and OT assets and uses that to generate new insights that can help resolve significant business issues.

EMERGING TECHNOLOGIES AND THE WAY FORWARD

What do you think are the most promising use cases for 5G in the manufacturing sector? And what are Hitachi's key focus areas for 5G initiatives and investments?

— We are now focused on the real-time control aspects of 5G, particularly telepresence and interactive remote collaboration between workers and machines. The advanced sensing technology of Augmented Reality (AR) glass and the low-latency video transmission enabled by 5G afford 360° high-resolution vision in real time, thereby allowing remote workers to monitor developing situations and take appropriate preventive or reactive measures. This will have applications not only in manufacturing but also in the fields of mobility and energy. We have established 5G networks for testing applications with our partners at our Kokubunji co-creation center in Japan and also at our Silicon Valley site in California.

A couple of years ago, Hitachi announced it was teaming up with the World Economic Forum and government organizations to accelerate blockchain deployment across supply chains. Could you talk about its progress and shed light on emerging areas for blockchain deployment in Hitachi?

— Hitachi R&D was an anchor partner for blockchain in supply chain from 2018 to 2020. The Forum and other large organizations came together to develop the "Redesigning Trust with Blockchain in the Supply Chain" project to guide supply-chain executives and decision makers in the deployment of blockchain technology. The group planned to co-design an open-source toolkit to highlight the requirements, technical and non-technical drivers of success, and risks involved. The blockchain deployment toolkit was released as a web tool in April 2020. It garnered quite a bit of interest from supply-chain and trade stakeholders, and we registered 24,000 access requests and 15,000 users in the first three months. The next step in this process is addressing the challenges of interoperability. This includes looking at accessibility for users at scale.

"At Hitachi, we are interested in the application of blockchain as an authentication platform, including biometric authentication. We have already released a contactless authentication solution that uses finger vein pattern for personal identification."

At Hitachi, we are interested in the application of blockchain as an authentication platform, including biometric authentication. We have already released a contactless authentication solution that uses finger vein pattern for personal identification. Amalgamating this with a blockchain platform could be a good use case for self-sovereign identity (SSI), an approach that allows individuals to control their digital identities.

24,000

REQUESTS FOR ACCESS

15,000

USERS

We registered 24,000 access requests and 15,000 users in the first three months [for the blockchain deployment toolkit].

MAKING TECHNOLOGY WORK FOR SOCIETY

Could you tell us about Hitachi's Social Innovation Business program?

— We want to create a sustainable and human-centric society built on three pillars: social, economic, and environmental values. For instance, in sectors such as mobility, we are developing ideas in fields as diverse as smart-city transportation, rail, fleet management, and Mobility-as-a-Service (MaaS). In manufacturing, we are harnessing IoT and big data to transform the structure of industry, making it both sustainable and more efficient.

Which initiatives has Hitachi taken to move towards carbon neutrality and how does it plan to extend these initiatives across the entire supply chain?

— Hitachi announced a target to make all its business sites (factories and offices) carbon neutral by end-2030, extending to the entire value chain by end-2050. Our facility at the Kokubunji site achieved carbon neutrality in 2021, and now runs entirely on renewable energy. A prototype was developed using smart meters to manage the use of renewable energy and blockchain technology to visualize how much renewable energy is needed by a building or production line. This can provide companies with assurance that 100% of the electricity that they are using is generated from renewable sources. We believe that data will be key to realizing a fully sustainable value chain, and are developing a digital integrated management service to collect the factory data, as well as the process, depot, goods, and equipment data, and a full simulation tool to achieve this optimization, from procurement up.

"Our Lumada platform focuses on analyzing the combined data from our customers' IT and OT assets and uses that to generate new insights that can help resolve significant business issues… We want to create a sustainable and human-centric society built on three pillars: social, economic, and environmental values"

What is your advice to other organizations who want to adapt their technologies for social good?

— There are a number of initiatives that we are undertaking to help create a more sustainable society. Our CDP (Carbon Disclosure Project) score[13] for fiscal year 2020 for water security is "A," the highest rating possible, and for climate change, it is "A-," so we're making progress. One thing we realized is that we, Hitachi, cannot make this happen by ourselves. That's why we are working with numerous communities and consortiums to build innovation ecosystems. We partnered with the University of Tokyo to establish the Hitachi University of Tokyo Laboratory (H-UTokyo Lab) for collaborative creation to realize "Super Smart Society." One area of collaboration is future energy systems. Our goal is to realize carbon neutrality by 2050 but this will not be easily achieved. So, we are working with our customers, both on the demand and supply sides, such as the energy companies, automotive manufacturers, and steel manufacturers, on how to achieve this carbon neutrality. We are discussing countermeasures and will advise government as to which initiatives they should look at, and what support is required for industry to realize this vision.

2050

Hitachi announced a target to make all its business sites (factories and offices) carbon neutral by end-2030, extending to the entire value chain by end-2050.

13 The CDP (formerly the Carbon Disclosure Project) score is indicative of a company's environmental awareness, advanced sustainability governance, and leadership to address climate change.

OUTLOOK: A SMARTER FUTURE

How do you see smart manufacturing evolving?

— Current ways of working and production processes will change dramatically. The effective use of technology will mitigate location constraints on factory employees, allowing them to work remotely, and evolving robotics technology (i.e., collaborative robots or "cobots") will enable advanced on-site work collaboration between people and the machines.

The digital transformation of industry, partly owing to the impact of COVID-19, will continue to accelerate globally and there will be more emphasis on collecting data in all industries. By looking at the data from manufacturing systems in real time and optimizing production using advanced technologies, industry will be able to achieve resilient operations.

We see the Japanese concept of *kizashi* – which broadly speaking, means recognizing and understanding the early signs of change – as essential to future success. As the focus shifts for manufacturing organizations from selling products to creating more value for customers, co-creation – sharing solutions and visions with customers and partners; designing business models; and realizing them through verification and simulation – will be crucial. And *kizashi* will be paramount to lead in the new age.

Conversations for tomorrow

Dr. Norihiro Suzuki
CTO and Head of the Research & Development Group, Hitachi, Ltd.

"We see the Japanese concept of Kizashi – which broadly speaking, means recognizing and understanding the early signs of change – as essential to future success. As the focus shifts for manufacturing organizations from selling products to creating more value for customers, co-creation ... will be crucial"

DR. ANASTASIA CHRISTIANSON

Vice President,
R&D Business Technology
Janssen, Pharmaceutical companies
of Johnson and Johnson

TRANSITIONING TO DATA-DRIVEN R&D

Dr. Christianson has more than twenty years of experience in the biotechnology and pharmaceutical industry. She works on drug discovery and development, focusing on developing technology solutions that enable and accelerate scientific and clinical research and drug development. She received her doctorate in biological chemistry from the University of Pennsylvania and pursued her postdoctoral training in cellular and developmental biology at Harvard University.

The Capgemini Research Institute spoke to Dr Christianson about the data-driven transformation of the pharma R&D, and the value of data-sharing ecosystems.

PHARMACEUTICAL R&D IS POWERED BY DATA

Can you tell us how you use data in the drug discovery and development process?

Dr. Anastasia Christianson
Vice President,
R&D Business Technology
Janssen, Pharmaceutical companies of Johnson and Johnson

— There are a number of ways in which we use data in each step of the drug discovery and development process. The process can take up to ten years to yield a drug to patients so anything we can do along the way to save time is beneficial for getting the therapy to patients faster. Making best use of the data we generate along the way can definitely accelerate the process. In a typical drug discovery experiment, cells representing a specific disease (such as lung cancer) are exposed to a variety of compounds, and data are collected to evaluate how cells respond to each compound. For example, a microscopy snapshot might be taken of each reaction that follows the initial exposure of cells to a compound. One such experiment might generate half a million snapshots. Artificial Intelligence (AI) technologies help us to sort the data from such experiments with the goal of finding a compound that could create the desired reaction for the disease we are studying. Further, machine learning algorithms help us to predict how other types of cells are likely to react to the same compound(s), giving us a leg up when starting a new study. This AI-based

250 TIMES

AI-based method can be 250 times more efficient than the traditional method of drug discovery.

method can be 250 times more efficient than the traditional method of drug discovery.

In clinical trials, data and AI are being used for designing better trials. For instance, researchers today have access to hundreds of millions of real-world data points from a large number of diverse sources that provide insights on how or when people use treatments. These data points can, in some cases, be as useful to researchers as trial data, and could be used to select patients who are most likely to respond to a particular therapy for example, thus accelerating trials. Digital health technologies and digital biomarkers are also accelerating clinical trials by enabling faster collection of data during a trial for patient selection, monitoring response and outcome.

"In clinical trials, data and AI are being used for designing better trials."

While there are huge benefits from making better use of our data across the entire R&D process, right now, my team and I are focusing on accelerating drug discovery and drug development programs.

STRENGTHENING THE DATA-SHARING ECOSYSTEMS

Where do you see the benefit of data-sharing ecosystems?

— We partner with a number of groups such as Innovative Medicines Initiative (IMI) in Europe to ensure that we're sharing data in both directions. The major driver behind these data-sharing practices is to make informed, data-driven decisions. The more data we have, the better questions we can ask and thus more accurate responses. While we have a lot of experts, we can't be the experts on everything. When it comes to specific diseases, for example, others may have more data or additional knowledge that complements our knowledge. We partner with experts as needed to ensure that we benefit from their experience and data.

Conversely, we also aim to share our data that might be beneficial elsewhere. For example, a couple of years ago, we signed a first-of-its-kind agreement with Yale School of Medicine's Open Data Access Project (YODA) to facilitate the sharing of clinical trial data – aiming to enhance public health and advance science and medicine. The project has been hailed as representing a new standard for responsible, independent clinical data sharing.

"The major driver behind these data-sharing practices is to make informed, data-driven decisions. The more data we have, the better questions we can ask and thus more accurate responses."

APPROACH TO DATA-DRIVEN R&D

How can organizations advance towards data-driven R&D?

— Being a data-driven organization means you have to be a learning organization and ensure that your employees are data-focused, utilizing advanced data analytics capabilities like machine learning and AI, and employing decision frameworks and decision memory capabilities. Your data need to be Findable, Accessible, Interoperable, and Reusable (following FAIR principles) and your scientists and leaders must be well versed in the tools and capabilities that allow them to make best use of data. This includes all the steps from data generation to decision-making.

Your data provide important information, knowledge, and insights; the next step is to use those insights with all the information and knowledge around them, to make the best informed decision, tracking decisions, and learning from them. Making decisions on the right target, drug candidate,

disease indication, or biomarker(s) to choose/measure requires a certain level of risk-taking that is dependent on available information. You might have the option to measure one, two or three biomarkers in a given trial to monitor trial efficacy and/or outcome. Choosing how many and which biomarkers to use requires balancing scientific and medical knowledge along with trial feasibility, cost, and speed. You make the best decision based on the data available and you want to track the decision and outcomes for the next time you are faced with a similar scenario, so that you can apply the learning for the next decision. Right now, this process of documenting learnings from each trial or project is very manual and is not always easy to track, but we are looking at ways to digitally capture decisions and associated information for learning and reuse.

" Being a data-driven organization means you have to be a learning organization and ensure that your employees are data-focused, utilizing advanced data analytics capabilities like machine learning and AI, and employing decision frameworks and decision memory capabilities."

FUTURE OF DATA-DRIVEN R&D

What changes do you see in data-driven R&D in the future?

— There will be more use of technology in R&D and healthcare, such as 5G connectivity, to help underserved areas. Real-time monitoring through sensing technologies, digital biomarkers, and edge computing, as well as the use of AI at scale will lead to more and earlier predictions in discovery and in the clinic. Quantum computing is

another emerging area where qubits can be useful in genomic analysis, protein structure prediction, or accelerated diagnosis, to name a few. For example, current computing capabilities may require several weeks to simulate the formation of protein complexes, protein-to-protein, or protein-to-ligand interactions. Quantum computing is expected to significantly shorten this time.

If we look at discovery specifically, by understanding disease at a molecular, phenotypic, and patient-level, and by feeding these data into our "discovery engine", we can enable the best-informed drug design decisions. At the same time, through robotics, intelligent automation, and sensors for monitoring, we can run more experiments and collect more data in parallel in the labs.

Conversations for tomorrow

Dr. Anastasia Christianson
Vice President,
R&D Business Technology
Janssen, Pharmaceutical companies
of Johnson and Johnson

"If we look at discovery specifically, by understanding disease at a molecular, phenotypic, and patient-level, and by feeding these data into our "discovery engine", we can enable the best-informed drug design decisions."

DR. GUNTER BEITINGER

SVP Manufacturing & Head of Factory Digitalization, Siemens

A BLUEPRINT FOR FACTORY DIGITALIZATION AND A MORE SUSTAINABLE FUTURE

SIEMENS

Dr. Gunter Beitinger heads factory digitalization for Siemens AG, supporting 121 factories on their transformation journey. As Senior Vice President Manufacturing, Dr. Beitinger is also responsible for the manufacturing element of the Factory Automation business unit, which is part of Siemens's Digital Industries division. He joined Siemens in 1999 after five years as a research collaborator at the University of Erlangen.

The Capgemini Research Institute spoke to Dr. Beitinger about how Siemens responded to the unprecedented market changes of the pandemic environment and the drive to ensure supply chains, factories, plants, and networks are more efficient, intelligent, and sustainable.

THE COVID-19 PANDEMIC AND THE MANUFACTURING SECTOR

The past year and more had an unprecedented impact on the manufacturing sector. How did Siemens navigate through this disruption?

— The COVID-19 pandemic emphasized the importance of automation in the manufacturing sector. Due to the high degree of digitalization and automation in many of our factories, people from maintenance or from quality could observe the situation in near-real time, even in the pandemic. With access to our systems and dashboards, they could identify abnormalities and provide remote assistance. Although, in the first week of lockdown, we came down to 85% productivity output, after just six weeks we were back to 95% productivity.

Dr. Gunter Beitinger
SVP Manufacturing & Head of Factory Digitalization, Siemens

"We have a "market-oriented production" concept in our factories. This means our China factories are mainly producing what is required for the Asian market, and our European factories are mainly producing for the demand in Europe or the rest of the world. "

Another aspect that helped us to overcome the situation was the fact that we have a "market-oriented production" concept in our factories. This means our China factories are mainly producing what is required for the Asian market, and our European factories are mainly producing for the demand in Europe or the rest of the world. The impact was therefore limited because we didn't have an interconnection between the factories – we had one product in many plants, and they were mainly meant to serve their region. We will continue with this market-oriented production concept and now insist on producing more closely to the market we are supplying.

SIEMENS AND INTELLIGENT OPERATIONS

Recently, Siemens Electronics Works in Amberg – which is regarded as a digitalization hub for its work demonstrating the potential of future technologies such as artificial intelligence – was nominated as a "Lighthouse Factory" for the World Economic Forum, recognizing its role in systematically implementing Industry 4.0 technologies. Can you tell us more about your "Lean Digital Factory"?

— The journey to become a lean digital factory always begins with becoming a lean factory first – focusing on eliminating waste from processes. We have had continuous improvement, lean management, and process optimization activities running for a long time in our factories. As a result, we saw that the amount of shop floor productivity projects increased dramatically over the years. To take this productivity level to the next step, we realized that we had to actively support our people by adopting new technologies. So, our "Lean Digital Factory" (LDF) program was initiated to strengthen the focus on automation, digitalization, and shop floor productivity from data and analytics based on the lean production philosophy. Alongside that, we wanted to focus on employee engagement, plant network design, supply chain design, and supplier collaboration.

The overall digitalization roadmap consists of five work streams. First, is digital twins, which focuses on digital twin of product, production, and performance. Second, processes, which looks at autonomous end-to-end coordination of supply chain resources based on AI. Third, is big data and analytics, which covers smart algorithms and AI for decision making as well as for preventive or prescriptive maintenance. Fourth, is robotics – focusing on cooperation of digitally guided workers and interlinked autonomous production systems to enable efficient, flexible, and easy-to-scale-up manufacturing. Finally, we have new ways of working, which looks at the skills and competencies required for digital efficiency and the sustainable factories of the future.

> **"[Our] digitalization roadmap consists of five work streams [including] digital twins, AI, robotics, big data and analytics [as well as] new ways of working."**

We started with these five areas in 2016, and since then we have been driving and implementing them in 30 factories worldwide. Besides a significant productivity increase, the major benefits are synergies, balanced workforce and capacity, speed learning, and a reliable supplier base.

The Siemens Electronics Works Amberg (EWA) was founded in 1989 and manufactures a range of products, including type Simatic programmable logic controllers (PLCs). Over 1,200 product variants are manufactured in Amberg.

The Amberg plant has 99.9999% perfect quality daily, a 14x productivity increase since 1990 (70% less downtime) in the same footprint with 120 variations per day, 1 product per second (17 million product per year), and 350 changeovers per day to handle 1,200 different products, and 200 new products per year.[14]

The production functions here are largely automated, with 75% of the value chain handled independently by machines and robots.

A "lean digital factory" with smart robotics, AI-powered process controls and predictive maintenance algorithms has helped EWA to achieve 140% factory output at double product complexity without an increase in electricity or a change in resources.

14 Control Engineering, "Digitalization, automation advice, benefits," March 2021.

99.9999% PERFECT QUALITY DAILY

The Amberg plant has 99.9999% perfect quality daily, a 14x productivity increase since 1990 (70% less downtime) in the same footprint with 120 variations per day, 1 product per second (17 million product per year), and 350 changeovers per day to handle 1,200 different products, and 200 new products per year.

What is the "recipe" for scaling smart factory initiatives?

— When one use case is implemented in one factory, it can have a great impact as the use case was customized for that particular factory's IT environment. But, when we are looking at scalability, we focus on having a reference architecture defined from the IT aspect. That doesn't mean that all factories are able to immediately implement this reference architecture, but this acts as a north star.

The second aspect we look for is accessibility to our data. We came up with a need for a standardized data lake where different factories are able to store data, access the data, and do data mining in a structured way. We came up with solutions such as a "data-lake-to-go" – where factories can immediately start to collect the data from edge devices and have accessibility because there is already a standardization coming up with this.

And finally, it is about collaboration. When one factory comes up with a solution or with an idea that has the potential for scalability, we bring the other factories into the program. So, it is like the musketeers with "all for one and one for all" - where one does it for the others and the others do it for the one.

What advice would you give to business leaders who want to use a digital twin?

— We focus on digital twins, as it allows us to automate the simulation and it also drives further productivity – leveraging synergies with new technologies and data analytics while reducing IT and software investment risks. We aim to align digital twins to the ECLASS cross-industry standard – which contains all levels of detail to automize the process from product design to production on the shop floor.[15] This means that the product knows in which order it wants to be produced, on which machines or with which technologies it wants to be produced.

15 The worldwide ISO/IEC-compliant data standard for goods and services: https://www.eclass.eu/en/index.html

Secondly, our machine providers receive a very detailed requirement from us based on simulation and drawings. They are able to integrate these in the digital twin, and we are able to simulate material flow and all the logistics aspects, including the potential to feed in real data later. The performance model – along with real-time data – is shared back to our engineers for further improvement for new lines.

So, a key learning from this is that we get better and better by feeding information on areas such as design for manufacturability or design for testability back to our engineering team. This will help to enable a closed loop manufacturing process.

SUSTAINABILITY: A LIGHTER CO_2 "BACKPACK" FOR PRODUCTS

Siemens is pioneering an approach to determine its product-related carbon emissions. Can you tell us more about this?

When you think about a "carbon neutral" product, you realize that the steady globalization of product supply chains has made it increasingly difficult for manufacturing companies to actually determine a product's "CO_2 backpack." More than 95% of the carbon emission impact of a product lies in the supply chain, with tremendous potential for optimization.

> **"Steady globalization of product supply chains has made it increasingly difficult for manufacturing companies to actually determine a product's CO_2 backpack."**

For example, we wanted to identify the product carbon footprint (PCF) of our controller SIMATIC S7-1500, which is manufactured in our Amberg factory. We could almost completely determine our product-related Scope 1 and 2 carbon emissions, by applying our own products such as Energy Management and Industrial Edge. However, understanding Scope 3 emissions is more difficult than it sounds – mainly due to lack of reliable and secure data transfer across the supply chain ecosystem.

So, we developed an ecosystem using cryptographic encryption within a blockchain, where verifiable certificates and proofs can be forwarded to the next company in the delivery chain along with the product's carbon value. This distributed ledger technology allowed us to generate and forward a product's real data, including its PCF. And this required very low energy consumption – as it has nothing to do with crypto mining – it is just sharing data with verifiable and cryptographic credentials over an ecosystem.

And this is what we are now developing and are also planning to bring this into an open source, so that anyone can participate in this ecosystem because we really want to make an impact in carbon emission reduction.

75%

of the value chain handled independently by machines and robots.

Conversations for tomorrow

Dr. Gunter Beitinger
SVP Manufacturing & Head of Factory Digitalization, Siemens

"We developed an ecosystem using cryptographic encryption within a blockchain, where verifiable certificates and proofs can be forwarded to the next company in the delivery chain along with the product's carbon value. We are now developing and are also planning to bring this into an open source, so that anyone can participate on this ecosystem because we really want to make an impact in carbon emission reduction."

KIM KIRKCONNELL

Vice President, IT Global Digital Supply Chain, Kimberly-Clark

AMY SAUSEN

Global Director, Digital Technology, Kimberly-Clark

DELIVERING SMART-MANUFACTURING OPERATIONS

Kimberly-Clark

Kim Kirkconnell is accountable for enabling technology for the Kimberly-Clark supply chain organization. Her current focus is ensuring successful delivery of Manufacturing Execution System (MES) and quality systems for manufacturing, supply chain planning, demand planning, transportation management, and warehouse management systems. In her previous role, she was responsible for leading digital transformation, including establishing product management teams and technology platforms for sales, marketing and supply chain platforms.

Amy Sausen is leading smart manufacturing strategy hyper-connected to supply chain organization with a focus on planning and logistics, for end-to-end visibility. She is also driving innovation within CPG manufacturing and is leading the IIOT strategy and deployment, and developing edge computing vision. She is also responsible for executive partnership with global and regional manufacturing, research & development, engineering and other supply chain leaders.

The Capgemini Research Institute spoke to Kim and Amy about driving smart-manufacturing operations, interesting use cases, and their approach to upskilling.

TRANSITIONING TO SMART MANUFACTURING

Could you elaborate on how Kimberly-Clark is driving smart-manufacturing operations?

— **Kim:** We launched our smart-manufacturing operations transformation a few years ago. To be competitive and consumer centric, we knew we had to have the right foundations in place. This included the need to have a standardized Manufacturing Execution System (MES), rather than multiple platforms, as was the case. We are also working on ensuring that we have strong master-data governance in place. Instead of allowing our regions or mills to set their own standards, we are working on a global standard template with strong master data.

— **Amy:** We are also finally focusing on scaling operations quickly when we pilot a technology. If we are working on a digital-twin pilot to improve reliability, for example, how can we scale it quickly to all other mills by using the foundational systems implemented? At the same time, if the pilot fails, we need to fail fast. We must imbue the mindset among our people that it is okay to fail, provided we learn from it and then roll into the next idea.

> **"To be competitive and consumer centric, we knew we had to have the right foundations in place. This included the need to have a standardized Manufacturing Execution System (MES), rather than multiple platforms. "**

Kim Kirkconnell
Vice President, IT Global Digital Supply Chain, Kimberly-Clark

Amy Sausen
Global Director, Digital Technology, Kimberly-Clark

Has there been any changes in your technology strategy in light of the COVID-19 crisis? What are your top three priorities going forward?

— Kim: There hasn't been a change in strategy because of COVID-19. But there has been a greater focus on delivering a flexible and agile organization that can work in a new way. COVID-19 certainly reinforced the message that we need to have more automation in the mills; more tools that enable people to work remotely; more ways to train and onboard employees faster. Another area of focus is real-time dashboarding. Being able to see accurate data in real time when trying to make decisions about customer orders without having to wait for days or weeks for an analysis to be run, is critical.

How can the manufacturing process become more efficient? What are some of the applications of technology that interest you?

— Amy: There are a number of opportunities. In this industry, augmented reality (AR) and virtual reality (VR) are areas I'm very excited about, from the standpoint of whether I can train the workers faster. Can I enable mill workers to be connected and mobile, so that they aren't having to go and print a sheet of paper for work orders? Can I give the worker a headset and a mobile device that will make them more effective in a very large manufacturing facility? If I can, this is a powerful use case.

Another compelling use case is in the digital-twin space. The technology is not yet ready to help us in product innovation, because using fluid dynamics in a digital environment (for example, trying to model how a Kleenex tissue or a Huggies diaper absorbs moisture) can become very complex. However, using a digital twin to create an environment where a system can be monitored in real time, learning from that, and converting those insights into predictive or prescriptive actions is a stronger application because of

the vast amount of data available within manufacturing operations. We are piloting the predictive maintenance use case for a machine currently, to understand when the machine might breakdown and the reason for breakdown.

A third area that we are beginning to explore is intelligent automation, robots and cobots [collaborative robots]. We are exploring how automation can be used to benefit the workforce.

We would like to augment – not replace –our workforce, to relieve human workers of repetitive tasks and reduce the risk of injury, making the environment safer. These are some of the things that are most interesting to us right now.

"Using a digital twin to create an environment where a system can be monitored in real time, learning from that, and converting those insights into predictive or prescriptive actions is a stronger application because of the vast amount of data available within manufacturing operations."

What would be your recommendations for organizations to scale these transformation initiatives?

— **Kim:** Focus on having the right data, whether to run a digital twin or provide predictive maintenance. Also, you need to work with an engineer or an employee at the mill to understand this data. If you just have data scientists running models without truly understanding the process, implementation is going to be challenging.

It is also very important to marry the technology and the business. At Kimberly-Clark, we don't start a project until the business is ready to commit resources to it. We tell them upfront how much time we need from each team, who needs to be involved, and what we need them to do.

— Amy: A lot of companies get caught in "pilot purgatory." They start a pilot and find there is a pocket of knowledge and expertise to be tapped into. But what they have created is not scalable because they are not working from a common data framework, and the effort to cleanse and transform data impedes the success of a fast and scalable rollout approach. Without addressing these areas, pilots do not scale. In our organization, we encourage teams to innovate and work on these fun, creative things, but direct them to using our established enterprise platforms in a manner where things can be scaled. This definitely needs to be a management-led conversation. Leaders of the regions and the lines of business need to be really attuned to where their teams are spending their efforts, and ensure the pilots are built on established enterprise foundations with master data, or risk getting stuck with benefits that cannot scale.

USING DIGITAL TECHNOLOGIES TO MEET SUSTAINABILITY GOALS

By 2030, Kimberly-Clark aims to have reduced absolute greenhouse-gas emissions by 50% and the business's plastics footprint by 50%. What role will digital technologies play in helping the organization fulfil its sustainability agenda?

— Kim: We are using technology and innovation in various areas. For instance, in North America, the Huggies brand introduced diapers made with plant-based ingredients. We are already using sensor analytics to track our energy and water consumption to monitor our footprint. In the future, we will be looking at opportunities to apply digital twin technology in making our products more sustainable.

UPSKILLING WORKFORCE FOR INTELLIGENT OPERATIONS

How are you building the skillset required for these "intelligent operations"?

— Amy: This space requires IT and OT skillsets to work together in a new way. At Kimberly-Clark, we have put together a cross-functional workstream that's made up of both IT and engineering operations personnel. But we are also focusing on digital skills for manufacturing, and on imbuing IT skills into engineering and the operational technology (OT) environment. Similarly, we are looking at infusing the IT function with engineering knowledge and experience. We are starting to collaborate on training sessions and tools. This is a new way of learning and will evolve as we go forward.

Kim Kirkconnell
Vice President, IT Global Digital Supply Chain, Kimberly-Clark

“In North America, the Huggies brand introduced diapers made with plant-based ingredients. We are already using sensor analytics to track our energy and water consumption to monitor our footprint."

Amy Sausen
Global Director, Digital Technology, Kimberly-Clark

"We are also focusing on digital skills for manufacturing, and on imbuing IT skills into engineering and the operational technology (OT) environment."

TORBJØRN FOLGERØ

SVP, Enterprise Digital, Technology, Digital & Innovation, Equinor

GETTING THE FULL VALUE OF DATA

Torbjørn Folgerø is responsible for information technology and the overall digitalization agenda in the Norwegian energy company, Equinor. His remit covers cybersecurity, infrastructure, enterprise applications, software development, data science, and data-platform management.

The Capgemini Research Institute spoke to Torbjørn about digital transformation in the energy sector; the benefits that Equinor has derived from data and digital technologies; and the challenges organizations can expect to face on their journeys to intelligent operations.

Digitalization is paramount to the success of energy transition, with data collection and analytics technologies enabling this shift. "

How are digital technologies enabling a successful energy transition for Equinor?

— Digitalization is paramount to the success of energy transition, with data collection and analytics technologies enabling this shift.

While a degree of global dependency on oil and gas is inevitable, it is nevertheless vital that we focus on carbon- and cost-efficiency on top of safe operations when using these resources. Data, analytics, and digital technologies are helping us achieve this efficiency. As an example, we are streaming operational data from all our 26 offshore fields in Norway and using it to develop and utilize machine learning (ML) models to improve our operations on a continuous basis. Since the launch of our digital roadmap in 2017, we have delivered around USD1 billion in value creation through efficiency gains from our oil and gas business. Our Johan Sverdrup field, a giant field on the Norwegian continental shelf, is an important contributor to the value creation.

Torbjørn Folgerø
SVP, Enterprise Digital, Technology, Digital & Innovation, Equinor

The field uses a range of new digital solutions to increase subsurface understanding, ensure more efficient start-up of wells, higher stable production and more efficient maintenance. This capital is re-invested in our renewables business, thereby helping to fuel the green transition.

"AI and advanced analytics can help to identify the best locations for offshore windmills and how to optimize their operations."

Secondly, at Equinor, we want to take a global position in offshore wind-power production. Digital technologies such as AI and advanced analytics can help to identify the best locations for offshore windmills and how to optimize their operations.

Lastly, a low-carbon agenda is key for us. We have initiated a project called Northern Lights as a part of the Norwegian full-scale carbon capture and storage (CCS) project. We're working on developing a full-scale CCS value chain, including capturing CO_2 from industrial plants; transporting compressed CO_2 by ship; and storing it below the sea bed under the North Sea. We are working with partners to digitize the CCS value chain, as well as using data and analytics to help other companies reduce their carbon footprints.

HARNESSING THE POTENTIAL OF DATA TO TRANFORM OPERATIONS

How is Equinor utilizing data and digital technologies (such as cloud, AI, and 5G) to reshape its operations?

At Equinor, we have huge amounts of operational and production data. We established Omnia, Equinor's cloud-based data platform, to ensure this data is available on a single platform across our value chain, including development and production, transportation, marketing, and trading.

Easy access to this data facilitates operations at our recently established operational support center The IOCT (Integrated Operation Centre & Technical Efficiency) uses a digitalized system to contribute to enhanced production efficiency, production potential, energy efficiency, safety, and reduced emissions from the fields Equinor operates on the Norwegian continental shelf.

The IOCT works with predictive maintenance by interpreting the data sent by sensors and scanning it for discrepancies. For example, if the exhaust temperature of a motor has been at around 700°F for the last three months and then it suddenly hits 800°F, this can be an indication of mechanical or electrical malfunction. It is the IOCT's job to detect "weak signals" using digital technologies such as AI/ML, before they develop into bigger problems, leading not only to unplanned downtime or financial loss, but also potentially posing a threat to worker safety.

We have also built a digital twin solution, Echo, which is a tool used to access and visualize data stored in Omnia. It allows for a virtual, real-time representation of our physical installations, and aims to improve safety and efficiency in project development and operations across our business areas.

Could you highlight some of the beneficial results obtained from the Integrated Operation Centre?

From a sustainability perspective, the Integrated Operation Centre plays a key role in reducing CO2 emissions from the Norwegian continental shelf. With more than 300 energy improvement measures implemented since 2008, it has resulted in annual emission reductions of 1.6m tons of CO2.

From a financial perspective, as well, the Integrated Operation Centre has already been quite successful. In 2018, we announced our target to raise cash flow by USD2bn by 2025. By June this year, we had already managed to make USD1bn, and the centre has been the main contributor. Subsequently, we heightened our aspirations and increased our target to USD4bn by 2025.

An increasing part of that USD4bn will come from using unmanned robots and machinery on our fields, which will reduce our capital and operational expenditures while improving safety and security by reducing human involvement in physically intensive activities. At Johan Sverdrup, a number of other digital initiatives are also being tested out, such as robots over and under water, machine learning, and the use of 3D printing technology.

1.6M TONS OF CO_2

From a sustainability perspective, the Integrated Operation Centre plays a key role in reducing CO2 emissions from the Norwegian continental shelf. With more than 300 energy improvement measures implemented since 2008, it has resulted in annual emission reductions of 1.6m tons of CO_2.

Staying with the safety aspect, could you describe some of the technologies available to your field workers to make their jobs easier and safer?

We have developed an operational planning tool to extract insights from our safety records. It uses natural language processing to provide a single interface, displaying data from all of its sources, highlighting technical issues and safety incidents that have the potential to reoccur, raising risk levels. "

We have developed an operational planning tool to extract insights from our safety records. It uses natural language processing to provide a single interface, displaying data from all of its sources, highlighting technical issues and safety incidents that have the potential to reoccur, raising risk levels. The operational planning tool gathers all the incident reports in one system, and the system can say, "you really should read this report, because the last time someone did something similar, something went wrong."

We have also equipped all our field workers and operators with tablets. We have set up an industrial app store that has apps related to different work areas including safety, job analysis, maintenance, etc., which workers can access through their tablets. Operators in the field still make decisions and create goals but now they can have the data they need to hand, rather than having to return to the office to use a PC.

We are also using HoloLens (Microsoft's holographic remoting device intended to improve clarity and accuracy of remote working) and our digital twin solution, Echo. We have made all our 3D models available in Echo, so that they can be accessed in the field via tablet or laptop. We have enriched these models with required data, so workers can navigate on Echo to access information on any part of the plant. The HoloLens helps workers visualize the work to be done and execute them more quickly as it takes Echo's 3D drawings and elegantly superimposes themselves over reality in the field.

Another area in which these technologies are being used is gamification of safety training. Traditionally, workers had to undergo safety training on an e-learning platform, but now, we are able to use VR. Workers can get a feel of being in the field while sitting in the office. They can compete with colleagues in league tables and make training much more fun.

OVERCOMING TRANSITIONAL CHANGES

What challenges do organizations face on their digital transformation journey and how can these be overcome?

Digital transformation generates opportunities to create new revenue streams and drive new business models as an organization, working together towards it. However, it can be challenging to get business units onboard, change their ways of working, upskill employees, and build competencies. A key principle is that business units (as opposed to the technology centers) own the digital initiatives, because it is the business unit that, ultimately, is going to realize the benefits.

From a technology perspective, data management is a huge challenge for large organizations such as Equinor. We process a lot of data, and the first step is to get it out of the on-premises siloed solution into a single data platform. While we have made good progress in doing that for raw data, we now have to focus on making that data ready for analytics.

It is vital to be able to focus. If we try to do everything at once, we are unlikely to succeed.

How do you see the energy industry evolving: with increased adoption of future technologies or more use cases of current technologies?

First, in terms of use cases of cloud, AI, and ML, I believe we are just starting to explore these technologies and there is much more we can do with them in areas of safety, sustainability, and new revenue opportunities. Data can be made much more accessible through cloud solutions, allowing organizations to share data more efficiently internally and externally with partners and suppliers and thereby enabling new services and business-model opportunities for a company like ours.

> **"Last year, we conducted the world's first offshore drone transportation of a spare part that had been 3D printed."**

We are testing a lot in terms of the physical side of digitalization, as well – drones, 3D printing, robots that can navigate their way around the plants – but we are still in the pilot phase. Last year, we conducted the world's first offshore drone transportation of a spare part that had been 3D printed. A lot will happen in this area in the next year and the whole supply chain is going to be much more efficient through these technologies.

We are also looking into some use cases of blockchain. Notably the implementation of blockchain in the US for streamlining of contract execution drives increased safety, quality, and cost saving. Further down the road, we believe quantum computing could be interesting for us, for example to design more profitable drilling paths that also take into consideration the limitations imposed by required drilling angles and geophysical features. I think the organization needs to engage with multiple technologies but, in the end, it is all about managing the business by data. Data is the key.

Conversations for tomorrow

Torbjørn Folgerø
SVP, Enterprise Digital, Technology, Digital & Innovation, Equinor

"In the end, it is all about managing the business by data. Data is the key."

Articles

...from leading experts and academics.

VERKOR

Sustainability, circularity, and collaboration: recharging the European battery industry

Gilles Moreau, Chief Innovation Officer, Verkor

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UNIVERSITY OF OXFORD

Building safer AI for the next era of transformation

Marta Kwiatkowska, Professor of Computing Systems, University of Oxford

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Gilles Moreau
Chief Innovation Officer, Verkor

SUSTAINABILITY, CIRCULARITY, AND COLLABORATION: RECHARGING THE EUROPEAN BATTERY INDUSTRY

An electrochemistry expert and a seasoned entrepreneur, Gilles has a solid background in stationary energy storage. Well versed in building start-ups, he was Co-Founder and Battery Lead at Lancey Energy Storage. During his time as Project Manager at the French Alternative Energies and Atomic Energy Commission (CEA), Gilles worked on various French and European lithium-ion battery projects. He is also an expert in fuel cells thanks to his experience at 3M and Renault.

The backdrop of climate issues relating to the transport industry, and the surge in electric-vehicle (EV) sales in response to them, has put the development of eco-friendly batteries center-stage as a key catalyst for energy transition, re-shoring industry, and enabling a low-carbon economy.

But how can the battery lifecycle – from extraction, to production, to end-of-life management – be made truly sustainable? How can the raw material sourcing strategies focus on a green differentiation? How can the battery-manufacturing carbon footprint be minimized? And how can battery recycling be streamlined and rendered more efficient? Finally, what new business and operating models can emerge in this space? These are the key questions, which – if properly addressed – will ensure the industry's social and environmental viability in the long term. These areas are also fundamental requirements of the new European regulatory framework, making them an unavoidable part of organizational strategies. Together with the optimal management of shared resources, they are vital to the energy transition, and therefore to a company such as Verkor.

Constructors and regulators are increasing pressure on battery manufacturers to authenticate the provenance of their raw materials and provide assurance that the extraction of these materials neither pollutes the local environment, nor involves unethical labor practices."

Below, we highlight five key recommendations in this space and illustrate the role new technologies can play:

Focusing on provenance of raw materials

Lithium-ion batteries contain materials often described as "critical." These include lithium and cobalt. It is important to note that, although they are finite resources, lithium and cobalt (unlike fossil fuels, which evaporate to leave CO_2) can be reused. This means that, with careful management, the flow of these resources can be relatively secure. However, the sourcing and extraction of these raw materials also raises questions around environmental, social, and governance (ESG) aspects.

It is for these reasons that constructors and regulators are increasing pressure on battery manufacturers to authenticate the provenance of their raw materials and provide assurance that the extraction of these materials neither pollutes the local environment, nor involves unethical labor practices.

A manufacturer who wants to guarantee traceability and high ethical standards can either procure its raw materials directly, or work with an active-materials supplier who can guarantee the origin of the material. This is where partnerships within the value chain play such a vital role. Technologies such as blockchain can help to address traceability challenges. Track-and-trace functionality solutions implemented with blockchain enable entire supply-chain networks to document updates to a single shared ledger, which provides total data visibility and a single source of truth. Volvo is a case in point. The Swedish automotive manufacturer works with its EV-battery suppliers to create a digital ledger that tracks the source of critical materials, such as cobalt.[16]

16 Volvo Cars, "Volvo Cars to implement blockchain traceability of cobalt used in electric car batteries," November 2019.

> **Track-and-trace functionality solutions implemented with blockchain enable entire supply-chain networks to document updates to a single shared ledger, which provides total data visibility and a single source of truth."**

Manufacturers who procure their supplies with a long-term perspective are generally rewarded with greater sustainability, which has knock-on benefits in terms of competitiveness and improved quality and, consequently, reputation. The provenance of raw materials is one of the pillars of the strategy adopted by French battery manufacturing startup, Verkor. The organization is focused on building key strategic partnerships across the entire value chain, so that it has oversight of every step of the way.

Reducing the production carbon footprint

Time and again, the question is raised of the size of the carbon footprint produced by the battery-manufacturing process. EVs have a considerably larger carbon footprint in manufacturing than internal-combustion engine (ICE) vehicles, owing to the demands of the battery-production process (for instance, a standard 10 tons of CO_2 for EV car versus only five tons for an ICE car). However, over its lifecycle, the EV footprint is smaller (for instance, in Europe, 10 tons of CO_2 is produced in powering an EV for 150,000 km, and even lower at two tons in a country such as France, which has a decarbonized energy mix — versus 25 tons for an ICE car).

In the same way that low-carbon energy reduces the battery's carbon footprint, production can be optimized by using certain manufacturing procedures and processes:

- **Smart manufacturing:** Verkor's strategy is to use digital and smart manufacturing to create a new generation of "gigafactories" (huge, multi-component manufacturing bases capable of end-to-end production), and guarantee a more efficient, productive, and environmentally sound process. To this end, the organization has joined forces with a number of strategic partners to refine the manufacturing process, minimize waste, and improve its environmental and economic performance.

- **Low-carbon power supply:** Power supply also has a very important impact. For instance, France's low-carbon energy mix – 67.1% from nuclear power and 24.1% from renewables – ensures a lower carbon footprint in battery production.

- **Proximity to market:** Keeping production close to the consumer market also lowers emissions, limits imports, and drives local job creation.

Giving batteries a second life

ONLY 36%

of automotive original equipment manufacturers (OEMs) partner with suppliers and utilities in promoting a second life for EV batteries.

The volume of end-of-life lithium-ion batteries is set to increase significantly over the next few years, as the EV market and, as a consequence, the manufacturing of batteries escalates. The manufacturer's responsibility should not end when the product goes from production line to client. However, a recent study from Capgemini reveals that only 36% of automotive original equipment manufacturers (OEMs) partner with suppliers and utilities in promoting a second life for EV batteries.[17]

The European battery industry can benefit greatly by collectively developing business models for second-life batteries. Initiatives should include:

17 Capgemini Research Institute, "The automotive industry in the era of sustainability," March 2020.

- Securing partnerships with local stakeholders that deal with the batteries' end-of-life (such as collectors and recycling companies).

- Cracking the logistics conundrum to centralize the collection and testing of used batteries and reducing transportation and storage costs to a minimum.

- Pushing the development of energy-management systems that can combine first- and second-life batteries, using different brands, chemistries, and designs; in this regard, the use of artificial intelligence (AI) will play an important role.

- Staying in close contact with battery manufacturers to understand their technological roadmap and anticipate disruptive innovation.

Future sustainable business models must trace the entire lifespan of a battery cell — from extraction from the vehicle; its second life in stationary storage; recycling; and then return to the factory floor — thereby closing the loop to initiate a circular economy. A strong circular economy backbone will increase the lifespan of batteries; for instance, EV batteries can be given a second life as storage-grid batteries, making renewable energy more economical. Renault Group has already launched several experiments in this area – and is testing stationary battery-storage systems in several European cities.[18]

"Future sustainable business models must trace the entire lifespan of a battery cell — from extraction from the vehicle; its second life in stationary storage; recycling; and then return to the factory floor — thereby closing the loop to initiate a circular economy."

18 Renault Group, "The circular economy of the electric vehicle battery," May 2020.

"The technology for recycling batteries already exists and, today, it is possible to salvage over 70% of a battery and over 90% of critical materials."

Closing the materials loop

As soon as the first and second life are over, it is important to recover critical material. There are already regulations in place to encourage the use of recycled materials and, from 2030, the minimum proportion of recycled content will be raised (from 12% to 20% for cobalt; 4% to 10% for lithium; and, from 2035, 4% to 12% for nickel). This trend will lead to new forms of recycling, as well as new concepts in material reuse. In the shorter term, reuse of manufacturing scrap — another hot topic in the battery industry — can increase recycling capacity before batteries reach their end of life.

Collaborating for a more open and sustainable business model

The technology for recycling batteries already exists and, today, it is possible to salvage over 70% of a battery and over 90% of critical materials.[19] Although still in its infancy, the recycling industry is making great strides in lithium-ion battery recycling and will continue to do so in the years and decades to come — starting with the recycling of scrap for new batteries to achieve a circular economy.

19 LeParisien, "Electric vehicles: 700,000 tonnes of batteries to be recycled in 2035," August 12, 2019.

The shift to EVs is part and parcel of the energy transition, and manufacturers will need to play their role sustainably. Developing this industry in Europe opens up new opportunities and will spark new and more open synergies. Verkor's strategy is to form robust and efficient local partnerships, both upstream and downstream, in order to build in more efficient product management and stronger ethics across the value chain. The objective is to create a product with the smallest possible ecological footprint and the greatest possible positive impact on society.

To make their marks on this competitive market, organizations need to look for ways to optimize technological innovation, while fully realizing the potential of their human capital and strategic partnerships. Verkor has achieved this by entering into a number of strategic agreements with key partners positioned across the value chain – from key innovators to industrial production experts.[20]

The development of the EV is a fantastic opportunity to introduce more open and sustainable business models. European regulations are pushing in this direction and embedding the development of Verkor in a sustainable model will give the company an indisputable point of difference. At a time when the challenges of climate change are beginning to impact on our daily lives, addressing the imperatives for traceability, recycling, reducing carbon content, and developing open business models, is by far the best way to ensure the long-term sustainability of Verkor, other players in the battery industry, and the EV market in general.

20 Verkor, "Verkor brings five new partners on board, raising €100m to develop high-performance sustainable battery cells in France," July 2021.

Marta Kwiatkowska
Professor of Computing Systems,
University of Oxford

BUILDING SAFER AI FOR THE NEXT ERA OF TRANSFORMATION

Marta Kwiatkowska is Professor of Computing Systems and Fellow of Trinity College, University of Oxford. She is known for fundamental contributions to the theory and practice of automated techniques for verification and correct-by-construction synthesis of systems from quantitative specifications, which have been adopted in diverse fields, including security, robotics, healthcare, DNA computing and nanotechnology. Her current research focus is on safety, robustness and fairness of AI decision making software.

Kwiatkowska is the first female winner of the Royal Society Milner Award, winner of the BCS Lovelace Medal and Van Wijngaarden award, and received an honorary doctorate from KTH Royal Institute of Technology in Stockholm. She is a member of the GPAI Working Group on Responsible AI, Fellow of the Royal Society, Fellow of ACM and Member of Academia Europea.

Artificial intelligence (AI) plays a key role in modern society. It drives cars, detects images, understands natural language, and controls complex industrial machines. When compared with traditional human-controlled operations, AI tends to be more consistent. In the near future, AI applications will take on greater autonomy in military, engineering, and industrial applications. However, these decision-making systems have critical exploitable flaws, which, if not addressed, will inevitably lead to loss of economic benefits, human life and, ultimately, trust in the technology.

The underlying method for building these AI systems is called deep neural networks (DNN). Loosely based on the neural networks in a human brain, they are vast and complex, but mathematically decipherable by normal human understanding. However, while mathematically transparent, logically they are "black boxes": they work, but we don't know how. If operators fail to remain vigilant, this fissure in our understanding of AI can expose it to adversarial exploitation.

Breaking an AI system

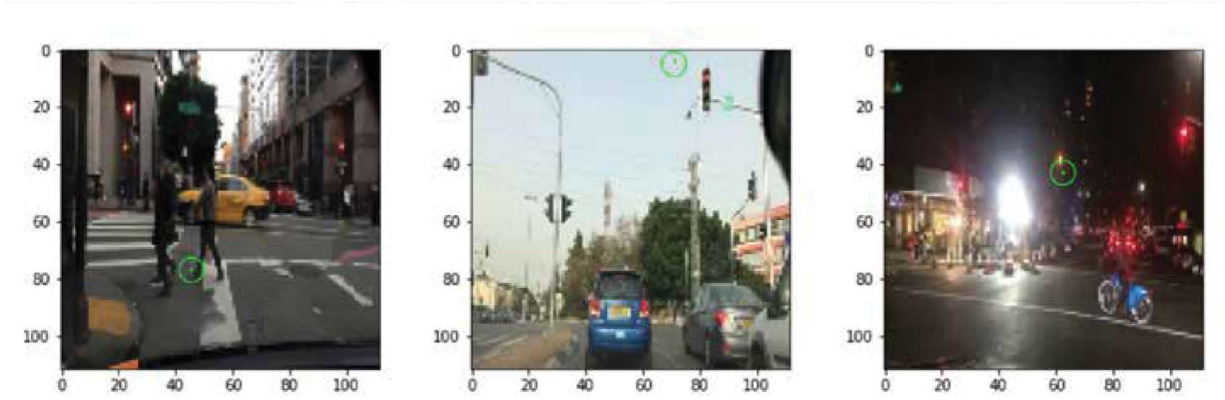
Research has shown that very simple changes can drastically impact an AI model's outcomes, with potentially catastrophic consequences. Adversarial techniques[21] can fool the AI into misclassifying the input, even when the perturbation is minor. The Nexar Deep Learning Traffic Light Challenge, for example, has a database of 18,000 dashboard-camera images, to which the public has access and can contribute, to build AI models for traffic-light identification. The challenge is for researchers

> **"Our research shows that the modification of just a few pixels can alter the AI object identification process completely – meaning a traffic light can be perceived as completely different object."**

21 Adversarial examples are inputs to machine-learning models designed to cause the model to commit a mistake.

to use technology that can identify and label each image as either "red," "green," or "null" (meaning no light has been detected). However, it requires only one inconsistent pixel to misguide the AI model into misclassifying the image in question, meaning that a red light can be recorded as green, or vice versa. "Moreover, these false classifications are often made with a high degree of confidence that they are correct (sometimes as much as 95%)."

Figure 1: A single pixel can drastically change outcomes, even using a state-of-the-art AI system



Source: Nexar Deep Learning Traffic Light Challenge. (a) Red light classified as green with 68% confidence after one pixel is changed. (b) Red light classified as green with 95% confidence after one pixel is changed. (c) Red light classified as green with 78% confidence after one pixel is changed.

These flaws have hugely significant change outcomes in computer-vision applications. A single stray pixel can easily overwhelm even a state-of-the-art vehicle-mounted AI system. Moreover, these adversarial examples are transferable, in the sense that an example misclassified by one network is also misclassified by a network with another architecture, even if it is trained on different data.

Implications of adversarial outcomes resonate across sectors

These simple input manipulations can cause large deviations of standard outcomes in autonomous cars. It could cause cars to drive into barriers, jump signals, or drive off road. While my group's research has shown this to be the case for cars, it can be easily applied to any image-identification use case from optical character recognition (OCR), handwriting interpretation, or natural language processing (NLP) systems.

A few other applications that can lead to adversarial outcomes are listed below:

1. **Natural language processing:**
   Today, natural language processing (NLP) software is regularly used to interpret legal documents and contracts.[22] These documents could be purposely designed to deliver flawed interpretation or impede progress. Similarly, this can be applied to language translation, speech-to-text applications, or document processing.

> **"In the near future, AI applications will take on greater autonomy in military, engineering, and industrial applications. However, if critical exploitable flaws in these decision-making systems are not addressed, they will inevitably lead to loss of economic benefits, human life and, ultimately, trust in the technology."**

22 Thomson Reuters Blogs, "Legal AI: A beginner's guide," February 2017.

2. **Computer vision:**
   Our research shows that the modification of just a few pixels can alter the AI object identification process completely – meaning a traffic light can be perceived as completely different object. Applications range from remote sensing to radar systems and industrial quality control. With computer vision applications being the most successful and most critical application area, flaws exploited here can lead to suboptimal outcomes, economic loss and, in a worst-case scenario, even the loss of human life.

3. **Decision-making process:**
   Most decision-making systems utilize an array of inputs, from sensor-based or monitoring systems. More complex decisions are usually based on precedent. For example, if different sensors give different results, the critical decision making is based on prior probability outcomes. This means that digital applications such as finance and trading, cybersecurity, and healthcare can easily be intercepted through a critical input network.

Building safer AI systems

Building safer AI systems is the most critical challenge we are faced with today. Capgemini Research Institute's research into Ethics in AI shows that 60% of organizations have attracted legal scrutiny and 22% have faced a customer backlash in the last 2–3 years, owing to decisions reached by their AI systems.[23] The consequences for safety-critical systems will be a more drastic erosion of trust.

While a considerable research effort has gone into building more explainable, transparent, and robust AI systems, organizations and regulators can also take initial steps to mitigate these challenges:

1. **Foster awareness and understanding of possible adversarial exploitation**
   AI developers and teams usually have a singular focus on improving confidence rates and overall outcomes. This was the right direction to take when AI was in its infancy, as it helped establish AI as a tool that could be consistently useful to industry. However, with AI now being actively deployed in safety-critical systems, AI developers and teams need to understand the shortcomings of this traditional approach in building

23 Capgemini Research Institute, "AI and the ethical conundrum," September 2020.

"We, at Oxford, are actively developing software tools to verify safety of AI systems, including diagnostic testing for the robustness issue relating to computer-vision applications. "

models, architectures, and autonomous decision-making systems. A more robust, safety-first approach is required.

2. **Develop tool chains to reduce exploitable flaws**
   It is well known that testing can detect software flaws but not prove their absence. A widely adopted method that can prove the correctness of software systems is model checking (an automated software technology to verify that given requirements are met for a variety of real-time embedded and safety-critical systems). Model checking techniques are today deployed by organizations such as Microsoft, Intel, and Facebook to check the correctness of their software. Model-checking methods for neural networks are still poorly understood, however; the development has been hampered by a lack of understanding of the theoretical fundamentals of neural networks, alongside their technical complexity. We, at Oxford, are actively developing software tools to verify safety of AI systems, including diagnostic testing for the robustness issue relating to computer-vision applications.[24]

24 arXiv, "Feature-Guided Black-Box Safety Testing of Deep Neural Networks," Matthew Wicker, Xiaowei Huang, Marta Kwiatkowska, In Proc. 24th International Conference on Tools and Algorithms for the Construction and Analysis of Systems (TACAS'18).

3. **Regulators need to build safety guidelines and testing frameworks for safety-critical AI systems**
   Regulators also need to put emphasis on developing robustness criteria for safety-critical AI systems and frameworks for checking that such criteria are met. Standardized testing and evaluation frameworks should be created to support the development of safety-critical autonomous systems. These should extend the existing safety regulations found for cars, medical devices, and the workplace.

4. **Develop collaborative research into AI systems and their associated transparency, and ethical status**
   The current field of adversarial exploitation and model checking for neural networks is still in its infancy and we still have a long way to go to establish a complete understanding of it. Industry-wide collaboration is required to guide the development of appropriate frameworks and standards and to develop new ways of working. Collaboration is required to build open-source tool chains and evaluation methodologies and to govern practices among AI developers and teams.

Adversarial AI is still in its infancy in terms of industry understanding. To date, there has been no (detected) concerted effort to exploit these loopholes. However, it is only a matter of time before hostile players work to exploit them. Currently, as well as the potential involvement of hostile actors, these AI systems also show potential flaws relating to a sensitivity to naturally occurring "noise" in the environment. The reliability, robustness, and possible economic value of AI is directly linked to the trust we have in these systems. A significant effort to address these challenges is required to ensure we fulfil the social and economic potential of AI.

Capgemini's Perspectives

...from our
internal experts.

INTELLIGENT INDUSTRY: THE NEXT BIG TRANSFORMATION

Authored by
Roshan Gya, Managing Director, Intelligent Industry, Capgemini
and
William Rozé, CEO, Capgemini Engineering

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DIGITAL TWINS: MIRRORING THE REAL WORLD FOR A BETTER AND SUSTAINABLE PERFORMANCE

Authored by
Corinne Jouanny, Chief Presales & Innovation Scaling Officer, Capgemini Engineering
and
Christophe Vidal, Head of Digital Manufacturing, Capgemini Engineering

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REALIZING THE POWER AND PROMISE OF INDUSTRIAL 5G

Authored by
Monika Gupta, Vice President, Group 5G & Edge Lead for Industries & Partnerships
and
Pierre Fortier, Vice President, Global 5G & Edge lead, Capgemini Invent

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INTELLIGENT INDUSTRY: THE NEXT BIG TRANSFORMATION

Roshan Gya
Managing Director, Intelligent Industry, Capgemini

William Rozé
CEO, Capgemini Engineering

Executive Vice President, leading Global Intelligent Industry for Capgemini and Managing Director for Southern & Central Europe and India for Capgemini Invent. Roshan Gya was previously Managing Director of Operations Transformation and the Global Head of the Energy, Utilities and Chemical industry. He has spent more than 15 years in consulting and has built a renown international expertise in Capex-intensive industries on complex large scale digital transformation at CEO / Board level.

A member of Capgemini Group Executive Committee, William Rozé is CEO Engineering and R&D, the global business line combining engineering activities of Altran and Capgemini. Previously Executive VP in charge of Europe, William Rozé joined the Altran group in 2001 in France. He developed the activities in Aeronautics, Space and Defense and supported the launch of Altran's first outsourced R&D programs. In 2014, he was appointed Chief Executive Officer for France, and Chief Operating Officer Europe in 2018.

"The growing convergence of products, software, and services holds the key to the next big transformation opportunity for organizations across industries. "

While digital transformation is not a new concept, companies across industries are facing a variety of factors – growth in ecommerce, shortage in chips, mass personalization, growing concerns around sustainability, and climate change – that compel them to accelerate this transformation. Digital technology is no longer simply a lever with which to optimize a process for efficiency gains but also a means by which a product can be connected to the interactive environment around it. The growing convergence of products, software, and services holds the key to the next big transformation opportunity for organizations across industries.

The COVID-19 pandemic has further exposed vulnerabilities within organizations, putting pressure not only on production and distribution of products and services but also on design and engineering. Organizations are employing unique solutions to these challenging problems. Pharma companies such as GSK, Novartis, and Pfizer are using micro-factories, no bigger than a shipping container, to produce drugs and vaccines faster, more cheaply, and more efficiently.[25] The COVID-19 crisis has acted as a catalyst for ongoing transformation. Research has shown that 68% of organizations will accelerate their transformation investments in the next 12 months, with technology-led initiatives at the core.[26]

25 Fast Company, "Corporate America must learn to innovate frugally to get through the coronavirus crisis," March 27, 2020.

26 Capgemini Research Institute, "Fast-forward to the future defining and winning the post-COVID new normal," July 2020.

In addition to the market trends, a technology avalanche is forcing a sea change in business and operating models and is set to transform industries across all facets of customer interaction, business operations, manufacturing, and supply chains.

- **Product digitalization:** The evolving role of software in the automotive industry, for instance, is set to rebalance the competitive landscape in the coming years. We have already seen the contours of the industry change owing to the growing need to adopt, adapt, and master new software to design and produce the next generation of vehicles. Today's vehicles are packed with more software features than ever. More functionality in the cars that can be controlled by software means that new features can be introduced through over-the-air updates, without the customer having to visit a workshop. This also means that the OEMs need to rethink their customer journey.

  Connected products also allow organizations to mine and monetize the wealth of information they collect. Otis, an elevator manufacturer, moves around 2 billion people on any given day and holds troves of data on how people get around. The company plans to monetize this by sharing the insights it collects. Chris Smith, vice president of product strategy, says, *"We can share this data and help others make peoples' experiences more seamless and efficient. Now, maybe we could tell coffee shops around a building about what they can expect on a good day, that people will be going there around 11am based on our historical data, so they might want to staff up [at that time]."*[27]

"A technology avalanche is forcing a sea change in business and operating models and is set to transform industries across all facets of customer interaction, business operations, manufacturing, and supply chains. "

Roshan Gya
Managing Director, Intelligent Industry, Capgemini

27 IoT Agenda, "3 companies successfully monetizing IoT data," May 2019.

- **Process digitalization:** The combination of technology, cloud, and data is accelerating the digitization of core industrial processes, at scale.
  - Take, for instance, 5G and edge technologies. Worcester Bosch, UK-based industrial manufacturer, realized a nearly 2% efficiency gain from their 5G trial.[28] 5G enables organizations to realize a variety of use cases that were hitherto deemed unfeasible, including video-based quality inspection, remote operations, AGVs and other autonomous robots, and remote collaboration using AR/VR-based applications.
  - In the Life Sciences sector, data-driven transformation will enable R&D teams in biopharmaceutical companies to take a novel approach to drug discovery; better understand pathologies and patient care diseases and patients; identify therapies with higher potential; digitally optimize clinical trials; and accelerate time to market for new medicines and medical products.

- **Digitalization of both product and process:** Digital twins are enabling organizations to connect virtual systems with the physical world via real-time models that can be constantly simulated and optimized. Public authorities around the world, in Singapore, Shanghai, Stockholm, and Brooklyn in New York for instance, are turning to digital twins to help them in optimizing urban planning, infrastructure management, traffic monitoring or even disaster management.

"Intelligent Industry is the next generation of digital transformation. It is about fostering synergies between the digital and engineering spheres to help companies build intelligent products, operations, and services, at scale."

Products, processes, services, operating models, and even business models are all undergoing a transformation.

28 Ericsson. (n.d.) Worcester Bosch launches the UK's first 5G factory. Retrieved from https://www.ericsson.com/en/cases/2020/the-5g-factory-of-the-future. Business & Innovation Magazine, "Worcestershire 5G testbed report shows productivity gain with 5G applications," December 2020.

At Capgemini, we call this new era of transformation "Intelligent Industry": Intelligent Industry is the next generation of digital transformation. It is about fostering synergies between the digital and engineering spheres to help companies build intelligent products, operations, and services, at scale.

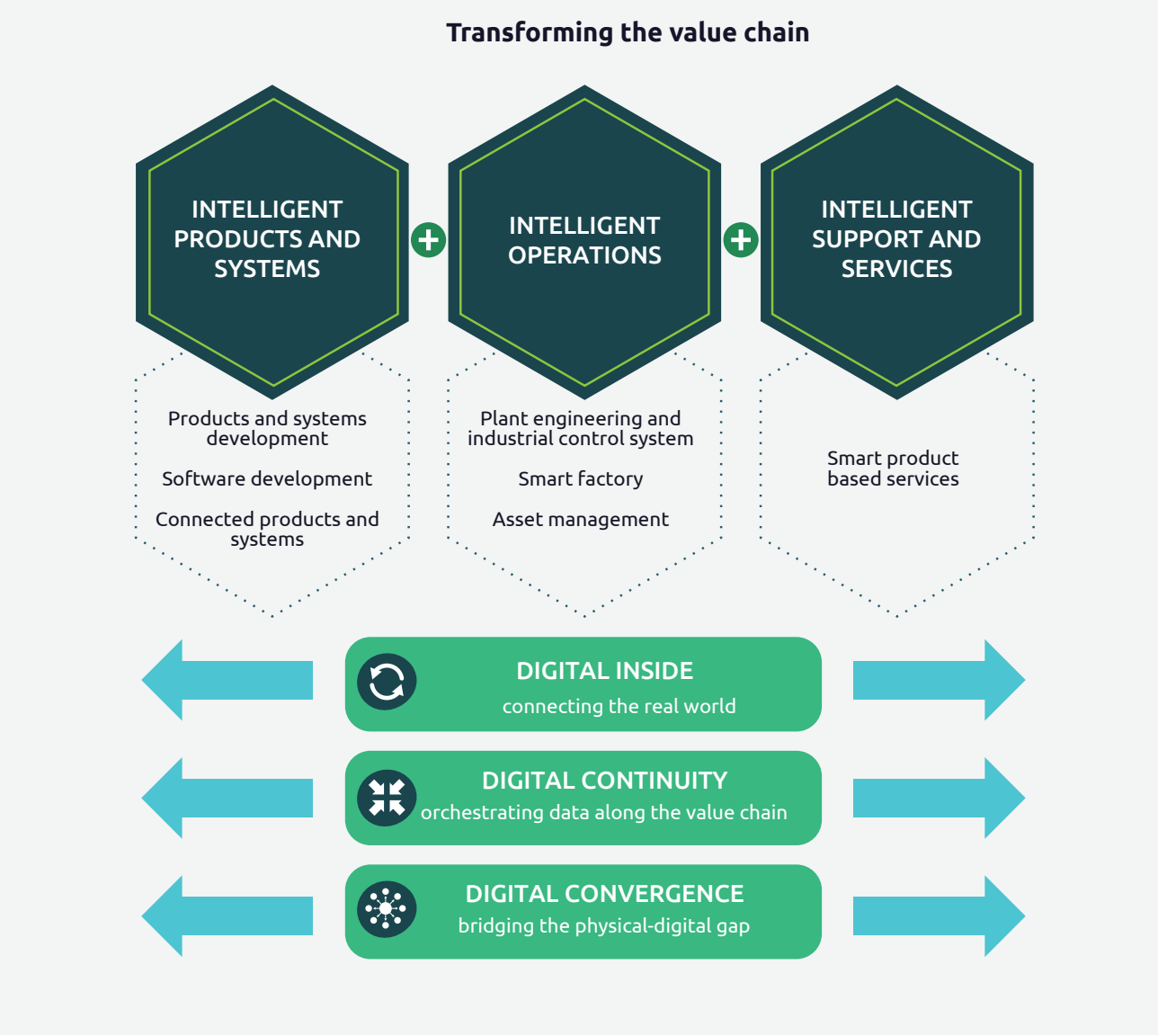
Intelligent Industry: a paradigm shift

From the pipette to the airplane engine, anything can become "intelligent." Using state-of-the-art sensors that facilitate augmented control and data acquisition, robots on a production line will be able to communicate with each other and adapt the production process in real time, depending on maintenance requirements, market developments, or customer demand.

William Rozé
CEO, Capgemini Engineering

"Using state-of-the-art sensors that facilitate augmented control and data acquisition, robots on a production line will be able to communicate with each other and adapt the production process in real time, depending on maintenance requirements, market developments, or customer demand. "

Intelligent Industry encompasses everything from intelligent products and systems to processes and services:



Source: Capgemini.

- **Intelligent products and systems**
  Industrial systems and products are now connected and are powered by data. These smart and connected products mean increased uptime, improved efficiency, and also reduced costs. They also enable companies to move towards a "servitization" model. Intelligent products and systems also address the process digitalization to deliver these products in a more efficient manner.

- **Intelligent operations**
  Intelligent operations encompass supply chain and manufacturing activities. It is about creating new "digital native" capacities or optimizing existing operations thanks to digital. Intelligent operations can also augment the sustainability goals of the organization by reducing emissions and conserving resources.

- **Intelligent support and services**
  With connected products and platforms, after-sales services will be reinvented to focus on delivering a richer customer experience and proposing a set of new data-driven services, driving new revenue streams for organizations.

"With connected products and platforms, after-sales services will be reinvented to focus on delivering a richer customer experience and proposing a set of new data-driven services, driving new revenue streams for organizations."

68%

of organizations will accelerate their transformation investments in the next 12 months, with technology-led initiatives at the core.

Data is the lifeblood, enabling the reunion of all these components. Organizations that are proven data leaders realize a significant performance advantage; for instance, they see 22% higher profitability than the average.[29] This is prompting organizations to undertake large-scale data-management programs. Volkswagen, for example, embarked on a multi-year industrial cloud project with the aim of combining the data of all machines, plants, and systems from all 122 of its group facilities. The objective of this massive transformation exercise is to optimize production processes and generate productivity improvements.[30]

To continue to grow in this new business environment, organizations must rebuild their product portfolios with the latest software and technologies embedded to make them smarter – but also more sustainable. Moreover, they must rethink the entire manufacturing and supply chains and adapt

29 Capgemini Research Institute, "The data-powered enterprise: Why organizations must strengthen their data mastery," November 2020.

30 Volkswagen AG. (2019, March). Volkswagen and Amazon Web Services to develop Industrial Cloud. Volkswagenag.com. https://www.volkswagenag.com/en/news/2019/03/volkswagen-and-amazon-web-services-to-develop-industrial-cloud.html

them to the growing demand for personalization and seamless delivery. The ability to capitalize on data assets will be key, both for optimization purposes and for creating new value-added services.

For a successful transformation to the Intelligent Industry, organizations will also need to bridge the talent shortage. Many are facing a demand-supply gap for skills related to AI, machine learning, and software engineering. A few are turning to upskilling to address this issue. Realizing the mismatch between the AI projects it was working on and the number of data scientists required to deliver them, Shell has made online training courses available to all interested employees.[31] Apart from its more than 200 data scientists, Shell has also trained 800 of its employees in basic programming skills to work on its AI projects.[32]

Intelligent Industry is helping organizations improve their operations and unleash innovation, thereby crafting a profitable and sustainable path forward."

While climate-change concerns and regulatory pressures are forcing organizations to change, the rise of digital technologies is bringing the physical and digital worlds together, creating an ocean of opportunity. Intelligent Industry is helping organizations improve their operations and unleash innovation, thereby crafting a profitable and sustainable path forward. The future of Industry is Intelligent – and it is here now.

31 CNBC, "Royal Dutch Shell reskills workers in artificial intelligence as part of huge energy transition," April 2020.

32 Udacity, "Announcing our newest collaboration with Shell," February 2020.

DIGITAL TWINS: MIRRORING THE REAL WORLD FOR A BETTER AND SUSTAINABLE PERFORMANCE

Corinne Jouanny
Chief Presales & Innovation Scaling Officer, Capgemini Engineering

Christophe Vidal
Head of Digital Manufacturing, Capgemini Engineering

Corinne is Executive Vice President, Chief Presales & Innovation Scaling at Capgemini Engineering. She is leading Centers of Excellence deployment to co-build and leverage Intelligent & Sustainable industry offerings. Corinne joined Altran in 1993 where she led numerous R&D projects in a variety of sectors for many international clients. As a pioneer in the practice of design thinking in the industry, since 2004, she develops new services offerings and catalysis projects of major innovations that put people and planet at the heart of developments, in open innovation dynamics.

Member of Capgemini Engineering Leadership Community, Christophe is global head of Digital Manufacturing for Capgemini Engineering, the global business line combining engineering activities of Altran and Capgemini. Christophe joined Capgemini in 2003 to conclude his engineering degree in Aerospace & Software Engineering at ENAC in Toulouse and Embry-Riddle University in Daytona. He puts people, innovation and transformation at the center of the strategic relationship with group clients to help them create value for the future. Prior to Altran acquisition, he was Vice President leading engineering activities of Capgemini for Toulouse area, the largest location in Europe at that time.

The city-state of Singapore has taken logistics technology to the point where it can seem like looking in a mirror. City authorities can look at a dynamic model in order to plan emergency evacuation routes or decide where to install solar panels; they can guide traffic with the help of real-time inputs; and they can even identify likely outbreaks of dengue fever by measuring the density of people who have been bitten by the disease-carrying mosquitoes. This is all owing to Virtual Singapore, the city's 3D digital twin.[33]

Technologies such as AI, 5G, and cloud have enabled the development of a smarter network that connects products, processes, services, and systems. The digital twin concept has strong potential to accelerate this transformation across multiple industries. The benefits it offers to organizations range from increased efficiency and increased lifecycle environmental impact to greater reliability and cost savings.

"City authorities can look at a dynamic model in order to plan emergency evacuation routes or decide where to install solar panels; they can guide traffic with the help of real-time inputs; ... thanks to "Virtual Singapore", the city's 3D digital twin."

33 GovInsider, "Meet Virtual Singapore, the city's 3D digital twin," January 2018

Modelling the modern environment

A digital twin is a virtual replica of a physical product, system, or process. The digital version can be used to monitor, control, and optimize all aspects of its physical twin – across both internal and external ecosystems and over time.

> **"A digital twin is a virtual replica of a physical product, system, or process."**

A digital twin is not just a simulation, a computing model, or a graphical user interface. Key characteristics of a digital twin include:

- The existence of a physical product, system, or process upon which its digital counterpart is based
- Connectivity and a flow of information between physical and digital entities
- The ability of the virtual entity to store and trace data through a network or system
- Periodic or near real-time synchronization of the states of the physical and virtual twins
- The ability of the virtual twin to simulate the physical entity, its characteristics, and its performance levels
- The ability of the virtual twin to predict the characteristics of its physical counterpart, and prescribe characteristics to make it more efficient
- The ability of the virtual twin to monitor, maintain, and optimize the operations of the physical twin.

This combination of shared characteristics is what makes the development of a digital twin useful across a number of industries.

System-of-systems digital twins

A digital twin, in its simplest form, is the duplicate of a single unit of equipment, such as a robotic arm (unit level). Organizations can also create a connected system of such individual digital twins, thereby augmenting the efficiency gains from the individual units to a broader, systemic level. For instance, digital twins of multiple robotic arms or machines can be combined to create the digital twin of a production line (system level). Taking the idea a step further, digital twins of multiple such production lines can be used to create the digital twin of a factory or even of several factories that are part of a shared supply chain (system-of-systems level). On a higher level yet is the concept of a digital twin on the scale of a city or even a nation, of which "Virtual Singapore" is the most prominent but surely not the last example.

Digital twins for sustainability

Intelligent Industry enables organizations to be economically profitable while being environmentally responsible. While organizations today are focused on reducing carbon emissions in their operations, only when they look at their entire value chain, including their customers and their suppliers, can they make a significant difference. Digital twins can play an important role here as they allow organizations to better utilize their resources, simulate emissions, and optimize the supply and transportation networks.

Digital twins find applications across industries

ENERGY AND UTILITIES

Renewable energy: Digital twins of wind farms or steam/gas turbines enable predictive maintenance based on data covering both general environment and current conditions

AUTOMOTIVE

Digital twins map extensive vehicle data, such as engine performance, as well as data from users' driver profiles

AVIATION

Digital twins of engines contain status data, monitoring vibration and pressure levels to predict required maintenance downtime

MANUFACTURING

Digital twins of production lines include data on the status of all machinery and information about every product

LOGISTICS

Digital twins contain material-flow data to optimize utilization of relevant processes and enable connected fleet management

BUILDING TECHNOLOGIES

Digital twins of dedicated building technologies enable a smart-home application based on smart connected products

HEALTHCARE

Digital twins include health data of patients based on continuous tracking of vital signs through mobile healthcare devices

COMMUNICATION

Digital twins of network and infrastructure enable intelligent network management based on historical data

Source: Capgemini.

Benefits range from process efficiencies and higher productivity to moving to a sustainable and circular economy

Aerospace: Airbus aims to cut its production lifecycle by 50% and is betting on digital twins to help it to achieve this ambitious goal. *"For each new product, we are actually building four digital twins. We not only create a twin for that product; we also create one each for the related production equipment, production process, and service process. We simulate all these aspects before we actually start to build the product or the factory to manufacture it. This helps us significantly reduce our engineering lifecycle and cost in production,"* says Peter Weckesser, former digital transformation officer at the Defense and Space arm of Airbus.[34]

Consumer products: Philip Morris International, PMI, has created a digital twin of its global manufacturing footprint. This allows the company to assess the impact of changes in product portfolio, market regulations, and even business disruption. The company has consequently reduced the use of spreadsheet simulations by 90% and was able to decrease the time required for scenario evaluation from weeks to hours.[35]

> **BMW recently announced the design of a digital factory twin that can be used to simulate the operations of 31 separate factories.**

Automotive: BMW recently announced the design of a digital factory twin that can be used to simulate the operations of 31 separate factories. All elements – associates, robots, buildings, and assembly parts – can be simulated in this model, which is expected to produce planning processes that are 30% more efficient.[36]

Healthcare: Even more interesting applications of digital twins are being made in the healthcare sector. Dassault Systèmes' Living Heart Project – a collaboration between industries, clinicians, and researchers, with members across 130 organizations in 24 countries – has developed the first 3D simulation of

34 I-CIO, "Airbus highlights critical success factors for digital transformation," September 2019.

35 PR Newswire, "River Logic Partners with Philip Morris International to Create Digital Twin of the Company's Global Manufacturing Network," September 2020.

36 FierceElectronics, "BMW features digital factory twin at Nvidia GTC21," April 2021.

a living heart, allowing the development of testing paradigms for virtual insertion, placement, and performance monitoring of pacemakers and other cardiovascular devices.[37] Today, there is ongoing research into the use of digital twins for the planning of surgical procedures; optimizing drug dosage for patients; and even improving drug safety in the design and testing phases.[38]

Manufacturing: Kaeser, a German air-compressor manufacturer, implemented a digital twin system for its air stations. This provides operational data such as the air-consumption rate, which can then be monitored by its employees. This, in turn, allows the company to implement "servitization" – charging consumers on the basis of usage, rather than for the machine units themselves.[39]

Sustainability: Through simulations and scenario analysis, predictive modelling and operational efficiency, digital twins allow organizations to optimize their resource utilizations. For instance, Unilever is making use of digital twins at a facility in Brazil to make production more efficient. The company used a digital twin to set manufacturing parameters; for example, the temperature at which soap is pushed out before being cut into bars. The project resulted in a savings of USD2.8 million by reducing energy usage and improving productivity by 1% to 3%.[40] Further, digital twins also enable infrastructure owners/operators in making the buildings more sustainable.

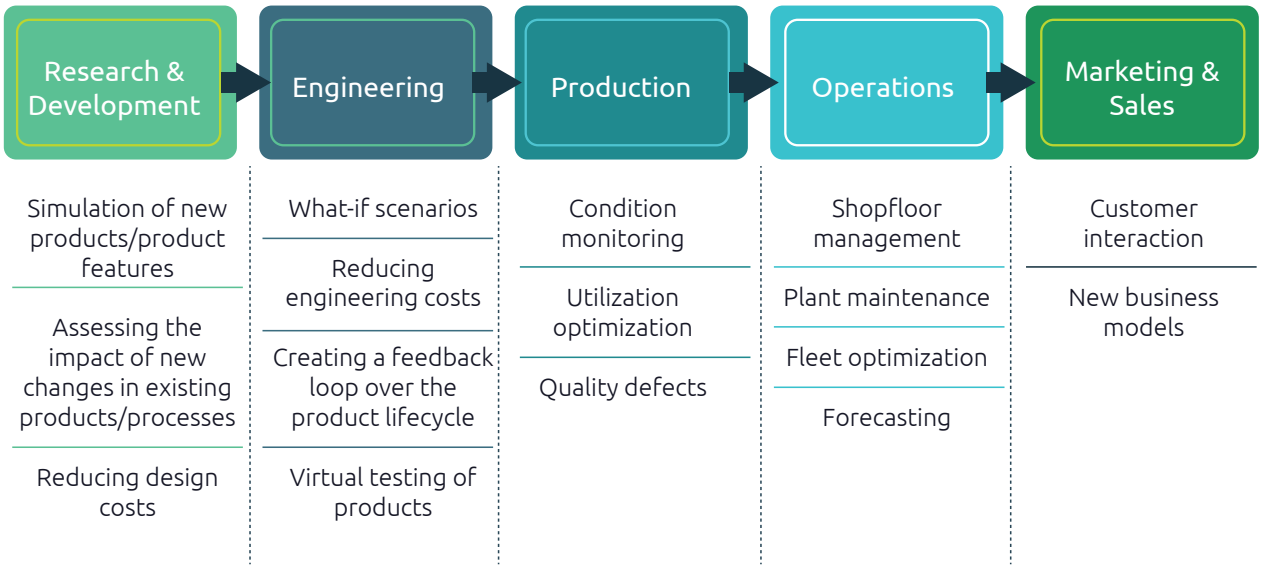
"Digital twins allow organizations to optimize their resource utilizations."

Corinne Jouanny
Chief Presales & Innovation Scaling Officer, Capgemini Engineering

37 Dassault Systèmes, "THE LIVING HEART PROJECT," accessed September 15, 2021.
38 VentureBeat, "21 ways medical digital twins will transform healthcare," July 2021.
39 Plant Services, "Developing a new business model by selling supply," April 2019.
40 The Wall Street Journal, "Unilever Uses Virtual Factories to Tune Up Its Supply Chain," July 2019.

Capgemini's Perspectives

For industries, the benefits from the use of digital twins span the lifecycle of a product. A few of these benefits are shown below:



Source: Capgemini.

Christophe Vidal
Head of Digital Manufacturing, Capgemini Engineering

"The digital twin concept has strong potential to accelerate transformation across multiple industries. The benefits it offers to organizations range from increased efficiency and increased lifecycle environmental impact to greater reliability and cost savings."

Navigating the digital twin waters

Connectivity and data management are key to successful implementation of a digital twin

To drive successful pilots or proofs of concept (POC), certain enablers are essential: [41]

- *Connectivity:* To allow transfer of sensor data into the virtual counterparts
- *Data management*: In order to analyze the raw data and convert it into actionable insights
- *Simulation capabilities:* Including artificial intelligence and machine learning, to build the virtual view of operations
- *A human-machine interface:* To augment employees take the necessary actions
- *Digital continuity:* Across the processes and assets to prevent information silos and to strengthen collaboration. While this is a critical enabler for digital twin implementations, "system-of-systems digital twins" can further drive digital continuity across the value chain of an organization.

While the digital twin model has applications across the value chain, *companies should not descend into "pilot purgatory."* This can be avoided by concentrating on a limited number of use cases (for example, an asset or simple-process twin) that have the highest potential value and seeing these use cases through to completion. Once these proofs of concept are completed, learnings from these projects can be implemented in other pilot projects.

41 Capgemini Engineering, "Digital Twins – Translate data into business outcome," October 2021.

Proper governance and increased collaboration are crucial

A successful digital-twin implementation in one part of the company will inspire more such projects in other functions. However, this is when companies need to take additional steps:

- To extract more value, companies should not simply build individual digital twins, but also plan to develop a *system of digital twins* that can combine information as well as resources, amplifying benefits and economies of scale. Setting and following common standards across data management and communication will enable easy integration of multiple digital twins.

- A *governance* program for digital twins, with defined roles for each team (global vs local; business vs IT, ecosystem of partners and suppliers, etc.) will facilitate management. A crucial subsection of this is data and security governance. There should be clearly defined guidelines as to what data digital twins have access to, who can access the data, and how the data is being utilized across the company.

- For complex twins, a successful implementation would require not only intra-organizational collaboration, but also strong ties with their *ecosystem* partners, both upstream and downstream.

Consortiums can play an important role in influencing the development of digital twins. Problems faced by early adopters in communication, particularly when dealing with a system of systems, can be addressed through the adoption of standard formats. Digital Twin Consortium, for instance, counts companies such as Microsoft, GE Digital, and Northrop Grumman among its founders, and is working on creating cross-industry reference architectures and definitions, refining digital-twin best practices, and providing a resource hub for digital-twin producers and consumers.[42]

42 Digital Twin Consortium website, accessed on September 15, 2021.

As the idea of digital twins becomes established, it is clear that their use can extend to just about anything, from water mains to production lines. While digital twins were originally developed predominantly for hardware, we can now just as easily have digital twins for the information-processing domains of finance and accounting, human resources, and supply-chain management. This opens the door to digital twins of entire organizations and promises exponential benefits – including greater visibility of business operations, more advanced monitoring, and prediction of business-impacting events,[43] to name but a few. The possibilities for business twins are truly endless – and, to date, we have just scratched the surface.

43 Capgemini, "Digital Twins for Business Operations" by Lee Beardmore, https://www.capgemini.com/in-en/business-services-thought-leadership/digital-twins-for-business-operations/

REALIZING THE POWER AND PROMISE OF INDUSTRIAL 5G

Monika Gupta
Vice President, Group 5G & Edge Lead for Industries & Partnerships

Monika Gupta is a global 5G & Edge expert leading industry use cases and partnerships. She also leads the industry focused 5G lab in Mumbai. She works with Capgemini clients on how they can adopt 5G, Edge and complementary technologies for their data-driven digital transformation. She has over 25 years of experience in the telecommunications and IT industry and has led large green-field and transformation programs.

Pierre Fortier
Vice President, Global 5G & Edge lead, Capgemini Invent

Pierre Fortier has 17 years of experience in consulting and transformation in the telecoms & connectivity space. He leads Capgemini Invent offers, thought leadership and business development activities in the 5G & Edge space. Pierre directs projects both for our telecom clients as well as for industrial organizations across sectors – from automotive to transportation, industry 4.0, and public safety, helping them shape their 5G & Edge strategy & roadmap and deliver on this vision through implementation & transformation programs.

The fourth industrial revolution is under way. Industrial organizations are harnessing the power of data and digital to enhance operations performance, increase flexibility and agility, and unlock innovation. This digital acceleration brings connectivity challenges to center stage. To become more "intelligent," organizations need advanced solutions to collect, share, and process exponential volumes of data in real time, with the right scale, velocity, and security. In this context, 5G and edge computing are two key technologies addressing these connectivity challenges, providing companies with opportunities to disrupt, innovate, and accelerate the development of factories of the future.

Early adopters have said that 5G is proving its value and delivering significant gains, with the potential for much more

The Capgemini Research Institute's recently published report, "Accelerating the 5G Industrial Revolution – state of 5G and Edge in industrial operations," examines the power and promise of this technology. It finds that these are still early days for 5G industrial adoption, with only a third (30%) of organizations conducting 5G pilots or progressing to 5G deployments and

> **"These are still early days for 5G industrial adoption, with a third (30%) of organizations conducting 5G pilots or having deployments."**

40% expecting to roll out 5G at one site at least within two years.

However, the experience of the early adopters indicates that the technology is matching or even exceeding expectations and proving its value: we found that three fifths have achieved higher operational efficiency.

As the global 5G deployment and industrial adoption gains momentum, now is the time for organizations to assess how 5G, specifically in convergence with other technologies, can enable new waves of transformation.

Unlocking opportunities across the value chain

Monika Gupta
Vice President,
Group 5G & Edge Lead for
Industries & Partnerships

51%

of organizations plan to leverage 5G to offer new products.

5G lends itself to a wide spectrum of applications across the manufacturing value chain, from enabling autonomous mobile operations to conducting video-based quality inspection and enabling remote collaboration using AR/VR-based applications. Industrial organizations are also optimistic about 5G driving revenues by enabling new products, services, and business models. More than half (51%), for example, plan to leverage 5G to offer new products.

5G use cases in manufacturing can be segregated into four categories:

- **Remote monitoring and control**
  When it comes to critical manufacturing operations, the higher bandwidth and lower latency of 5G allows real-time and high-resolution video monitoring and seamless communication with remote devices.

  For example, 5G can mobilize video-analytics for quality inspection. A high-resolution, low-latency video feed of a production line enabled by 5G and edge computing can help organizations detect faults in real time, have a more granular control on quality, and achieve higher accuracy. For instance, a 5G private network deployed at a Taiwan-based IT hardware manufacturer has led to a reduction in the re-inspection labor force of 50%.

- **Autonomous robots and machinery**
  5G greatly enhances the range and field of operations for robots and autonomous machinery – far exceeding the capabilities of current connectivity technologies such as WiFi.

  This becomes even more critical as autonomous mobile robots or drones become a more mainstream part of manufacturing operations. It can also help to adjust production lines faster. Audi and Ericsson are testing use cases that leverage 5G's features of mobility and low latency to run autonomous robots and machinery on the shop floor.[44]

44 Audi, "5G technology: unleashing the robots," February 18, 2020.

- **Connected worker**
  5G also offers a variety of ways to augment operators in an industrial environment, such as with AR/VR. AR/VR in its current form is either limited by range (connected via wires, leading to restriction in movement and range) or capacity (remote AR/VR devices are unable to offer a truly immersive experience due to limits of bandwidth). 5G can help alleviate both these constraints. A low-latency, high-bandwidth, stable remote connection opens up a number of remote collaboration opportunities in two-way communication using AR/VR – in the areas of design, production, maintenance, and customer service. Schneider Electric is testing the use of 5G to perform maintenance activities using AR/VR.[45]

- **Connectivity**
  Organizations can achieve a higher quality of service in connectivity with 5G. For instance, 5G enables supply chain partners to run their own devices and applications over a network slice of 5G with enhanced QoS, reliability, and governance – ensuring higher security standards. 5G also allows for simultaneous and scalable over-the-air upgrades.

60%

of industrial 5G early adopters are already realizing improved operational efficiencies.

45 Schneider Electric, "Orange and Schneider Electric Run Industrial 5G trials in French Factory," Septeber 28, 2020.

Within these four categories, below are the top-five uses cases for manufacturers that offer the most business impact for these sectors:

Manufacturing

Consumer products manufacturing

- Asset tracking
- Massive sensor networks for predective maintenance
- Use of AR/VR
- Human machine interface
- Over-the-air upgrades

Automotive

- Video-based site inspection
- Massive sensor networks for predective maintenance
- AMRs/AGVs/AIVs/ drones
- Over-the-air upgrades
- Supplier/partner connectivity

Industrial manufacturing

- Video-based quality inspection
- Asset tracking
- AMRs/AGVs/AIVs/ drones
- Mission critical voice, data, and video
- Supplier/partner connectivity

Semiconductor and hi-tech

- Massive sensor networks for pretictive maintenance
- Asset tracking
- Collaborative robots
- Over-the-air upgrades
- Supplier/partner connectivity

Aerospace and defense

- Video based site inspection
- Video based surveillance of plants/sites
- Collaboratives robots
- Mission critical voice, data, and video
- Supply/partner connectivity

Chemicals

- Video-based site inspection
- Collaboratives robots
- Smart tools and machinery
- Over-the-air upgrades
- Supply/partner connectivity

Life sciences

- Video-based surveillance of plants/sites
- AMRs/AGVs/AIVs/ drones
- Collaboratives robots
- Mission critical voice, data, and video
- Supplier/partner connectivity

Use case categories

Remote monitoring and control

Autonomous robots/machinery

Connected worker

Connectivity

Source: Capgemini Research Institute, 5G and edge in industrial operations survey, February–March 2021, N=302 industrial organizations that have run pilots/trials or full-scale implementations of 5G.

However, key challenges are yet to be conquered

There are a range of challenges holding back more widespread adoption of 5G in the industrial sector. The lack of 5G industrial devices is a major impediment – at least in the short run. In addition, there are challenges associated with the economics of rolling-out 5G networks for brownfield sites and identification of highest impact use cases (busines benefits, scale, technical feasibility, and 5G added value), as well as the integration of 5G with existing enterprise networks, IT and OT systems, among others.

To accelerate 5G adoption, industrial organizations should begin experimenting/testing the new technologies and the capabilities they bring, and applying them to address business challenges and driving innovation while progressively fine-tuning their approach as new features become available and they prepare at scaling up the adoption. For this, collective innovation and experimentation is key.

A holistic approach to the 5G implementation journey is critical

Given multiple stakeholders and a large and closely intertwined ecosystem, organizations need to follow a structured and cohesive approach:

- Develop a clear understanding of 5G and edge computing's capabilities and how they can drive innovation. This is essential to ensure that the adoption of 5G addresses actual business challenges instead of becoming a goal in itself. Organizations will need to evaluate how they can enable or enhance relevant use cases using 5G capabilities.

Capgemini's Perspectives

- Select the network deployment scenarios that best fits your requirements for selected use cases. Given the network deployment options offered by 5G, organizations must assess their requirements of control, security, and costs to choose a network model – private, public, or hybrid – to closely align with these goals.

- To effectively counter the challenges in identifying 5G use cases and estimating the ROI, engage with the ecosystem to tap into shared expertise and jointly test and develop.

- Build a business case for 5G adoption supported by a multi-year implementation roadmap. Some of the factors that organizations should consider include the top- and bottom-line impact of 5G, installation and operations costs, savings determined both in the long and short term, and net impact of greenfield versus brownfield deployments.

- Take a gradual and measured approach to operationalizing use cases. Create a roadmap that incorporates new features into the testing and adoption cycle as they become available.

- Ensure that security is built-in by design from the earliest stages of 5G implementation. To prepare for potential risks arising from 5G adoption, organizations should focus on security from the earliest stages of planning and ideation. Our research found that only 50% of organizations do this currently.

Pierre Fortier
Vice President, Global 5G &
Edge lead, Capgemini Invent

"To keep pace, organizations need to take a collaborative experimentative approach: working with the entire ecosystem of vendors, partners, customers, and governments to realize the exciting potential of 5G."

The 5G journey has begun and, already, some organizations are establishing an early edge over their competitors. To keep pace, organizations need to take a collaborative experimentative approach: working with the entire ecosystem of vendors, partners, customers, and governments to realize the exciting potential of 5G.

Insights from the Capgemini Research Institute

NEXT DESTINATION: SOFTWARE

How automotive OEMs can harness the potential of software-driven transformation

→ **p.147**

SUSTAINABLE OPERATIONS

A comprehensive guide for manufacturers

→ **p.157**

NEXT DESTINATION: SOFTWARE

Automotive companies are no strangers to software and new technologies. In recent decades, enterprise and industrial control systems have been implemented to support their increasingly complex global operations. Computer-aided design (CAD), engineering, and testing, supported by virtual and augmented reality (VR and AR, respectively), are now industry standards. The amount of code in vehicles has grown exponentially with the advent of electric vehicles. Now, the digitization of the industry is accelerating on multiple fronts: vehicle-specific, services-oriented, in terms of organizational structure and processes, and long-term strategy.

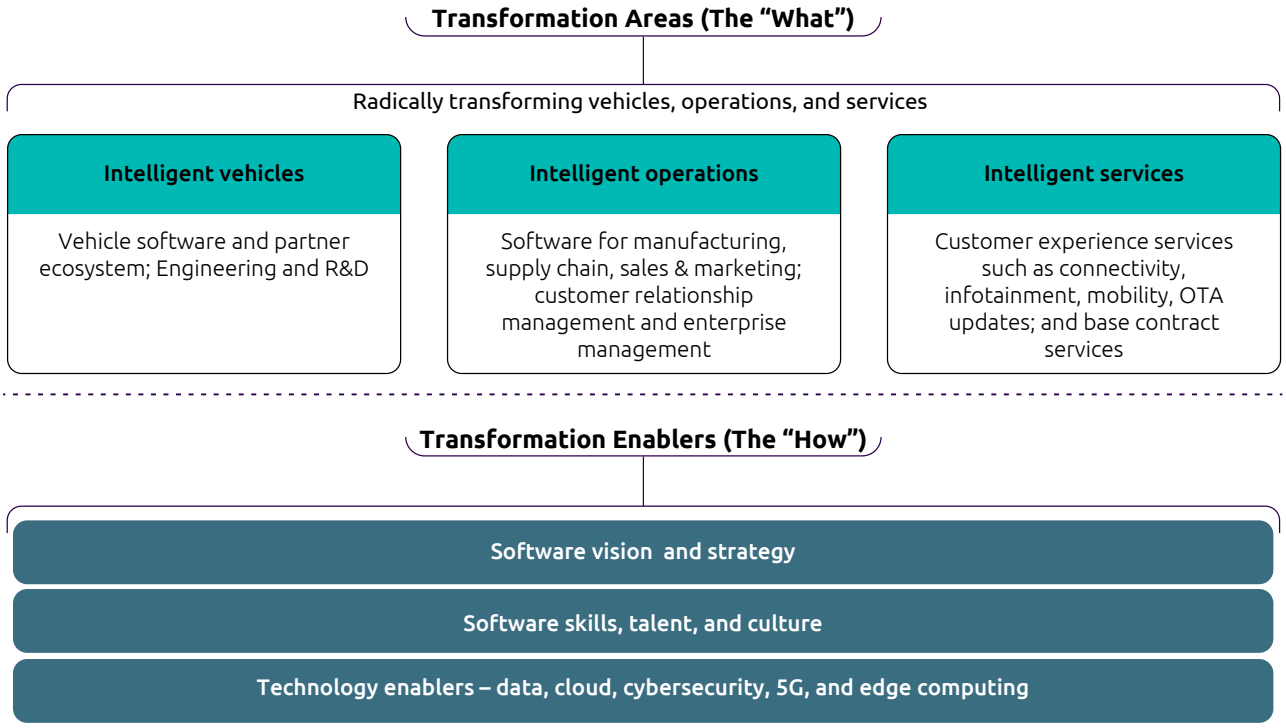
Software is now firmly in the driving seat of the automotive industry – a transformation driven by consumers, regulators, and business and operational benefits.

To assess how well original equipment manufacturers (OEMs) are navigating this transformational period, we surveyed 570 automotive executives from passenger-vehicle and commercial-vehicle manufacturers, headquartered in 12 countries. We also interviewed 17 automotive industry executives. This research, coupled with our experience in automotive-industry transformation, allows us to address the following key questions:

- How is software-driven transformation changing automotive revenue streams and how big is this opportunity?
- How mature is the industry when it comes to software-driven transformation and which advantages do the highly mature enjoy?
- How can OEMs overcome critical transformation hurdles and harness the full potential of software-driven transformation?

We define the software-driven transformation of an automotive OEM as an organization-wide initiative for transforming vehicles, organizational structure, processes, methods, and tools, to the extent that they are primarily defined, designed, and operated by software.

Figure 1: Key elements of software-driven transformation

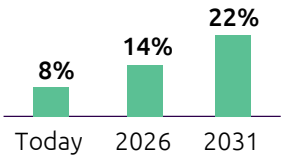


Source: Capgemini Research Institute analysis.

1 – HOW SOFTWARE IS DRIVING THE TRANSFORMATION OF THE AUTOMOTIVE SECTOR

As well as redefining the driving and passenger experience, software is bringing about a sea change in how vehicles are conceived, designed, and manufactured. This research examines the impact of software across three broad areas: the vehicle, the processes (internal and external – e.g., supply chain), and the OEM organization.

Figure 2: How software will change the face of the automotive industry over the next ten years



Software revenue

Revenue from software-based features and services as share of overall revenue will grow

3x

Software capabilities

By 2026,

22%

of all people in R&D will be software experts

Computing

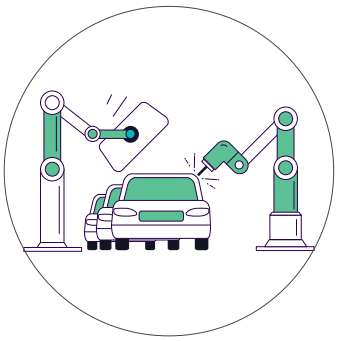
The share of offboard computing will increase to

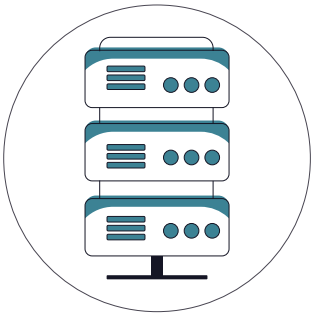
25%

by 2026, from

13%

currently





Software platform

By 2031, vehicles with common software platform will increase

5x

Share of vehicles by 2026

9%

Vehicles with Advanced autonomy (3/4)

36%

Connected vehicles with OTA

Connected services

By 2026,

80%

of OEMs plan to monetize connected services, compared to

13%

of OEMs today

Key software domain

81%

of OEMs rank software in product engineering as key to their software-driven transformation strategy - the most across all software domains

Partnerships

By 2026,

66%

of OEMs plan to partner with software firms and system integrator firms

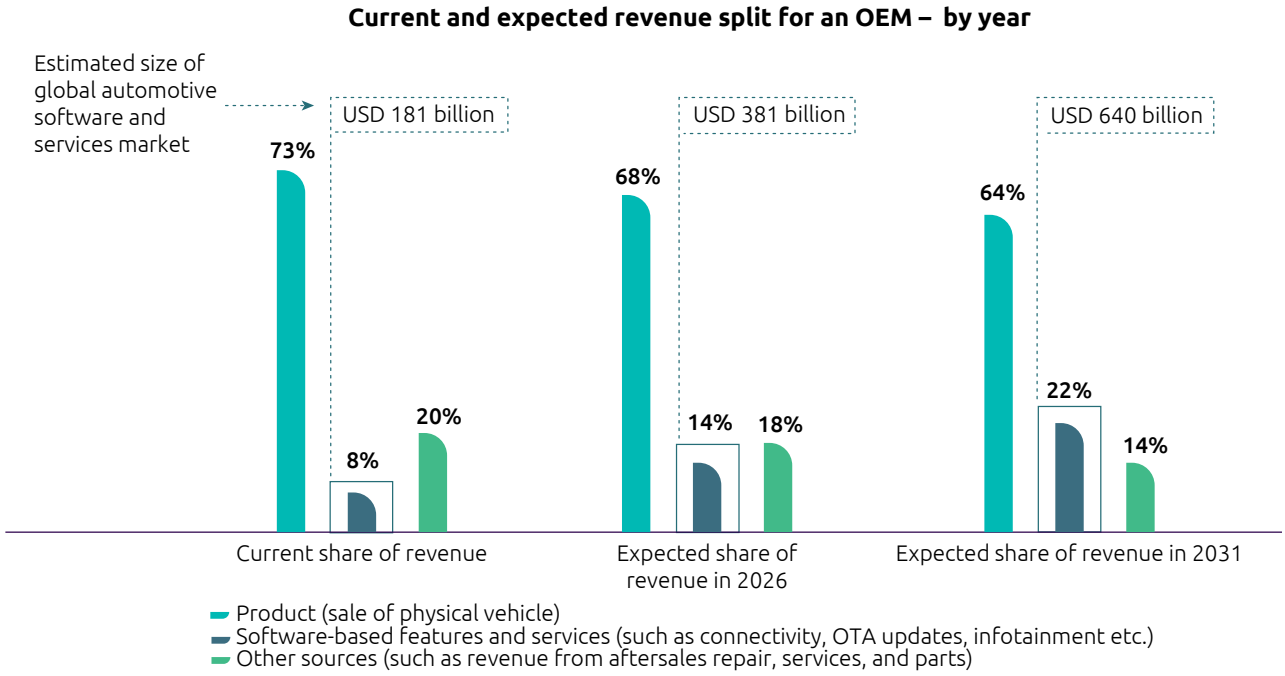
Source: Capgemini Research Institute, Software in Automotive Industry survey, July 2021; N=148 OEMs, Capgemini Research Institute Analysis.

2 – AUTOMOTIVE OEMs' SOFTWARE-BASED REVENUE SET TO MORE THAN TRIPLE IN THE NEXT 10 YEARS

Set to be operating in a $640bn market in a decade's time, more than one-fifth of OEMs' revenue could be based on software features and services

Over the next ten years, the share of OEMs' revenue that comes from software-based features and services is expected to nearly triple, from 8% to 22%. Consequently, the share of their revenue from the sale of physical vehicles will decrease over this period.

Figure 3: Revenue share from software-based features and services is expected to increase three-fold in the next 10 years



Source: Capgemini Research Institute, Software in Automotive Industry survey, July 2021; N=148 OEMs, respondents primarily from general management function.

Software revenue will be driven by connected vehicles and advanced autonomy

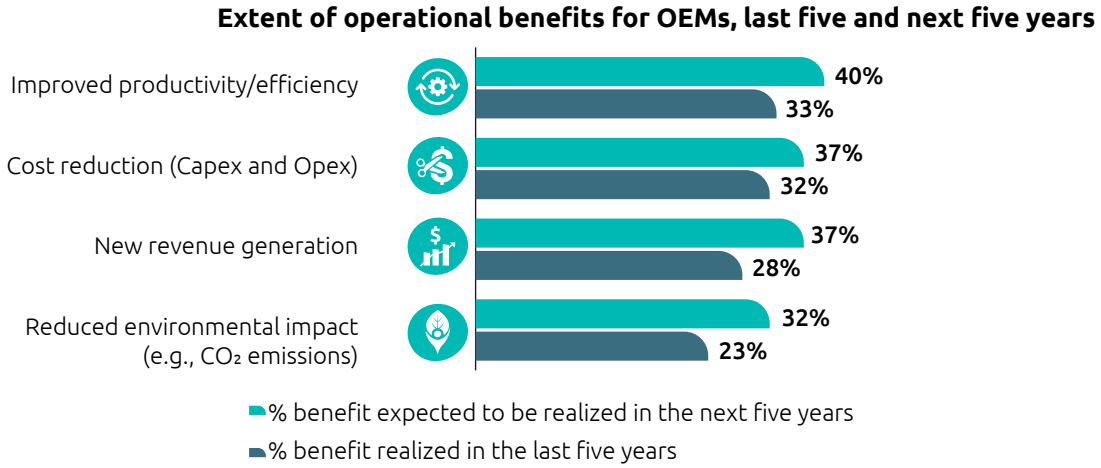
The growth in software-driven revenue will be enabled by vehicles with connected services and advanced autonomy features. Our survey reveals that, out of all the new vehicles produced, connected vehicles supporting 'over-the-air' (OTA, i.e., software-based) updates will increase more than three times in the next five years, to reach 36%. Further, new vehicles produced with advanced autonomy features (level 3/4) are set to increase nearly fivefold in the next five years, to 9%.

To implement connected services and OTA updates across their fleet and enjoy the related economies of scale, OEMs will require a common software platform to be used across their vehicle lines. Our findings show that, on average, the percentage of new vehicles based on a common software platform is going to rise in the next five to ten years. More than one in three vehicles (35%) are expected to be based on a single platform by 2031, up from 7% currently.

Software-driven transformation will yield significant benefits

Our survey findings (see Figure 4, below) indicate that the expected benefits of the next five years exceed the benefits that have been realized over the past five years.

Figure 4: Benefits of software-driven transformation will rise in the next five years



Source: Capgemini Research Institute, Software in Automotive Industry survey, July 2021; N=148 OEMs, respondents primarily from general management function.

Software will provide a point of difference and a competitive advantage for OEMs

Over the next 5–10 years, half of OEMs (51%) expect to be known for providing software features such as advanced driver-assistance systems (ADAS, which help motorists with driving, parking, etc.), self-driving, connectivity, and services, as much as for their engineering excellence. Leading OEMs also expect to get a 9% larger market share than their lagging peers by distinguishing themselves from the pack by implementing unique software-based features and services.

3 – HOW MATURE IS THE INDUSTRY WHEN IT COMES TO SOFTWARE-DRIVEN TRANSFORMATION AND WHAT ADVANTAGES DO THE HIGHLY MATURE ENJOY?

The software-driven transformation agenda is being backed by substantial levels of investment

To implement a software-driven transformation, OEMs, on average, plan to invest ~2.2% of their annual revenue every year for the next five years. Over three-quarters (79%) of OEMs are focusing on software in operations, with 74% of OEMs focused on software for product engineering. The top functions receiving significant budget include engineering/R&D and IT, at 23% each.

However, the vast majority of OEMs are only at the initial stage of their transformation journey and only 15% are mature frontrunners

- 71% have only gone as far as identifying application areas/use cases
- Just 28% have graduated to a pilot/proof of concept based on use cases
- No OEM has fully scaled the identified use cases based on their software-driven transformation for at least one model/production

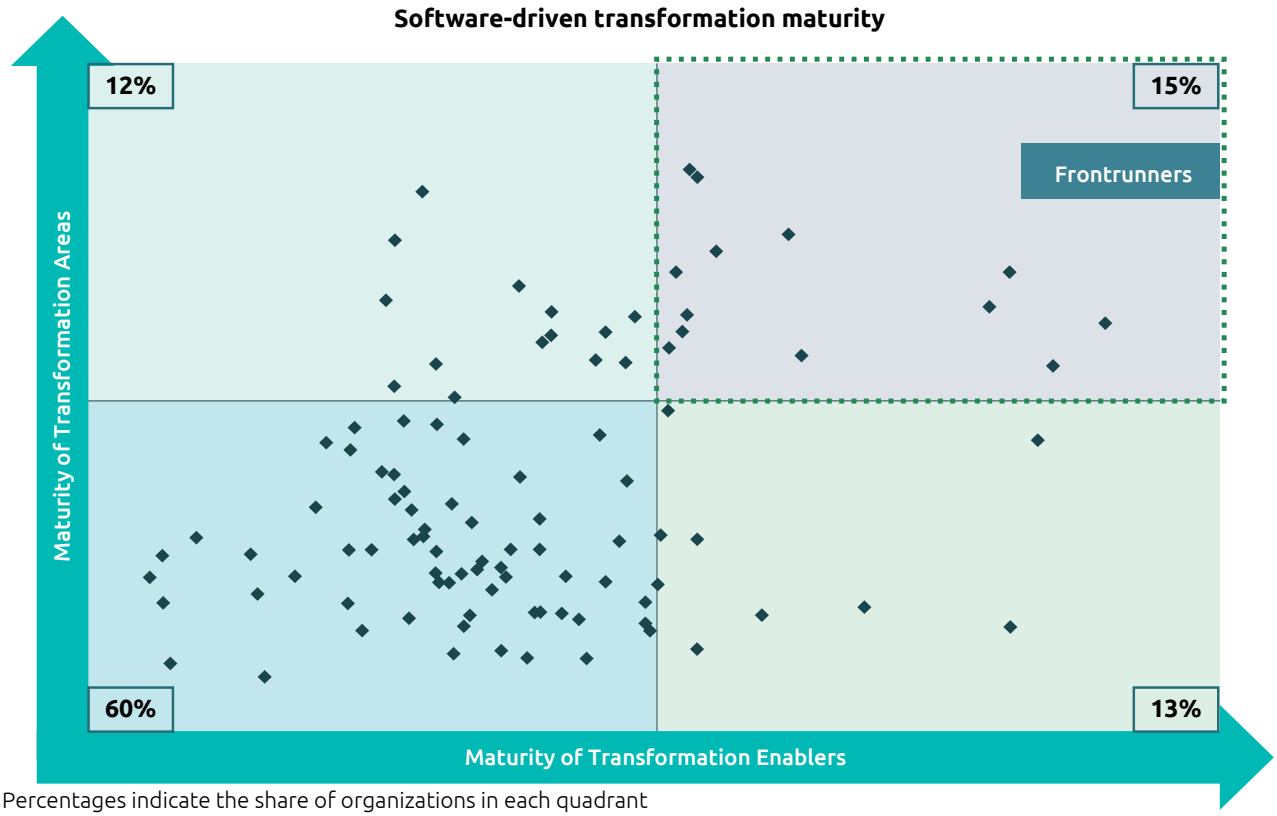
In order to understand the maturity of OEMs, we analyzed their current maturity in terms of two criteria:

- The intrinsic capabilities to develop, create, and implement use of software (which we call 'transformation enablers')
- The extent to which software is transforming the various operational areas, including manufacturing, the vehicles themselves, and internal administration systems

Only 15% emerged as highly mature frontrunners. On average, frontrunners tend to be twice the size of their peers in terms of annual revenue.

OEMs plan to invest ~2.2% of their annual revenue every year for the next five years to implement a software-driven transformation.

Figure 5: Very few OEMs have the maturity to implement software-driven transformation

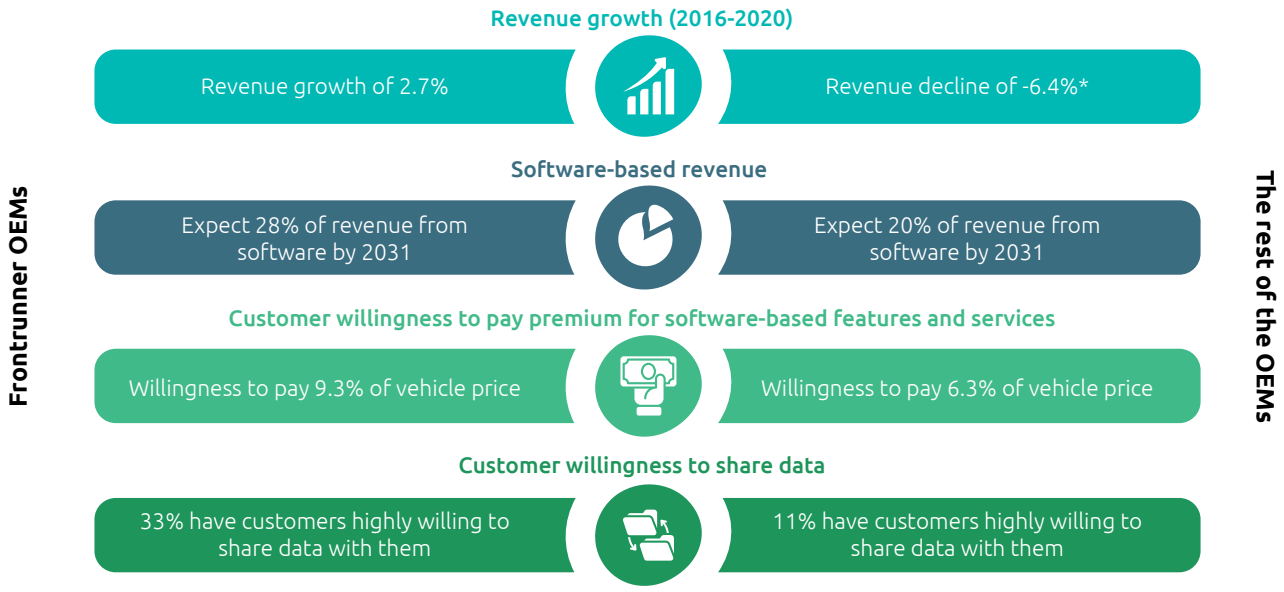


Percentages indicate the share of organizations in each quadrant

Note: Percentages indicate the share of organizations in each quadrant. Source: Capgemini Research Institute, Software in Automotive Industry survey, July 2021; N=100 OEMs with both General Manager and Engineering representative roles.

Software-driven transformation frontrunners are likely to achieve better results

Figure 6: Frontrunners are likely to achieve better results from their transformation initiatives than their peers



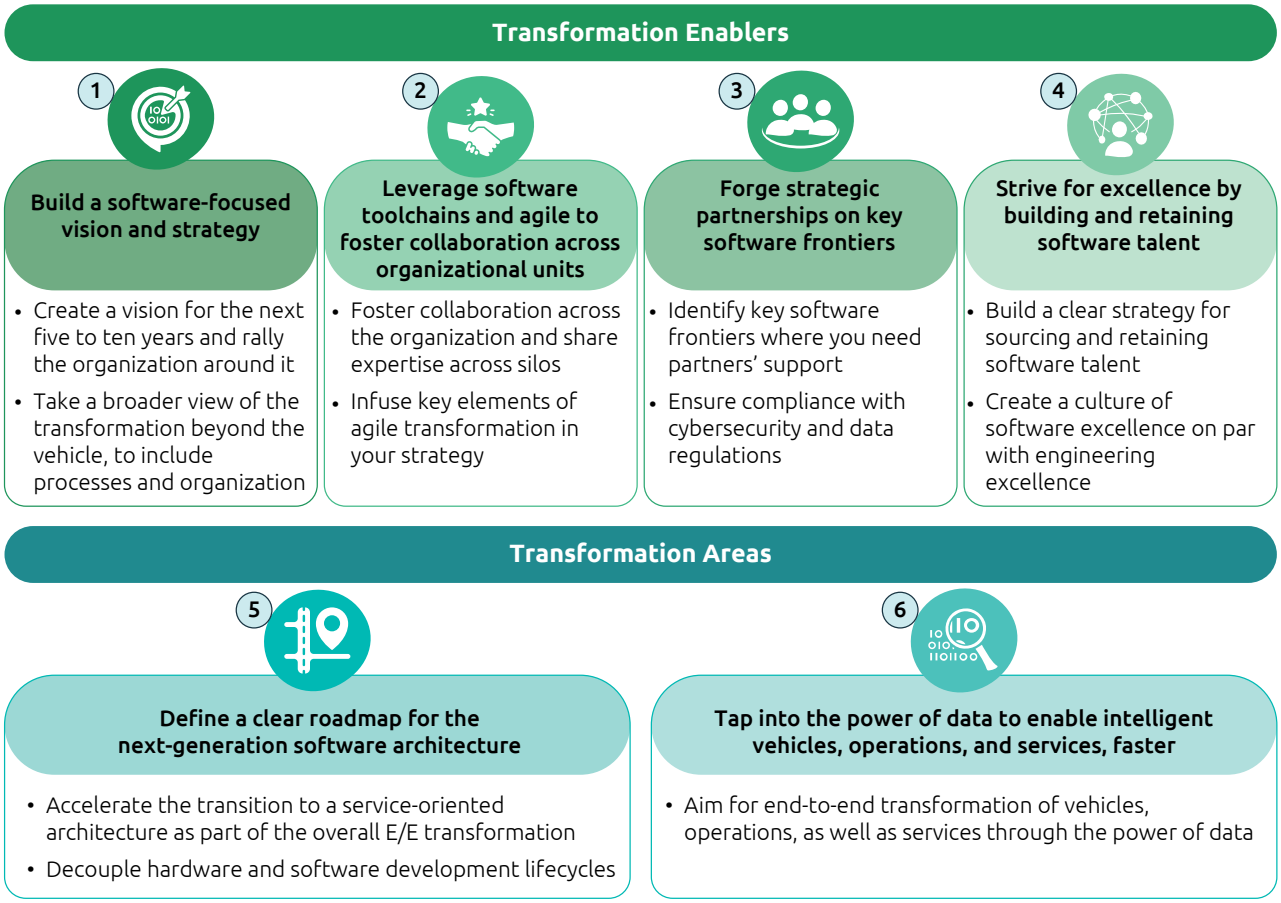
Source: Capgemini Research Institute, Software in Automotive Industry survey, July 2021; N=100 OEMs with at least both General Manager and Engineering representative roles. *Global automotive data from MarketLine.[46]

46 Marketline, "Global Car Manufacturing – Market Summary, Competitive Analysis and Forecast to 2025," June 2021.

4 – HOW CAN OEMs OVERCOME TRANSFORMATION HURDLES AND HARNESS THE FULL POTENTIAL OF SOFTWARE-DRIVEN TRANSFORMATION?

Drawing on our experience in working with leading OEMs globally, as well as insights from this research, we have identified a number of critical success factors for software-driven transformation.

Figure 7: A six-point framework to assist OEMs in making the best of their software-driven transformations



Source: Capgemini Research Institute.

For details on the research methodology and to read the full report, please visit:
https://www.capgemini.com/research/software-the-new-battleground-of-the-automotive-industry/

SUSTAINABLE OPERATIONS

Sustainability and climate change are now top of the global agenda. Today, successful manufacturers understand that environmental responsibility is an integral part of the manufacturing value chain, making stringent demands on organizations but also bringing significant business opportunities and benefits.

To understand where the manufacturing sector stands in terms of operational sustainability, we launched a comprehensive research program, surveying 480 executives from the business-facing side and the same number from the sustainability functions of large manufacturing organizations. The manufacturing industries surveyed include aerospace and defense, automotive, industrial and capital goods, high-tech, consumer products, pharmaceuticals, and medical devices. In addition, we conducted one-on-one interviews with sustainability leaders at a range of major manufacturers.

This research report offers answers to these key questions and examines four themes:

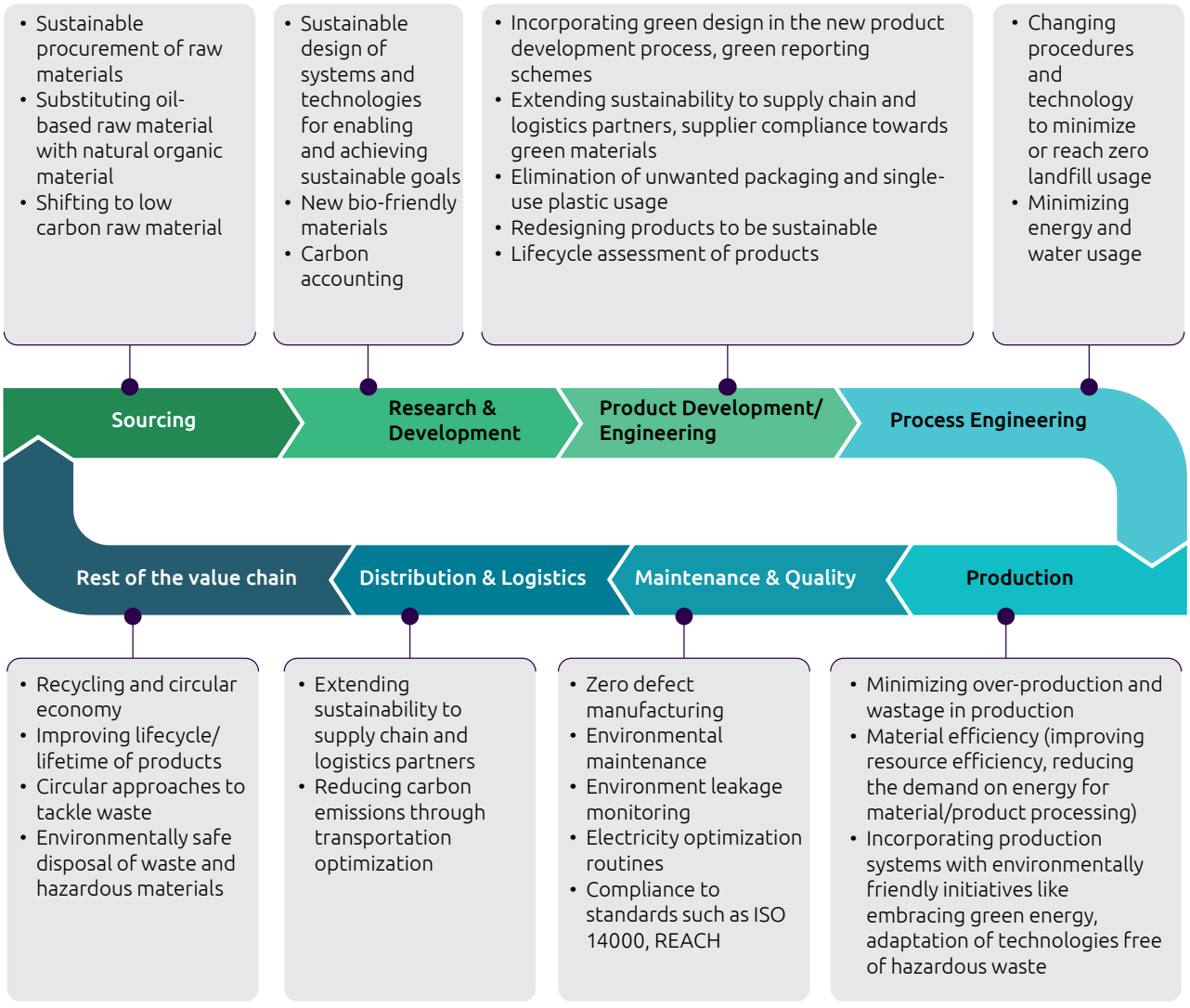
- What is 'sustainable manufacturing' and how does it constitute a major opportunity for manufacturers?
- Why are so few organizations on track to become sustainable manufacturers, despite the sector's high aspirations?
- How is technology helping manufacturers to achieve the goals set by their sustainability agendas?
- How can manufacturers reach their sustainability goals?

1 – WHAT SUSTAINABLE MANUFACTURING IS AND WHY IT IS A MAJOR OPPORTUNITY FOR ORGANIZATIONS

Defining sustainable manufacturing

The UN's definition of sustainable manufacturing covers three important aspects of sustainability: **economic growth**, **social inclusion**, and **environmental protection**. These elements are interconnected, and all are crucial to the well-being both of individuals and societies.[47] This research focuses on the "environmental protection" pillar of the UN definition of sustainable manufacturing.

Figure 1: Sustainable practices across the manufacturing operations value chain

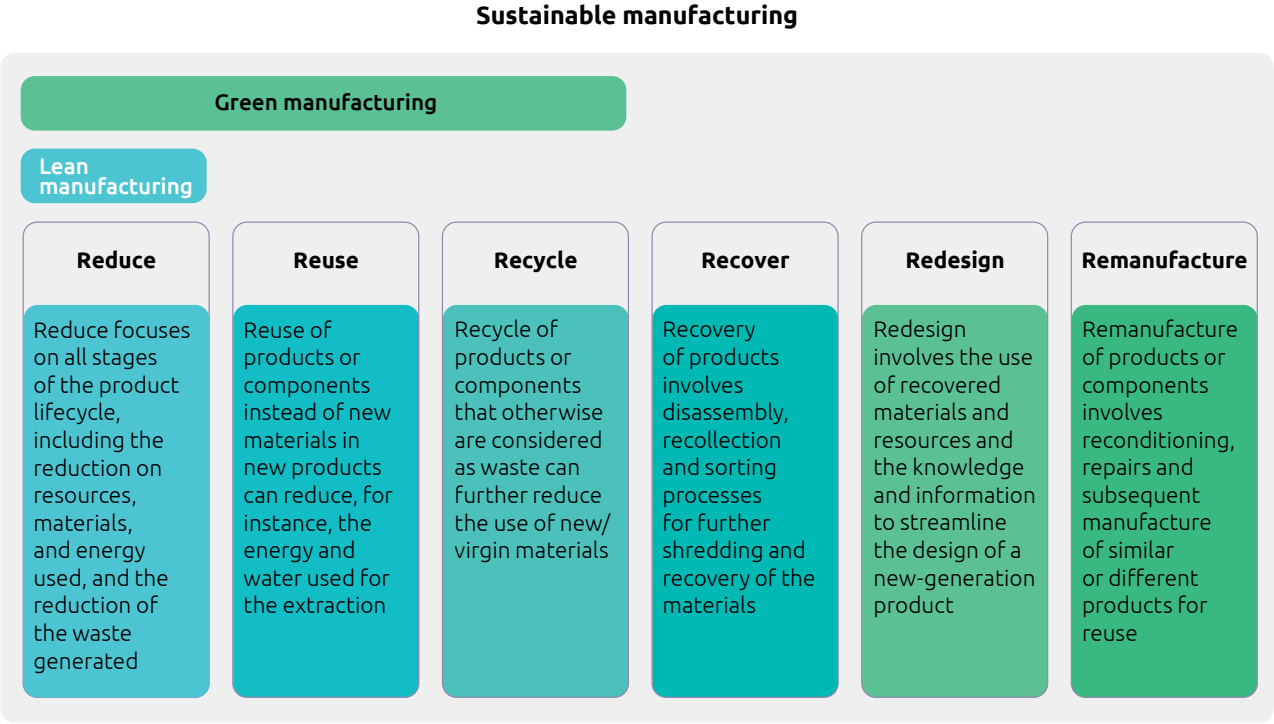


Note: In the above figure, "Rest of the value chain" covers product usage, disposal, and circular economy components.
Source: Capgemini Research Institute.

47 UN, The Sustainable Development Agenda, accessed October 27, 2021.

It is also important to note that sustainable manufacturing incorporates the 6R approach: Reduce, Recycle, Reuse, Recover, Redesign, and Remanufacture – rather than just focusing on waste elimination.[48]

Figure 2: The 6Rs of sustainable manufacturing



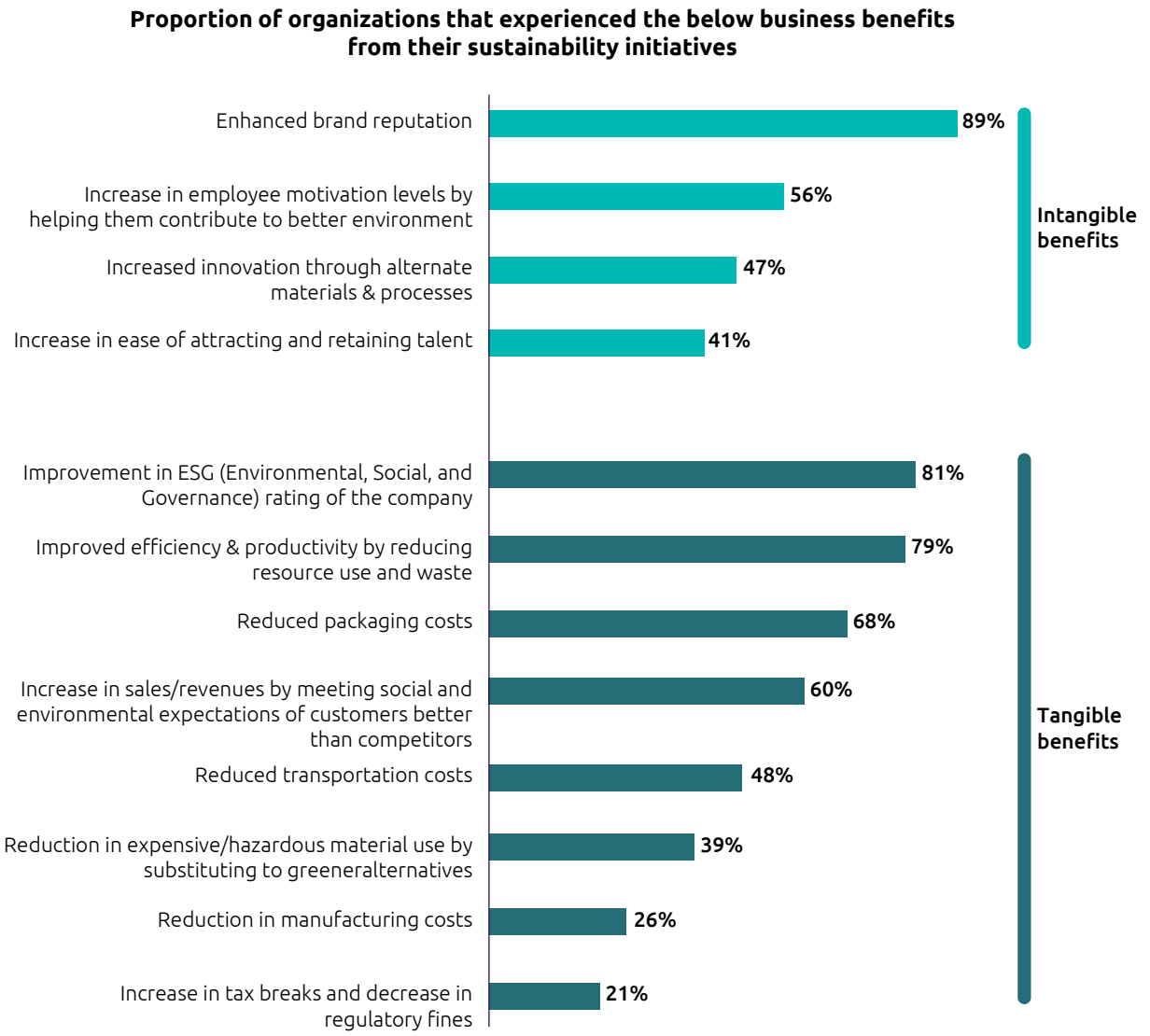
Source: Badurdeen, Fazleena & Jawahir, I.s. (2017). Strategies for value creation through sustainable manufacturing.

Sustainability initiatives are driving economic as well as environmental goals

Our research, however, shows that most organizations are seeing monetary and non-monetary benefits from sustainability initiatives.

48 Badurdeen, Fazleena & Jawahir, I.s. (2017). Strategies for Value Creation Through Sustainable Manufacturing. Procedia Manufacturing. 8. 20–27. 10.1016/j.promfg.2017.02.002.

Figure 3: Proportion of organizations seeing business benefits from their sustainability initiatives



Source: Capgemini Research Institute, Sustainability in Manufacturing Operations, Business executives survey, February–March 2021, N=480 business executives.

Moreover, our research shows that more than nine in ten organizations have seen a reduction in waste and greenhouse gas emissions owing to sustainability initiatives. More than half have seen the carbon footprints of their partners reduced, as well as reduced water use.

2 – DESPITE HIGH AMBITIONS, FEW ORGANIZATIONS ARE ON TRACK TO BECOME SUSTAINABLE MANUFACTURERS

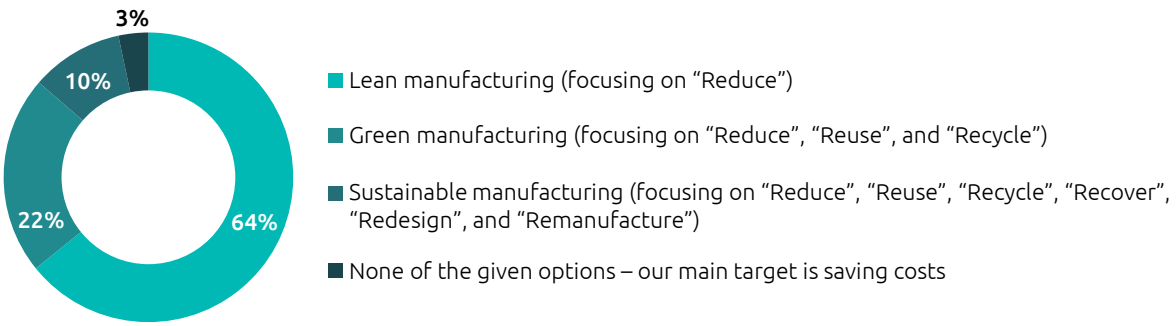
Manufacturers have set ambitious targets for the next decade; however only half of manufacturers aim to align with the Paris Agreement

One in five (20%) manufacturers are aiming to achieve carbon-neutral operations and two in five (40%) have set their sights on 100% renewable operations[49] by the end of this decade.

In our research, we found that only 51% of organizations aim to align with the targets for contained temperature rises set by the Paris Agreement.[50] Of these aligned organizations, only 58% are on track to achieve the targets set out in the agreement.

Comprehensive focus on sustainability is lacking, with the majority focusing on lean manufacturing

Figure 4: Most manufacturers are still focused on traditional lean manufacturing



Source: Capgemini Research Institute, Sustainability in Manufacturing Operations, Sustainability executives survey, Business executives survey, February–March 2021, N=480 organizations.

49 Carbon neutrality indicates that the operation has neither net greenhouse gas emissions nor a carbon footprint. This can be achieved either by eliminating emissions or through offsetting.

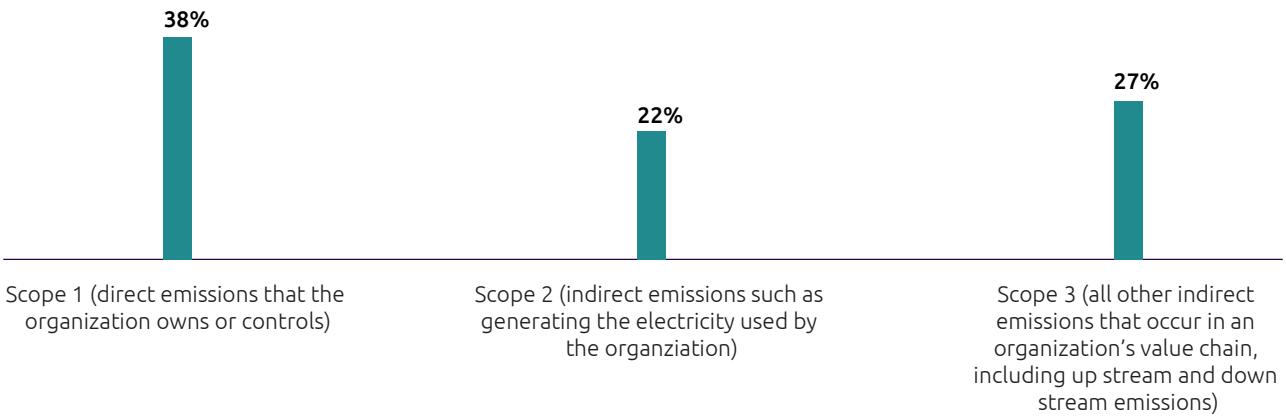
50 NRDC, "Paris Agreement aims to limit the global temperature increase in this century to 2°C above pre-industrial levels while pursuing the means to limit this increase to 1.5°C,." Paris Climate Agreement: Everything you need to know, February 2021.

Maturity of sustainability practices across the value chain is low

We asked business executives about their sustainability priorities in terms of different functions. The product development and engineering function receives the most attention when it comes to sustainability initiatives (48% make this area a priority), followed by production (44%).

The strongest emphasis is given to Scope 1 emissions (direct emissions that the organization owns or controls), but less attention is given to Scope 2 (indirect emissions caused by, for example, generating the electricity used by the organization) and Scope 3 (all other emissions generated within an organization's value chain, including upstream and downstream emissions).[51]

Figure 5: Scope 1 is the main priority for manufacturing organizations



Source: Capgemini Research Institute, Sustainability in Manufacturing Operations, Business executives survey, February–March 2021, N=480 business executives.

Lack of alignment between business and sustainability executives hinders progress

Alignment is an issue across the environmental agenda; only one in five organizations agrees that sustainability is fully integrated into the manufacturing strategy.

It is also an issue between stakeholders within an organization. In our research, we examined the extent to which business-facing executives and their sustainability-focused peers are aligned on key areas of sustainability. We found a lack of alignment was an issue both at an organizational level and in terms of the importance of sustainability for different functions.

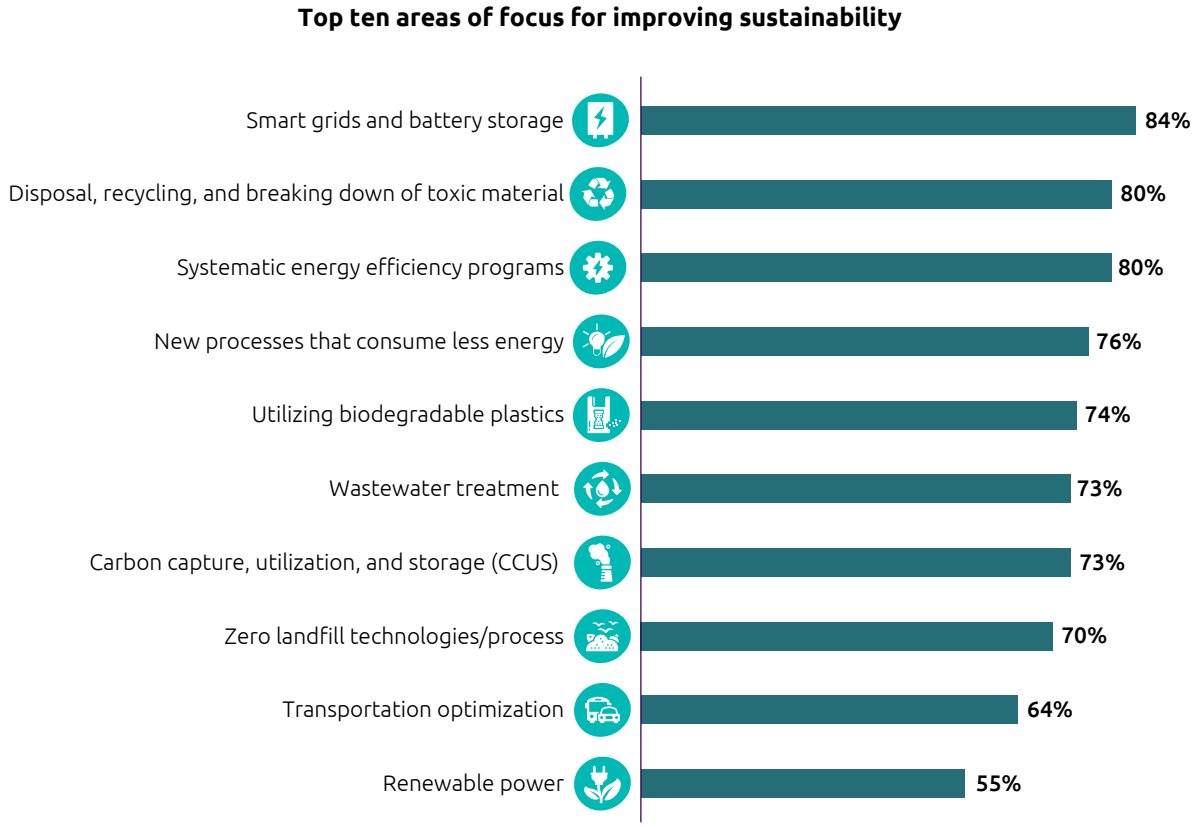
51 Greenhouse Gas Protocol. FAQ. https://ghgprotocol.org/sites/default/files/standards_supporting/FAQ.pdf, PDF file.

3 – HOW TECHNOLOGY IS HELPING MANUFACTURERS TO ACHIEVE THE GOALS OF THEIR SUSTAINABILITY AGENDA

Technology is playing a key role in sustainability initiatives

Manufacturers have wide-ranging sustainability agendas. As Figure 6 shows, 84% have smart grids and battery storage on the agenda. Similarly, 73% are focusing on wastewater treatment, as well as Carbon Capture, Utilization, and Storage (CCUS), which help in mitigating the level of CO_2 emissions.

Figure 6: Top initiatives on the manufacturing sustainability agenda



Source: Capgemini Research Institute, Sustainability in Manufacturing Operations, Sustainability executives survey, February–March 2021, N=480 sustainability executives.

Technology will be key to driving progress across the agenda. Our research shows that more than half of organizations say technology is a core focus of their sustainability strategy.

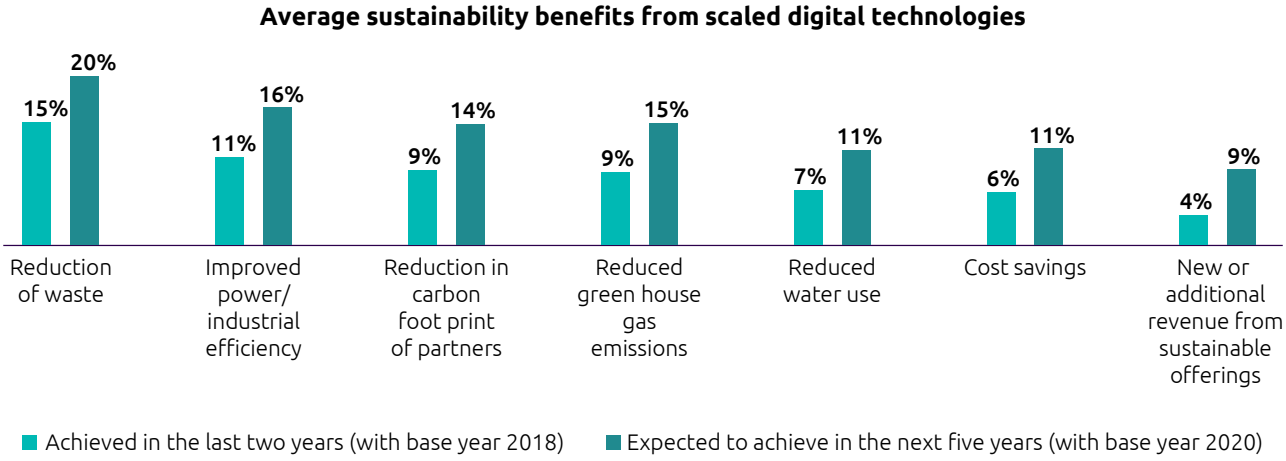
Digital technologies for sustainability are adopted by many and deliver significant benefits

Our research shows significant adoption of key technologies to drive sustainability in manufacturing operations:

- 73% are adopting automation
- 68% AI/machine learning
- 60% data analytics

This take-up reflects the potential of these technologies. As Figure 7 shows, for example, scaled use of technologies has resulted in a 15% reduction in waste, on average, over the past two years.

Figure 7: Digital technologies enable numerous sustainable benefits



Source: Capgemini Research Institute, Sustainability in Manufacturing Operations, Business executives survey, February–March 2021, N=480 business executives.

4 – HOW MANUFACTURERS CAN REACH THEIR SUSTAINABILITY GOALS

Based on our analysis of manufacturers' responses, and drawing on our experience in working with major players in this area, we have identified the top sustainable practices/applications within each of the 6R areas.

Figure 8: Top applications that deliver the greatest benefits

Type	Top applications
Reduce	• Reducing carbon footprint of operations through green hydrogen and renewable power • Improving material utilization through additive manufacturing and precision manufacturing in metal fabrication • Reducing transport carbon footprint by environmentally focused inventory management. • Reducing composite plastics and non-recyclable materials
Reuse	• Reusable transport packaging by constructing durable materials using metal, plastic, and wood that is designed to achieve multiple uses • Use of returnable/reusable plastic boxes and shipping containers • Building rainwater harvesting reservoirs or replenishing underground water reserves.
Recycle	• Using recyclable packaging material • Collecting and recycling scrap from customer processes • Recycling wastewater • Recycling process waste heat for environmental heating
Redesign	• Incorporating green chemistry in product safety • Incorporating environmentally oriented materials selection and sourcing sustainable materials • Redesigning products to remove fossil fuel feedstock sources (such as plastics) • New transportation networks supported by network design technologies and use of alternate transport methods • Redesigning systems using simulation platforms and data collected along the full life cycle to optimize direct and indirect impacts • Designing products in such a way that they can be remanufactured and incorporate lifetime-extension services • Implementing functional approach and embracing the opportunity to change the business model to improve the environmental impact and at the same time, taking the opportunity to identify new innovative products and services
Recover	• Being part of industrial waste exchanges that recover waste from a given industry to provide material of value to another industry • Collaborating with third-party vendors to recover as much waste as possible from site locations • Recovering the energy stored in residual material by turning waste into a fuel for manufacturing processes or equipment designed to produce energy
Remanufacture	• Reclamation of used durable materials, such as steels, and products that can be reused in future manufacturing processes • Taking back end-of-life products from customers so as to disassemble and use them in the remanufacturing process • Offering repurposed/reused products as a service offering • Building retrofitting service lines for extending the usable lifetime of products.

Source: Capgemini Research Institute, Sustainability in Manufacturing Operations, Sustainability executives survey, February–March 2021, N=480 sustainability executives along with Capgemini expert analysis.

We have identified five success factors that are critical to maximizing the results from these applications, and driving the sustainability agenda.

Figure 9: Five success factors for achieving sustainability goals

Align business teams and sustainability executives to explain synergies between performance and sustainability, and anchor the joint agenda

Work with customers and suppliers to reduce indirect emissions

Build transparency through effective reporting and ensure accountability

Incorporate sustainable ways-of-working and operating culture

Invest in technology and data-driven innovation to ensure sustainability goes hand in hand with profitability

Capgemini Research Institute analysis.

For details on the research methodology and to read the full report, please visit:
https://www.capgemini.com/research/sustainability-operations/

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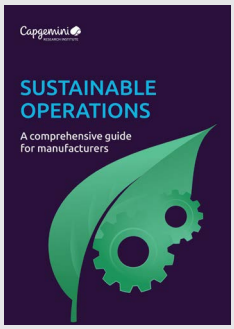

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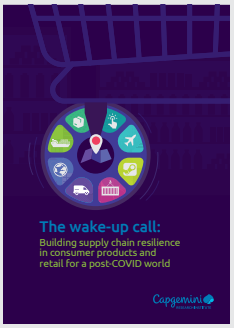

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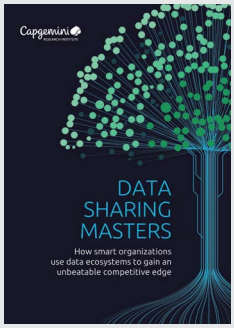

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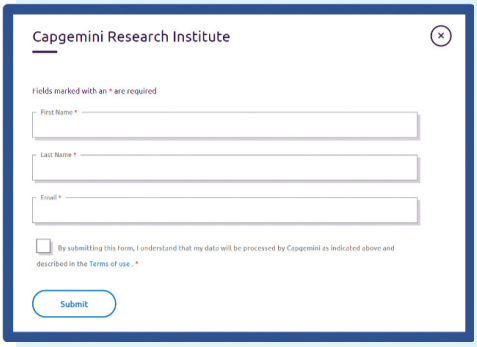

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