Managing Megatrends

Foreword

Dear Reader,

We live in an age of great changes and great opportunities. Five megatrends are transforming the global economy, shifting the geopolitical balance of power, and profoundly impacting the global workforce. At the same time, we have never had so many powerful technologies available to us. In recent decades, digital technologies have matured at a phenomenal pace and are now being combined to solve every conceivable problem in the real world. The opportunities are boundless.

The first aim of this paper is to inform debate by establishing a connection between the megatrends and the technologies and policies needed to meet the challenges arising from them. Hence, Chapter 1 examines the five megatrends, Chapter 2 describes key enabling technologies, and Chapter 3 outlines the policies needed to make the global economy more inclusive, more resilient, and more sustainable.

The second aim of this paper is to encourage multilateral collaboration. History proves that humanity's greatest achievements result from that. Given their scope and complexity, no country or company can solve the challenges we face alone. Our willingness to collaborate in open ecosystems and to accelerate the transformation needed to attain the United Nations' Sustainable Development Goals (SDGs)[1] will determine whether this decade will go down in history as a turn for the better or a squandered opportunity.

The future lies in our hands. Let's accelerate transformation, together.

Peter Koerte

Chief Technology Officer and Chief Strategy Officer of Siemens AG

CHAPTER 1

Five Megatrends

The five megatrends outlined in this chapter are evolving at varying speed, scale, and predictability. Solutions must be adapted accordingly for enterprises to stay competitive, resilient and sustainable. And that requires agile technology with purpose

1

Demographic change

- Population, labor and migration development
- Influence of population growth on GDP
- Age of population
- Healthcare costs

2

Urbanization

- Developed versus less developed countries
- Investments in infra-structure, buildings
- Vertical farming
- Demand for mobility and logistics

3

Glocalization

- From globalization to glocalization
- Shifting center of economic gravity
- Increasing trade restrictions
- Different political systems and values

4

Environmental Change & Resource Efficiency

- Current environmental policies
- Global plastic waste
- Water scarcity
- Material extraction and circular economy

5

Digitalization

- Digital value creation
- Connectivity and IoT
- Automation and artificial intelligence
- Industrial metaverse

Trend 1: Demographic change

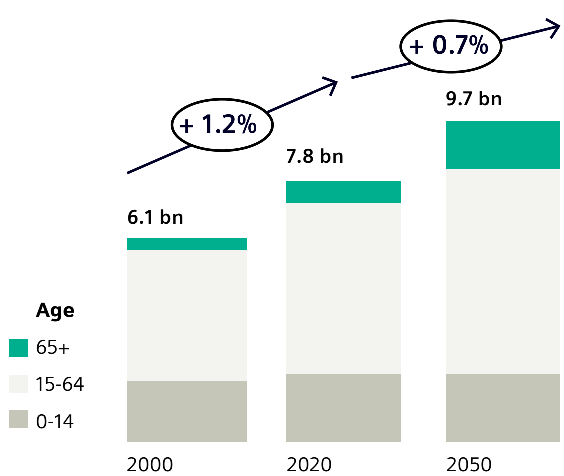
The global population will continue to grow, but we can expect to see marked disparities in this growth. Africa's population will almost double between 2000 and 2050, while the populations of Europe and China will decrease. Growth in some regions is slowing, yet the over-65s' share of the global population will almost triple over the same period.[2]

Consequently, younger generations will bear a larger share of healthcare costs. Consider the United States, where under-35s made up almost half of the population in 2019 but accounted for just 20% of healthcare spending.

Economic growth will become increasingly dependent on productivity gains achieved by technology and digitalization, rather than absolute population growth. Artificial intelligence (AI), automation, and robotics will help achieve these gains, by taking on labor previously performed by the working-age demographic.

The emerging industrial metaverse will allow the workforce to better collaborate in an immersive, intuitive, real-time environment. AI will perform highly repetitive tasks, freeing up humans to focus on what they do best: driving creativity, innovation, and inspiration.

Many of the challenges posed by demographic change can be addressed by technology. But are the world's organizations, governments, and workforce embracing this opportunity? The answer is a qualified "yes."



Aging society

Population development by age (bn, CAGR)[a]

- Slower growth but strong aging of world population
- Highest growth within group of people 65+ (2000 – 2050: 2.7%)

a) Source: United Nations, Department of Economic and Social Affairs, Population Division (2022, World Population Prospects 2022)

Trend 2: Urbanization

Megacities are on the rise. Today, the world has 33 cities with more than 10 million inhabitants and some of those – Tokyo, Shanghai, and New Delhi among them – are home to more than 20 million people. Forecasts suggest that, by 2030, there will be a total of 43 megacities, with most of the expansion occurring in developing countries.[3]

In a related development, the demand for mobility in 2050 will more than double compared with 2015. According to predictions, passenger-kilometers will triple in the next 30 years from 44 trillion to 122 trillion.[4] Meeting this demand will require significant investment in sustainable mass transit systems that provide seamless transportation.

Beyond public transportation, growing cities will require smart buildings, hospitals, schools, and communication networks that provide connectivity and edge computing. Software-based optimization and intelligent hardware technologies will help reduce energy consumption and boost the efficiency of buildings and factories.

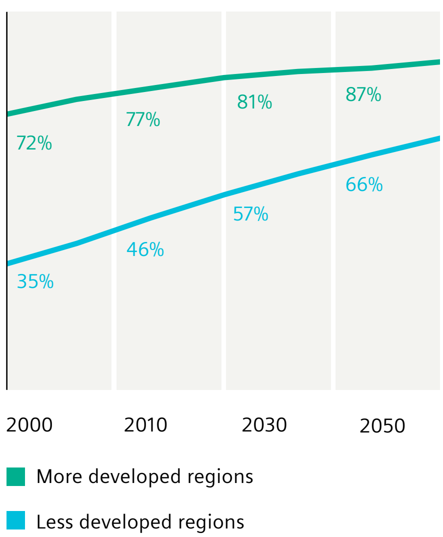
In less than a year, the 70,000-m² Coca-Cola European Partners production facility in Jordbro, Sweden, cut its energy use by 13%, thanks to an upgraded building management system and the installation of new fans and high-pressure compressors. This resulted in an annual energy savings equivalent to the amount of energy needed to charge a hybrid car 400,000 times.[5] Similar projects could make a difference all over the globe, and the G7's Partnership for Global Infrastructure and Investment (PGII) is making strides to do just that. Together with its EU investment partner, Global Gateway, it has already committed to over US$600 billion of investment in sustainable infrastructure in developing countries between 2022 and 2027.[6]

As populations in cities and developing regions expand, they encroach on arable land, and require more water and food. One response to this scarcity challenge is vertical farming, a market that is expected to grow at a compound annual growth rate of 25% from 2020 to 2030.[7] Enabled by advances in LED technology, robotics, and automation, vertical farming offers agricultural solutions in a controlled environment. AI-based crop management makes 17 to 20 more annual growing cycles possible and can help produce 300 times more food per square foot than conventional agricultural methods.[8] One vertical farm in Dubai, for example, requires 95% less water than a conventional farm and yields more than 1 million kilograms of food – free of pesticides, herbicides, and chemicals.[9] Solutions such as these will feed more people and support the increased demand for productivity while also reducing the need for synthetic fertilizers.

Digital technologies also play a decisive role in making urban expansion sustainable. Smart buildings, smart signaling powered by 5G, and software platforms have the potential to deliver significant energy savings and a better travel experience for millions.

Urbanization primarily takes place in less developed regions

% of total population residing in urban/rural areas over time[b)]



b) Source: UN World Urbanization Prospects (2018)

Trend 3: Glocalization

While decades past were marked by globalization, that is, the increasing integration of the global economy through free trade and the free flow of capital, a massive change has occurred in recent years: European and North American influence in the global economy has declined and economic power has shifted eastward. Both India and the Regional Comprehensive Economic Partnership (RCEP)[10], an Asia-Pacific free-trade agreement, will account for over 35% of global GDP by 2050. The GDP of its member countries already exceeds the GDP of the EU and that of the member countries of the USMCA (United States-Mexico-Canada Agreement – formerly NAFTA). Overall, what can be classed as the 'free' and 'mostly free' economies' share of global GDP has declined significantly, from 56% in 2006 to 46% in 2021.[11]

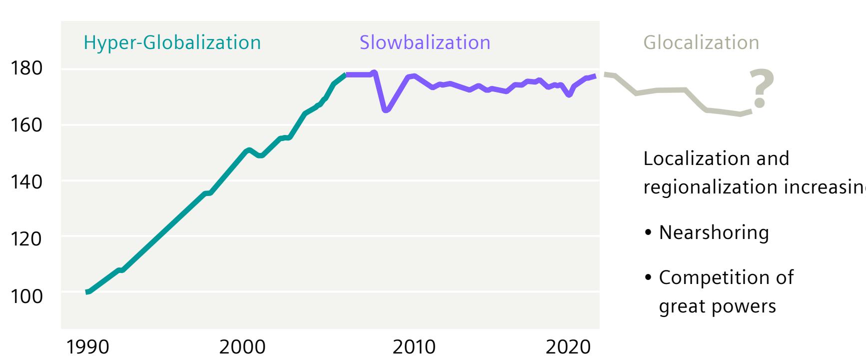
While a globally connected industry stimulates competition and innovation, locating production close to markets – known as nearshoring or local-for-local business – makes local economies more resilient and sustainable. This megatrend is termed "glocalization," and its prerequisites are economic freedom, standardization, a reduction of technical barriers to trade (TBTs), and policies that support the digital economy.

To a high degree, the success of glocalization depends on access to digital technology. A secure and trusted industry-wide exchange of digital information, such as envisioned by the ESTAINIUM Association,[12] will make it possible to reduce the emissions of global supply chains and develop strategies to establish and optimize circular economies and, so, to optimize resource efficiency on a local level. Successfully implemented standards initiated by industry players, like the IEC 63278 series of international standards, allow for the global interoperability of industrial digital twin architectures that result in improved circularity in local economies. A digital product passport would be another benefit of such advances.[13]

Deglobalization is not a viable option. Therefore, government and business should further strengthen and reshape international cooperation through strategic multilateralism.[14]

From globalization to glocalization

Ratio of global goods traded to global industrial production (Index 01/1991 = 100)[c)]



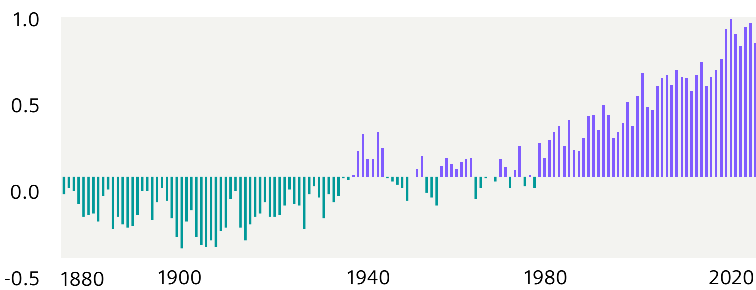
c) Source: Global Trade Alert, Bureau for Economic Policy Analysis

Trend 4: Environmental change and resource efficiency

As things stand, 90 to 100 billion tons of raw minerals are extracted and processed each year. This amount will double by 2060 to 190 billion metric tons. Plastic waste in marine ecosystems is expected to increase by 65% in 2030, even under the current ambitious commitments set by governments. Water scarcity in urban areas is expected to increase throughout the world, impacting 1.3 billion people in Asia by 2050 (in 2016, it was 609 million). The population affected by water scarcity in Africa will nearly quadruple, from 80 million in 2016 to 311 million in 2050. While progress has been made in addressing many of the causes of anthropogenic global warming, current policies will not suffice to limit it to +1.5°C compared to preindustrial levels, at least not in this century.[15]

Climate change continues

Global annual mean temperature variation (°C)[d)]



Current policies are insufficient to limit global warming to +1.5° C in this century

d) Source: National Oceanic and Atmospheric Administration (2022), deviation from global 20th century average

Resolving the sustainability paradox – doing more with less – is possible by combining the real and digital worlds. The [Azores island of Terceira] provides a great example of that. Terceira aims to reduce carbon emissions by more than 3,600 tons per year by combining forecast energy consumption and production with a powerful battery-based energy storage system[16].

Broadly speaking, comprehensive digital twins can help us achieve net-zero carbon emissions. The decarbonization of regional transportation is now becoming reality. [Hydrogen technology] is making rail transportation climate-friendly: CO_2 savings of 520 tons per train per year are now possible. Emission-free operation of long-distance trains is no longer a distant dream; it is becoming reality.[17]

Circular economy solutions – supported largely by digital passports, cryptographic tokens, and data analytics – represent yet another opportunity to improve resource efficiency. Product carbon footprints (PCFs) enable targeted emission management on a product level in the supply chain.[18] For example, a test-case analysis of an industrial circuit breaker showed that an increase of up to [37% recycled resins reduced the CO_2 footprint of the product by 5.3%].[19]

Another example is the growing market of lithium-based automotive batteries, which is expected to reach 4,400 GWh in 2030 and could increase to 11,000 GWh by 2050. Recycling rates of end-of-life batteries could progressively grow from 7% in 2030 to up to 43% in 2050.[20] Data analytics, closed-loop material flows, as well as the integration of sustainability criteria in product design will be key.

Indeed, we have the tools to halt climate change and environmental pollution. We can do more with less.

Trend 5: Digitalization

Digitalization is a megatrend in its own right as it pervades every industry and offers solutions for many of the challenges mentioned above.

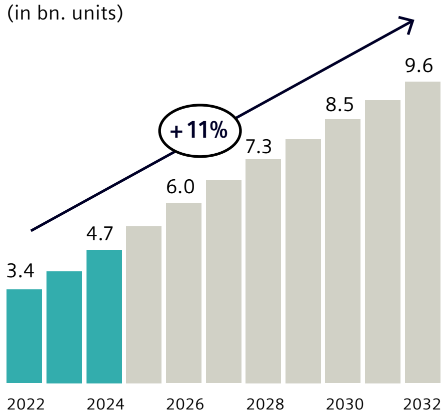
In all industries, software has grown at double the rate of industrial equipment, with a compound annual growth rate of 15% to 19%.[21]

Internet connectivity is expanding steadily. While in 2022 3.4 billion IoT communication interfaces were installed, this number is expected to significantly grow – to up to 9.6 billion devices in 2032 as further industrial and infrastructure devices are connected.[22] In 2030, 100% of the world population will have access to the internet.

The edge computing market in China, the world's second-largest economy, is forecast to reach a market size of US$2.4 billion in the year 2026, with a compound annual growth rate of 35% through the analysis period.[23] Machines controlled by AI will become autonomous and intelligent participants in markets – which will result in an increase of automation and robotics in the IT/OT space.[24]

Digital transformation continues

IoT communication interfaces[e)]
(in bn. units)



Number of industrial and infrastructure devices connected is constantly increasing

e) Source: Graphic created and calculation performed by Siemens based on Gartner research.

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Gartner® Forecast 2023: Internet of Things, Endpoints and Communications, Worldwide, 2022-2032, 2Q23 Update – IoT Endpoint Installed Base Worldwide by Sector, Healthcare Providers, Manufacturing & Natural Resources, Smart Buildings, Transportation.

Furthermore, the platform economy is entering B2B. For rail companies selling tickets to passengers, managing seat reservations, and tracking inventory availability can be both expensive and time-consuming – and passengers prefer easy booking processes. The digital transformation of these processes has led to more modular and scalable Mobility as a Service (MaaS) platforms. In Spain and the Netherlands, this is encouraging more and more people to choose door-to-door travel options. For one transportation operator, the MaaS platform contributes to a predicted additional revenue in the first five years of €156 million. This will be achieved by accelerating the process of finding collaboration partners like eScooter, taxi companies, car-sharing and other transportation providers. Elsewhere, a fully scalable and modular web-based platform already processes 10.5 billion trip queries and issues 300 million tickets per year for leading providers, enabling dynamic pricing that optimizes capacity utilization, and revenue.[25]

Digital twins and the emerging industrial metaverse (IMV) also give industry the ability to test real-world data in the digital world, using a minimum of natural resources and in real time. Open, interoperable, and collaborative. Infinite data will replace finite resources.

Given the large proportion of the world population currently entering retirement, the need for supporting technologies that offer assistance and an enhanced user experience will rise dramatically. These include plug-and-play digital solutions, industrial-grade AI, executable digital twins, edge computing, automation and robotics, 5G and cybersecurity. And power electronics, like smart converters, is important as well because it represents the digital access point for power system data and control. Additionally, an AI-enabled industrial metaverse will open new, immersive, photorealistic spaces for people to collaborate in and find new, better solutions to real-world problems.

The five megatrends outlined in this chapter describe how the world as we know it is changing.

How well we manage the challenges arising from these far-reaching changes will have a profound impact on both our individual and our collective future.

Fortunately, humans do not lack creativity and inspiration. In recent years, digital technologies have matured at amazing speed. They are being combined and applied to solve every conceivable problem. In the coming years, we can expect breakthrough innovations and new business models to emerge.

* * *

The next chapter reveals the technologies needed to make the global economy sustainable and resilient – with one important caveat:

The defining issues won’t be solved by technology alone. We will only be able to achieve inclusive economic growth if we have the willingness and commitment to cooperate across borders and collaborate on all levels.

CHAPTER 2

Key Enabling Technologies

Siemens' industrial control systems around the world generate 100 terabytes of data every hour – that's equivalent to all the movies available on Netflix.[26] Only a decade or two ago, no one could have predicted that digitalization would produce such huge amounts of data. Nor could anyone have foreseen the number of the technologies we now have at our fingertips to harness this data and extract its value.

Technology is our toolbox for meeting the challenges arising from the megatrends. It enables us to engineer agile, efficient solutions.

A large number of enabling technologies are already in play today, while others are only beginning to mature. This chapter identifies key enabling technologies – that is, technologies that are having a profound impact on industry because they are driving secular growth.

Artificial intelligence

With AI-based surrogates that facilitate a near real-time interaction between the real and digital worlds, engineers in the automotive industry can simulate vehicle aerodynamics in milliseconds – a task that used to take eight hours.[27]

This is the magic of AI. It combines computer science and robust data sets to offer complex problem-solving and decision-making capabilities in the real world, releasing workers from repetitive and exhausting tasks, and, at the same time, extracting value from data.

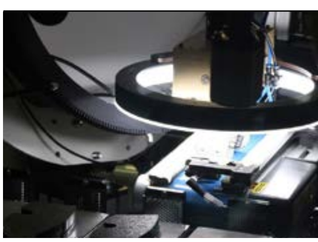
In the healthcare industry, radiologists are under pressure to evaluate more CT and MRI scans in less time. This often results in longer working hours, diminished cognitive performance, and diagnostic errors. AI's ability to read images at great speed can support the interpretation workflow and significantly reduce interpretation error rates, which currently stand at around 30%.[28]

Healthcare: Increased accuracy of medical diagnosis thanks to AI

In the transportation industry, the intelligent use of rail asset data is reducing maintenance costs up to 15% and cutting costs caused by delays by up to 40%.[29]

In the manufacturing industry, AI is enabling the automotive supplier EPF Elettrotecnica to reduce certain areas of manual quality control by up to 80%.[30]

Manufacturing: 80% reduction of manual quality control



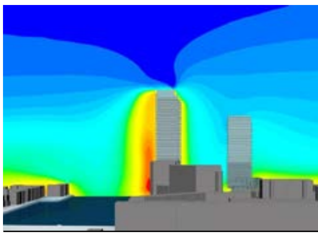
Deep learning is at the core of almost all AI technologies, mostly supported by technologies like physics-informed AI models (PAI), natural language processing (NLP), and reinforcement learning. Analytical AI helps find patterns in huge data pools within seconds. The capability of AI to work autonomously allows a higher level of automation. This capability is already being utilized in the management of traffic, rail systems, and smart grids. Even now, in its infancy with respect to accuracy, trustworthiness, and confidentiality, generative AI and large language models (LLM) are increasingly supporting content creation and programming.

At this point, there is no perfect "digital companion." But the power of AI is already abundantly clear: The global industrial AI market has the potential to top US$100 billion by 2026, spurred by a spectacular compound annual growth rate of 35% forecast between 2021 and 2026.[31]

Return on investment with respect to AI remains a top priority for decision makers. Although over 80% of C-level executives believe they must invest in AI to reach growth objectives, whether a return on that investment materializes depends on their company's ability to move beyond the proof-of-concept stage and to scale AI strategically in line with business goals. Research shows that those companies that manage to do that enjoy twice the success rates, and three times the ROI, compared with those that remain stuck in proof-of-concept silos.[32]

Digital twin

A digital twin is a virtual replica of a physical object or process, including the complex interactions of mechanical, electrical, electronic, and other physical factors. Digital twins enable users to test and run any number of what-if scenarios in design, manufacturing, and service processes. This all takes place without disrupting production – and without the costly consumption of natural resources associated with real-world trials.



Buildings: Simulation time decreases from days to just 30 minutes in the cloud. Preparation time: 1 day versus weeks

Thanks to cutting-edge digital twin technology, the Danish engineering firm ArcAero has been able to reduce runtimes for wind-effect simulation for buildings from several days to just 30 minutes.[33]

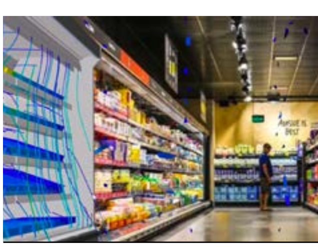
Elsewhere a digital twin for wind turbines has reduced hardware investment by 30% and enabled full-scale infield testing of blade performance and reliability.[34]

Urban expansion, increasing costs, pandemics, and environmental hazards put an enormous strain on urban infrastructure. Digital twin, supported by an AI-driven, systems-of-systems approach, can help accelerate the design of resilient and self-healing cognitive buildings, leading to a more efficient, sustainable, and reliable power supply, and interoperable and harmonized infrastructure operations.[35]

Automotive and manufacturing industries have latched on to the power of digital twins, too. In these sectors, traditional testing of processes is expensive, and making alterations to critical infrastructure carries huge risk. Digital twin technology has been employed to plan, run, and analyze changes to the production lines of customers and their plant setups in a safe environment, without disrupting ongoing production processes.[36]

For companies like the BMW Group, simulating different scenarios for the production of parts makes it possible to evaluate the profitability and feasibility of different concepts before implementation in the real-world production line.

Freyr, a battery production company, aims to build its next-generation gigafactories in Norway and in the United States, supported by a cloud-based digital twin. This way Freyr's customers will be able to mitigate 801 million tons of carbon emissions over a battery's lifetime.[37]



Food and beverage: 1,525 TWh of energy saved thanks to digital twin technology

In the food and beverage industry, inefficient refrigerators can enlarge carbon footprints significantly. In one case, digital twin technology and the innovative use of simulation has helped develop new high-performance "air wings" to control the cold air curtains of refrigerators. The benefits in this case were 1.103 TWh of energy saved, 307.000 tons CO_2 avoided, and British £151 million saved by the respective supermarkets.[38]

The simulation and digital twin market itself is predicted to grow between 40% and 60% in the coming years.[39] The evolution of technology and customer needs and the emergence of new business opportunities, including the convergence of AI, machine learning, simulation, and digital twins, will drive this growth.

Already, the "containerization" of digital twins – also known as executable digital twin (xDT) – makes it possible to run digital twin data on devices at the edge of networks. This can reduce the sensors needed in the field: An xDT can be executed locally, right at the production line, or in a car. No cloud is needed.[40] Another key driver of the development and deployment of digital twin technology is the continuously increasing adoption of sustainable practices. This makes digital twin technology increasingly attractive.

Decarbonization technologies

As things stand, industry accounts for one-third of the world's energy consumption, with manufacturing contributing around 20% of global carbon emissions. Buildings are responsible for one-third of global energy consumption and 18% of greenhouse gas emissions.[41] And as infrastructure becomes more complex, more automation and intelligence are required. Two key technological levers will be applied to make industry, mobility, buildings, and infrastructure more sustainable: decarbonization and digitalization.

Brownfield factories go green: Achieving CO_2-neutral production in Europe by 2025 and in the USA and Asia by 2030

ElringKlinger, a leading automotive supplier, aims to achieve carbon-neutral production in Europe by 2025 and in the United States and Asia by 2030.[42] This objective is within reach by implementing comprehensive transparency of energy data and energy efficiency in real time, extensive standardization across plants, and the ability to determine the carbon footprint of all products.

Cross-industry collaborations such as the ESTAINIUM Association are addressing the trust, confidentiality, and security issues of aggregated supplier information, as sustainable supply chain partners share information across digital ecosystems to reduce emissions. This supports web-based applications like SiGREEN as they use data-sharing innovations to reduce the carbon footprints of supply chains while protecting data sovereignty and business confidentiality.[43]

Sustainable battery production: New cells to consist of 50% recycled materials by 2030

Digitalization has allowed a Siemens factory in Berlin to shift the full load management of energy-intensive processes by a few hours, resulting in energy cost savings of €300,000 per year.[44] And by relying on a value chain in which every link is fully digitalized, Northvolt, a Norwegian supplier of lithium-ion batteries, will be able to power its production based on 100% renewable energy and will, by 2030, utilize 50% recycled materials in newly produced batteries.[45]

Furthermore, a kind of digital passport for resource and product lifecycles makes it possible for data analytics to give businesses insights into resource allocation, performance, and emissions. This alternative to existing extract-create-dispose economies has the potential to create US$4.5 trillion in economic value globally by 2030.[46]

To summarize, digitalization gives companies immediate access to emissions data and so not only heightens awareness, but also identifies areas where improvements are possible and where product carbon footprints can be minimized by recycling materials.

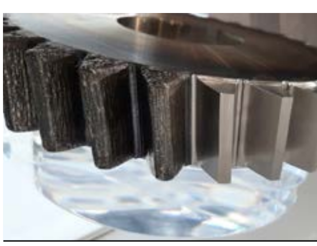
Automation and additive manufacturing

Predictive analytics in electronics manufacturing:
30% fewer x-ray quality tests,
capex reduced by €500,000
100% production efficiency

Imagine a factory that ensures the quality of over 17 million components, 24/7. The factory produces printed circuit boards, yet the quality control processes reduce production output and require expensive x-ray equipment. Enter an AI-driven, closed-loop data analysis, integrated into the on-site production process that only requires parts with a high probability of being defective to be x-rayed. The result: 30% fewer costly x-ray quality tests, a reduction of €500,000 of capital expenditure, and seamless on-site installation that maintains 100% production efficiency.[47]

The future of automation is even brighter: The goal of "automating the automation" is a game-changing step on the path to zero engineering:[48] this enables machines, buildings, and systems to autonomously learn, understand, interpret, and make decisions within defined limits.

Imagine AI-enabled systems that are aware of their environment, finding solutions autonomously; or open, prefabricated, modularized manufacturing cells that enable fast and flexible "plug-and-operate" commissioning; or sensor fusion technologies that allow autonomous rail and road vehicles to navigate safely and efficiently; or building automation systems that can be installed and commissioned without deep automation or programming knowledge.



German machine builder:
Industrialized AM reduces energy consumption by 60%

Today, additive manufacturing (AM) is a legitimate production technology for a wide range of sectors and supports the drive toward autonomous solutions and automation. It can help save up to 70% of raw materials in the manufacturing of components by using powerful AI-based tools and by providing diversified (and thus resilient) supply chains, which have become essential.

Companies like Siemens Mobility now use AM technology in production to reduce the global delivery time of spare train parts by up to 90% and carbon emissions by up to 10% – while achieving 100% system availability.[49]

One German machine builder has even been able to build a robotics-driven AM machine for metals, which makes it possible to repair gears for wind turbines on demand locally. This can reduce energy consumption by 60% to 85%, compared with the wholesale production of new gears.[50]

Going forward, digitalization and related emerging technologies – like AI, the Industrial Internet of Things, digital twin, edge, and the cloud – will enable much more flexible and easy-to-use automation solutions requiring even less engineering effort and delivering a significantly reduced carbon footprint.

Edge and connectivity

The Internet of Things (IoT) is pivotal to the success of digital transformation; this is where the real world and the digital world connect.

For the industry and infrastructure markets, it's the Industrial Internet of Things (IIoT) that meets the more stringent requirements of these markets, including reliability, longevity, privacy, and cost. Key components of the IIoT include smart sensing, edge computing, industry-grade connectivity (5G) and perception. These technologies deliver the raw data that – when analyzed – can be turned into valuable information. For example, sensors can monitor the vibration of a physical machine, and this data can be used to determine whether the machine is running smoothly or whether inspection or maintenance are needed.

Rail infrastructure: Smart Signaling by 5G can reduce amount of network cables up to 90%, and lifecycle costs by up to 25%

Food and beverage: 100% traceability of quality and grade classification

5G has the potential to inspire new business models in industry, for instance, railway operations.[51] Virtualizing train operations hardware across the network using 5G reduces signaling infrastructure for rail, which can translate into a 90% reduction in the network cables needed for smart signaling – and lifecycle costs can be reduced by up to 25%.[52]

Or the food and beverage industry, for example, where around 14% of food produced is lost between harvest and retail.[53] By combining edge technology with artificial intelligence and hyperspectral analysis, the Portuguese company Sonae is minimizing food waste thanks to 100% traceable classification of food quality and grade – for 50 metric tons of fresh fish and seafood each day.[54]

The megatrends urbanization, demographic change, and resource efficiency are driving the market for IoT-enabled devices across the world. The number of IoT devices worldwide is expected to almost triple to more than US$25 billion in 2030.[55] And the global edge computing market is anticipated to reach US$61 billion by 2028, with a compound annual growth rate of nearly 40%.[56]

Given their speed and low latency, industrial IoT devices and edge computing will increasingly populate safety-critical and security-critical applications. This will enable seamless communication throughout the entire value chain. It will also lead to massive data generation and semantic enrichment of data from field devices, such as sensors for temperature, as well as the ability to create a digital twin of an entire system.

Connectivity and edge technologies will close the gap between the real world and the digital world, enhance autonomy, and spur the development of collaborative systems.

Cybersecurity and trust

Estimates indicate that the IIoT market will be worth US$500 billion by 2025. But without the right technology to protect that investment, the costs caused by cybercrime will continue to rise.

According to industry forecasts, the cost of reported cybercrime alone will exceed a staggering US$10 trillion per year by 2025[57]. That's roughly equivalent to 10% of global GDP in 2025. Small businesses are particularly exposed: Over half of all cyberattacks target small and medium enterprises[58], and nearly three-quarters of small businesses have experienced at least one attempted attack in the last 24 months.[59]

Factories: Providing full visibility for OT security (OSA) with AI for behavior-based anomaly detection

So, which technologies are key to cybersecurity? AI-assisted security monitoring systems can detect previously unknown attack patterns in critical data. Digital twin technology makes new detection methods possible by comparing data from the real system with data from the system's digital twin – discrepancies indicate possible cyberattacks. Quantum computing addresses problems that are too complex for conventional computers, such as the mathematics on which cryptographic algorithms are based.

Cybersecurity is imperative for both the public and private sector. Fortunately, awareness of this issue is widespread. A full 85% of small and medium-size enterprises intend to increase IT security spending by 2023.[60] They know that today's digitalized and hyper-connected world comes at a price. Extortion is a growing threat, and business continuity, industrial processes, and critical infrastructure are at risk. Safeguarding against cyberattacks and protecting sensitive data will be vital to preventing disruptions to ongoing operations and establishing greater trust in technology.

Where are the key enabling technologies leading us?

Most likely to a fully immersive industrial metaverse (IMV). The initial idea behind the metaverse was to provide fun and entertainment through an enhanced user experience, mainly in the consumer market. And the expectation was that metaverse-enabled virtual realities would drive e-commerce.

But there are strong indications that the metaverse will develop its full potential and greatest impact in industry. The industrial metaverse will enable us to simulate and test different scenarios in the virtual world. We will be able to work on real things together virtually, in real-time, and from anywhere, whether designing buildings and power grids or servicing machines. All that will enable us to reduce costs and emissions and use fewer resources. The key enabling technologies mentioned above are already delivering these benefits, and as the industrial metaverse evolves, these benefits will scale.

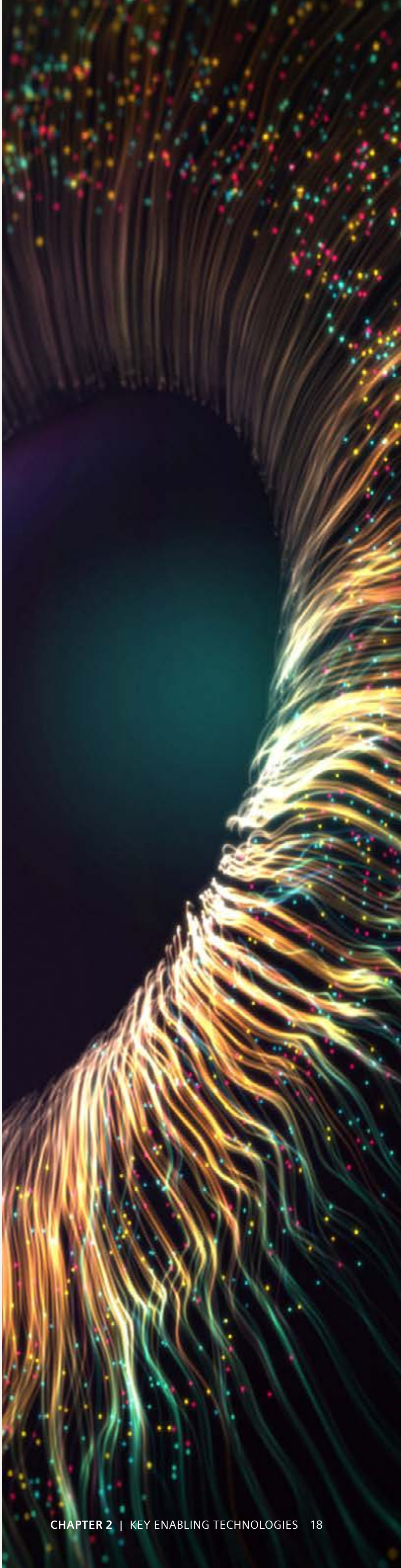
For aging societies these advantages will be critical. Labor shortage is already an acute problem in Europe, North America, and Japan, and it's not getting better. In China, almost 40% of China's population will be over retirement age by 2050.[61]

As megatrends intensify and their geopolitical, environmental, and economic ripple effects multiply, the real-time granular insights offered by the industrial metaverse can help us tackle the concomitant challenges much faster. It will open new opportunities for industry to train workers and attract talents.

People won't have to be engineers to operate sophisticated machinery. And mixed-reality technology and live feeds with experts will guide them as they set up and service complex systems. Better yet, upskilling employees will prepare them to take on new tasks and pursue new career paths in the digital economy.[62]

Still, no single organization can build the industrial metaverse alone. Collaboration remains key. That's why open digital business platforms and powerful ecosystems are indispensable. Well-governed open digital business platforms offer interoperable, flexible, and secure solutions as a service and ecosystems foster cooperation, collaboration and cocreation among members.

Government policies can help or harm the scaling of innovation – and its responsible and inclusive application. The next chapter explores how policymakers can help shape the digital economy of the future.



CHAPTER 3

Beyond borders – Multilateral Collaboration

The beginning of this decade was marked by events that will shape our world for years to come. The COVID-19 pandemic demonstrated how important it is to establish robust policies to successfully manage a public health crisis. Since then, governments have installed programs designed to accelerate digital transformation and the transition to a sustainable economy. Concurrently, supply chain bottlenecks and geopolitical tensions have fueled the drive to diversify markets and value chains, and so to strengthen the resilience and self-reliance of national economies.

These developments can help inform our strategies for managing the megatrends. Technology played a defining role in mitigating risk and propelling transformation during the pandemic, for example:

- The accelerated vaccine production through digitalization and automation technologies.
- The decentralization of energy production and the deployment of renewable energy, energy storage, and green hydrogen solutions in the drive to decarbonize energy systems.
- Vertical farming, which is becoming a reality to support cities and communities in overcoming food security challenges through water savings and in-creased resource efficiency.
- New digital technologies designing products that support circular economies and improve resource efficiency, like advanced manufacturing of batteries.
- Mobility solutions that integrate regional and high-speed trains and strengthen the electric mobility infrastructure for cars, buses, trucks, and metros on a local level.

Yet, despite these technological advances, it's collaboration that remains the key to progress. What counts is open and multilateral and multi-level communication and alignment among all stakeholders – whether they are political leaders, entrepreneurs, scientists, the representatives of NGOs or citizens.

In these times of global instability, we advocate policies that advance multilateral collaboration. This includes free trade, reduction of trade barriers, and the implementation of international standards that ensure sustainable development, safety, interoperability, and quality of infrastructure.

We believe that multilateral collaboration is crucial for the development of the digital economy and decarbonization. How well we put that into practice will determine our collective future on this planet.

Conclusion

As a long-standing member of the UN Global Compact that is committed to the UN Agenda 2030, Siemens contributes to the UN Sustainable Development Goals by meeting its own emission reduction targets, by providing technologies that help customers meet their environmental goals, and by implementing its ESG framework DEGREE.

We call on readers of this paper to join us in building bridges and making multilateral collaboration standard practice by supporting the following activities:

Foster innovation and open ecosystems

Prosperity comes from investment in innovation. Technology enables economic growth with fewer emissions.

- Promote knowledge sharing between the science and business communities.
- Invest in R&D, open technologies, and start-up-friendly ecosystems.
- Focus on technologies that benefit society: AI, digital twin, simulation, cybersecurity, edge computing, industrial wireless communication technologies and many more.

Develop a skilled workforce

Employers who empower people earn trust and build loyalty. This gives them a competitive edge and enables them to adapt to changing markets.

- Provide employees with growth and upskilling or reskilling opportunities to adapt to the changes associated with digital transformation.
- Facilitate skilled migration to meet the high demand for labor.

Establish a green global framework

Trusted interoperability across supply chains is needed to establish effective governance of green and digital technologies.

- Prioritize the adoption of international technology standards and respective industrial use cases and mobilize smart investments.
- Support sustainable urbanization by focusing on smart cities and smart infrastructure, and sustainable rail and public transportation systems.

Expand international trade

Trade promotes economic growth, creates jobs, and reduces poverty. Multilateral, rules-based trade benefits all, not just individual nations.

- Accelerate the ratification of multilateral trade agreements by leveraging technological advances that support diversification strategies and by reducing technical barriers to trade.

We are convinced that if we take these actions together, that if we take this leap of faith, then this decade will go down in history as the dawn of sustainable global development.

**The future lies in our hands.
Let's accelerate transformation, together.**

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