State of Industry 4.0

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KEARNEY

Photo by Can Erdal
Kearney, Dusseldorf

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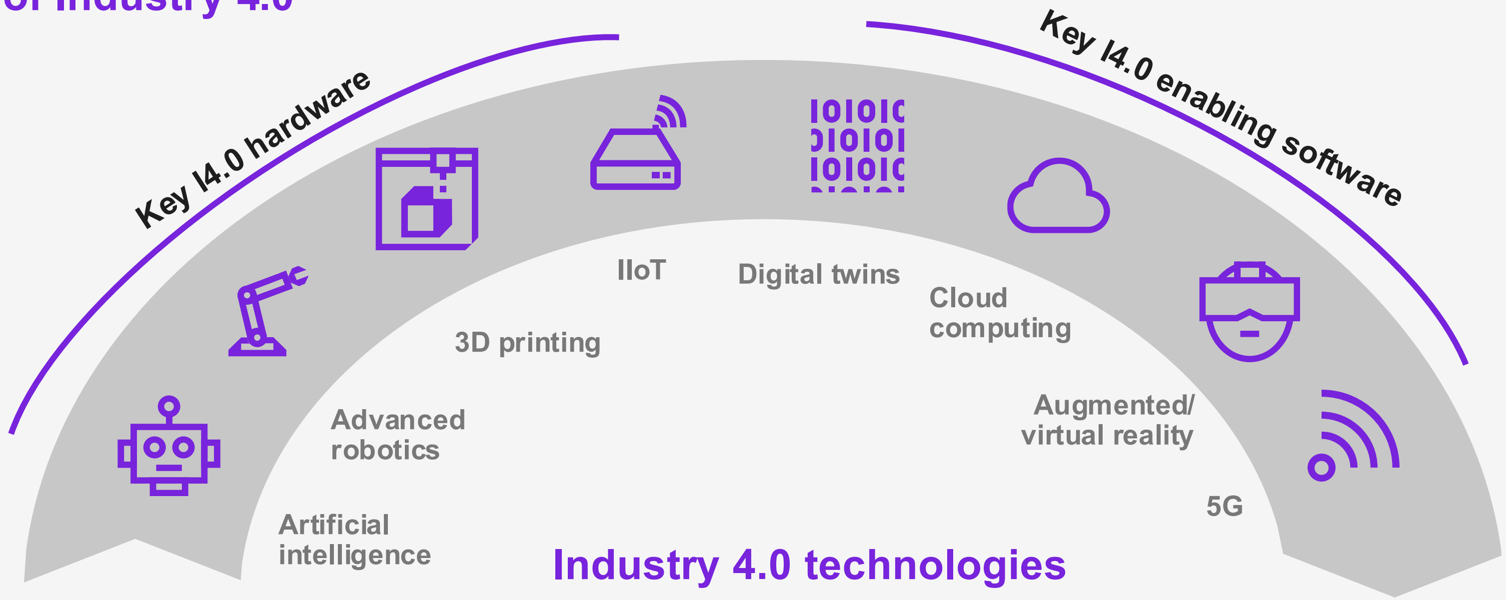
1. Introduction

Industry 4.0 technologies are revolutionizing manufacturing by automating processes, connecting devices, and enabling innovation

State of Industry 4.0



Features of Industry 4.0 in modern manufacturing

- Emergence of cyber-physical systems and AI, enabling human-to-machine communication
- Robots handle repetitive and low-value tasks to free up human resources
- Additive manufacturing enables agile and customized production
- IoT and big data enable real-time machine monitoring and analytics-driven decision-making
- Digital twins optimize manufacturing processes virtually
- Cloud computing provides on-demand access to scalable computing resources
- Augmented/virtual reality offers interactive experiences for workforce collaboration
- 5G delivers ultra-fast and low-latency connectivity for rapid data transfer and improved network capacity

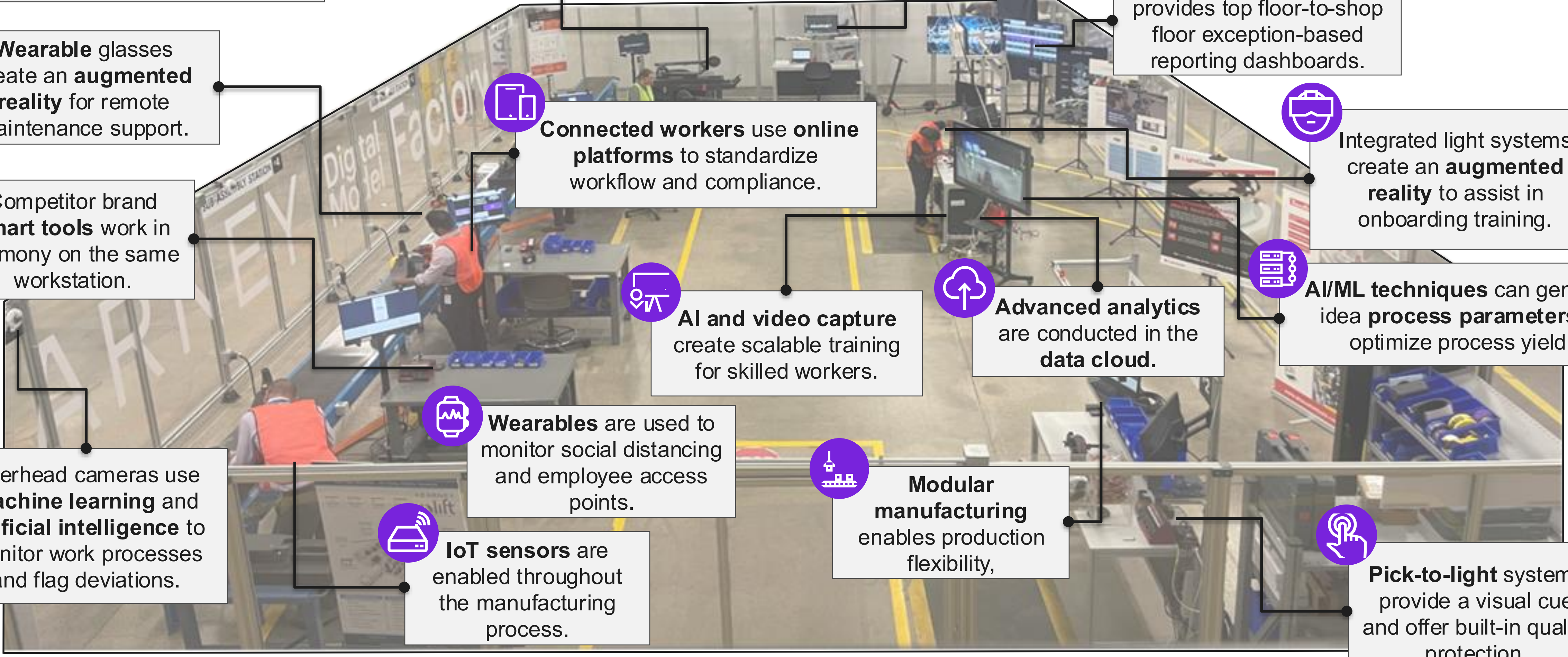
Benefits of adopting Industry 4.0 solutions

- Increased quality, speed, and efficiency in product development
- Reduced working capital
- Upskilled, engaged workers
- Improved customer service
- Improved resilience and agility, particularly in times of crisis
- Sustainability and waste reduction

Notes: IIoT is Industrial Internet of Things. AI is artificial intelligence.
Source: Kearney analysis

Kearney's Digital Model Factory in Detroit, MI, features future technologies in an interactive manufacturing setting, showcasing innovative possibilities in action

Non-exhaustive



Customized end-to-end planning tools allow data-driven decisions through predictive and prescriptive analytics.

Picking **cobot** enables repetitive, manual tasks to be automated.

Digital twin enables simulation of the production line and layout.

Integrated systems enable **end-to-end traceability.**

Artificial intelligence provides top floor-to-shop floor exception-based reporting dashboards.

Wearable glasses create an **augmented reality** for remote maintenance support.

Connected workers use **online platforms** to standardize workflow and compliance.

Integrated light systems create an **augmented reality** to assist in onboarding training.

Competitor brand **smart tools** work in harmony on the same workstation.

AI and video capture create scalable training for skilled workers.

Advanced analytics are conducted in the **data cloud.**

AI/ML techniques can generate idea **process parameters** to optimize process yield.

Wearables are used to monitor social distancing and employee access points.

Overhead cameras use **machine learning** and **artificial intelligence** to monitor work processes and flag deviations.

Modular manufacturing enables production flexibility,

IoT sensors are enabled throughout the manufacturing process.

Pick-to-light systems provide a visual cue and offer built-in quality protection.

Notes: AI is artificial intelligence. ML is machine learning.
Source: Kearney analysis

Industry 4.0 can allow companies to become resilient against macroeconomic uncertainties

Macroeconomic factor	Implications	Intensity of impact
Labor shortages	– With fewer available workers, companies will increasingly turn to automation technologies (like robotics and AI) to maintain or boost productivity. – This will also reduce reliance on human labor, thereby building resilience against future labor shortages.	
Trade policies	– As companies encounter higher tariffs and restrictions, many may opt to reshore manufacturing, with Industry 4.0 facilitating efficient in-house production to make this move more feasible and economical. – By investing in automation and smart manufacturing, companies can scale local production capabilities, reducing reliance on imports and minimizing the impact of sanctions.	
Geopolitical conflicts	– Companies may shift toward local sourcing to mitigate risks associated with international supply chains as Industry 4.0 technologies enable the development of smaller, more agile production facilities that can swiftly adapt to local market demands.	

Legend High Medium Low

Note: AI is artificial intelligence
Source: Kearney analysis

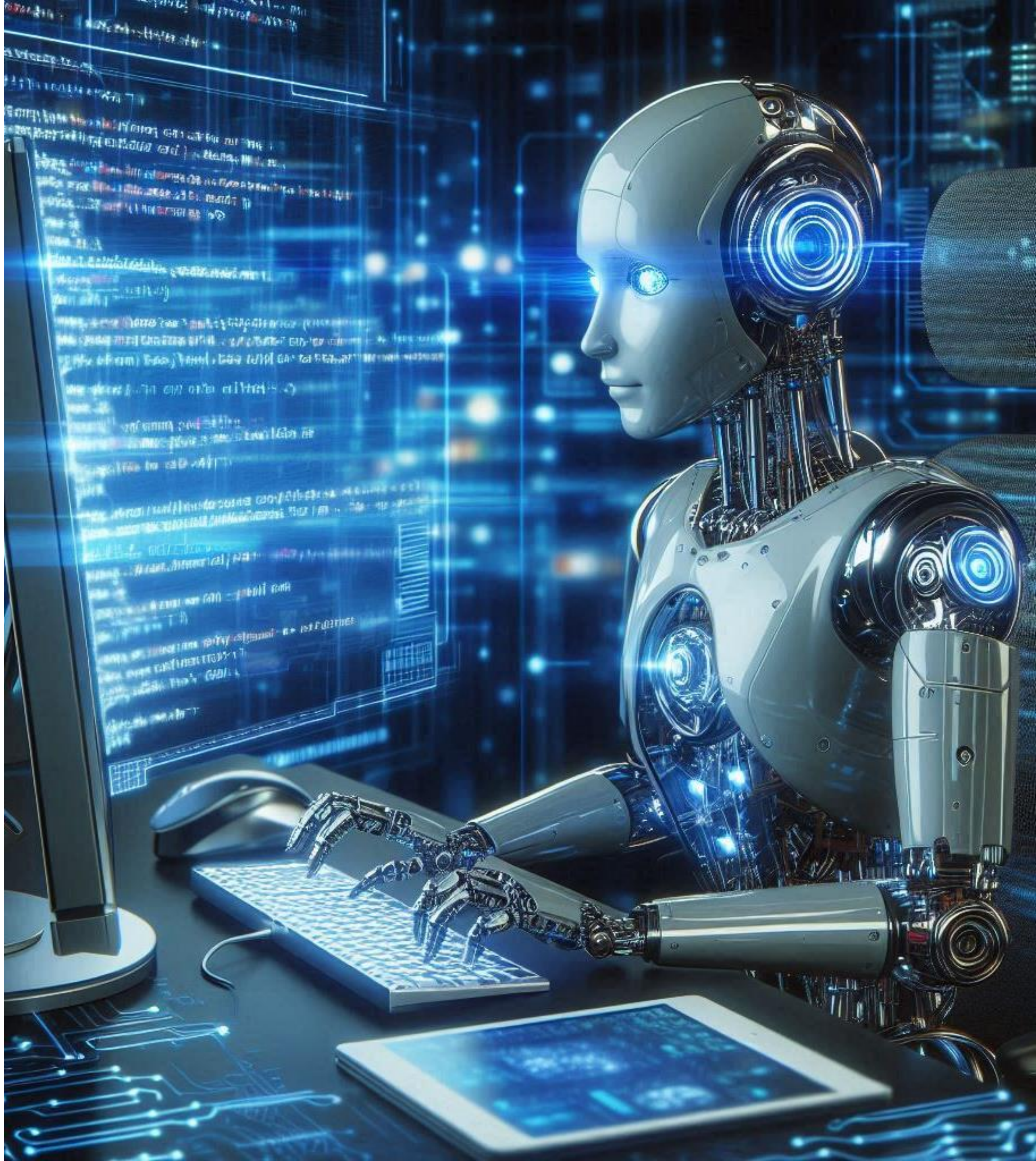
Industry 4.0 can allow companies to control costs by enhancing efficiency, reducing waste, and minimizing operational costs

Macroeconomic factor	Implications	Intensity of impact
Inflation	– To combat ongoing inflation, companies may leverage Industry 4.0 technologies like automation and predictive maintenance to enhance efficiency, reduce waste, and minimize operational costs. – Industry 4.0 may help manufacturers optimize the use of raw materials and energy, leading to significant savings.	
Skills gap	– Manufacturers can provide immersive training experiences to factory floor workers using I4.0 tools that allow for hands-on practice without the risks associated with real machinery. – Companies may invest in collaborative technologies such as cobots that can work alongside human operators and enhance productivity without requiring extensive technical expertise.	

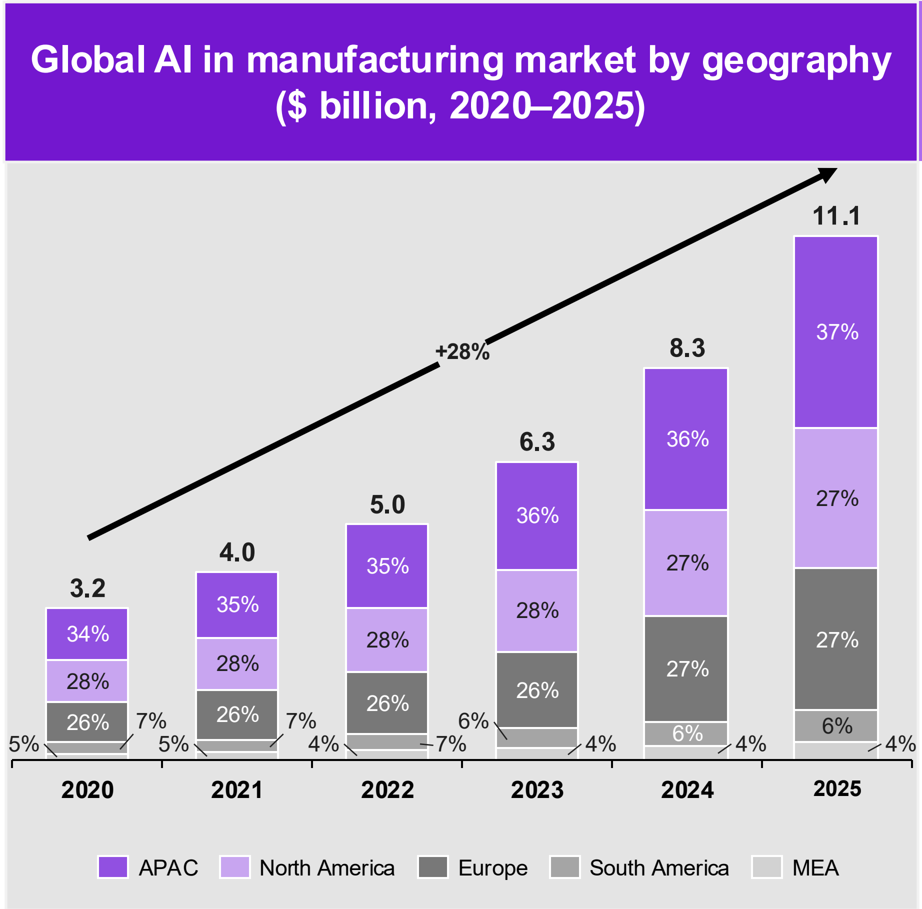
Legend High Medium Low

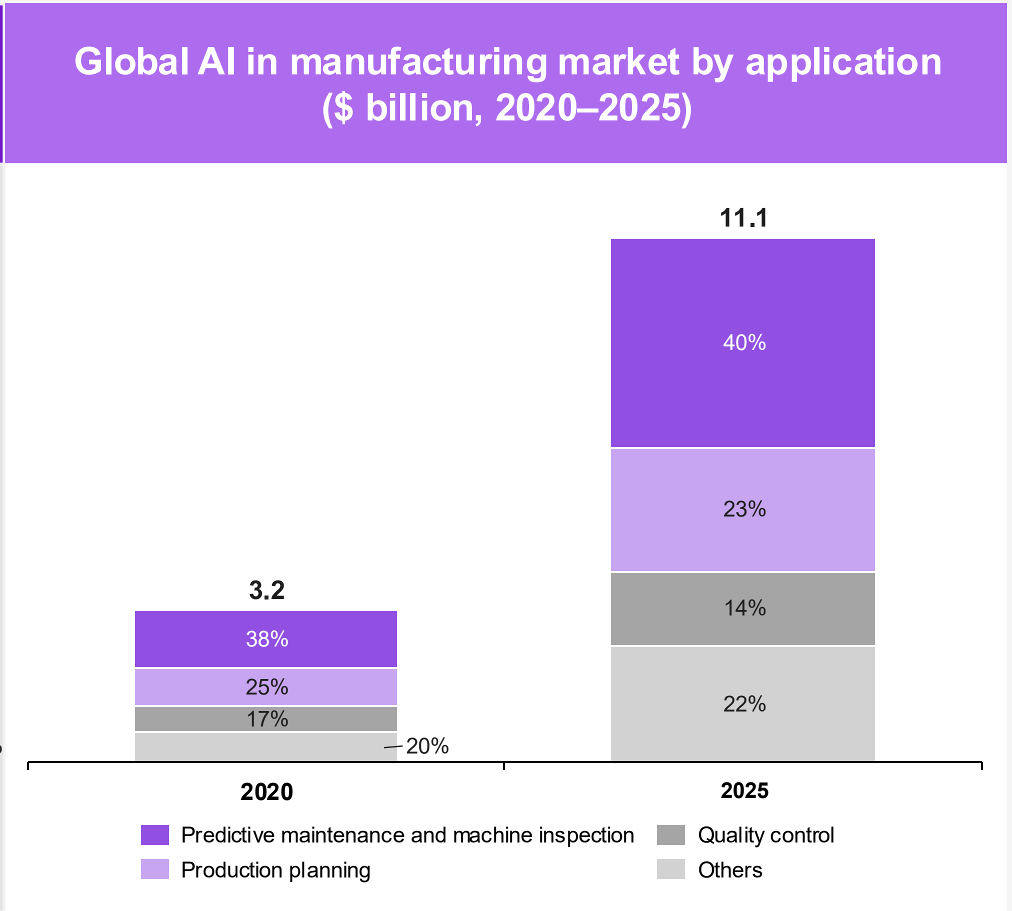
Source: Kearney analysis

2. Artificial intelligence



The growing need of manufacturers to reduce cost of operations and enhance operational efficiency requires AI adoption





- APAC is the hub for manufacturing, exhibiting 30% growth between 2020 and 2025.
- Automotive and electronics are the leading categories for China, India, Japan, South Korea, and Australia.
- Demands of high population require increased productivity, leading to integration of smart technologies.

- Growth factors for AI adoption include unpredictable customer demand, increasing use of big data, robotics, and computer vision technologies, as well as exponential growth in data volume for predictive analytics and strategic and real-time optimization.
- For 2023–2028, predictive maintenance to grow at 25%, quality control at 16%, and production planning and others at 18%.

Notes: AI is artificial intelligence. Percentages may not resolve due to rounding.
Sources: Technavio; Kearney analysis

An AI-enabled future in manufacturing is closer than we imagine; IoT proliferation will bring the future to us today

Micro-factories

Efficient, cost-effective, and sustainable

Highly automated and advanced, using smaller equipment and less space to create specialized, low-volume products that are customized and intricate.

IoT and AI analyze data, innovate for efficiency, and optimize workflows.

Lights-out factory

Cost-effective, increased productivity and safety

Enabling fully automated systems enables facilities to perform tasks with precision, efficiency, and accuracy, making human intervention unnecessary in most operations.

Current challenges

Workforce skill gap, cost of operational setup

High upfront cost, complex IT Infrastructure, and susceptibility to security breaches

Cobots and autonomous mobile robots (AMR)

Efficient material handling and streamlined operations

Advanced navigation and obstacle-avoidance tech enable dynamic movement for retrievals, deliveries, and part transport within the production area.

Generative artificial intelligence

Efficiency, innovation, and quality enhancement

Generative AI boosts manufacturing efficiency, speeds up product development, extends equipment lifespans, minimizes downtime, and optimizes operational equipment.

Current challenges

Workforce skill gap, cost of operational setup

Integration with legacy systems, product quality maintenance, high setup costs

Notes: AI is artificial intelligence. IoT is Internet of Things.
Source: Kearney analysis

IoT-enhanced data collection and connectivity enable an accelerated and more efficient deployment of AI across different business verticals…

Predictive maintenance

Manufacturers leverage AI to analyze sensor and machinery data, predicting and preparing for potential breakdowns.

Use case: Frito-Lay

AI-powered systems helped reduce unexpected breakdowns and losses, **saved 4,000 hours of annual manufacturing capacity**.

Quality inspection and assurance

Automated optical inspection uses computer vision to autonomously scan devices for catastrophic failures and quality defects.

Use case: Boeing

AI enhanced manufacturing efficiency and product quality, **resulting in reduced manufacturing costs and a 25% reduction in production lead times.**

Energy management

AI systems utilize data on usage, weather, and occupancy to automatically adjust lighting and climate control in real time, optimizing energy use and improving occupant comfort.

Use case: Aubert & Duval

AI digitized operations to prioritize sustainability efforts, **resulting in reductions of 3% in electricity consumption and 19% in gas usage.**

Demand forecasting

AI can analyze historical sales data along with external factors like economic indicators, weather, and events to accurately estimate demand.

Use case: Danone

AI in demand planning helped drive a 30% decrease in lost sales and product obsolescence, enhanced the accuracy of forecasts by 20%, and halved the workload of planners.

Supply chain optimization

IoT sensors and AI predict inventory levels, automate replenishment, and optimize delivery for better service.

Use case: Celonis and Mars

Helped **reduce manual work by 80%**, cut shipping costs, lowered emissions, and improved on-time deliveries.

Notes: AI is artificial intelligence. IoT is Internet of Things.
Source: Kearney analysis

…and across industries

Automotive

Enhances manufacturing quality and efficiency, detecting and preventing defects, optimizing workflows, reducing waste, and supporting design and innovation.

Industry example: Tesla

Oil and gas

Machine learning algorithms and predictive AI models evaluate various fuel and lubricant products against standards, enabling preemptive corrections to minimize waste and ensuring dependable, eco-friendly production.

Industry example: Saudi Aramco

Metals and mining

Autonomous vehicles and robotics reduce injury risk in hazardous environments. With dwindling mineral deposits, companies turn to AI for resource extraction optimization.

Industry example: Champion

Chemicals and pharmaceuticals

Identifies anomalies and hazards for compliance. AI optimizes pharmaceutical supply chains with forecasting, inventory management, and quality assurance.

Industry example: Aizon

Food and beverage

Helps reduce costs, minimize wastage, and improve product availability. AI-powered quality control systems detect defects, anomalies, and deviations in food and beverage products during production and packaging processes.

Industry example: Coca Cola

Semiconductor and electronics

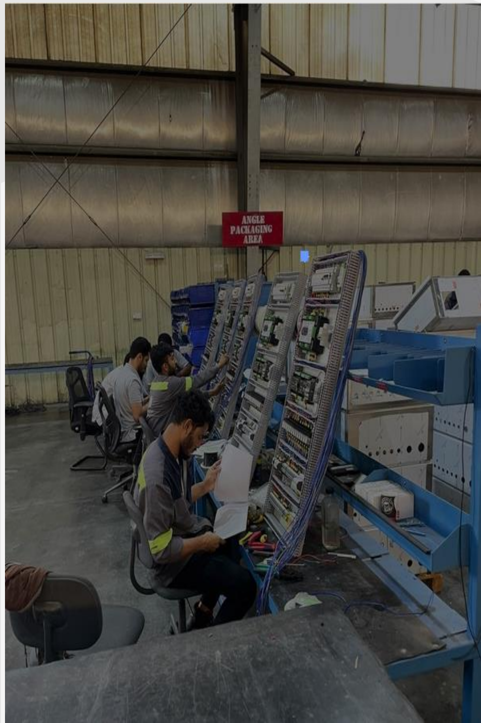
Machine learning algorithms and predictive AI models test process performance and outputs. This allows for preemptive corrections to minimize defects for customers.

Industry example: Xilinx

Aerospace

AI-assisted inspection tools (e.g., Commercial Jet Engine Borescope Inspection Solution) to enhance defect recognition and provide cheaper, quicker, more reliable, and safer solution recommendations.

Industry example: GE Aerospace



Note: AI is artificial intelligence.
Sources: Technavio; Kearney analysis

GenAI highlights existing opportunities to leverage IoT and AI

1

Operations/production optimization

Boosts manufacturing by real-time monitoring, problem spotting, predictive insights for efficiency.

Industry example: SAP
GenAI model leverages data from edge nodes to create a shift end report, improving operations and highlighting opportunities.

2

Product design

ML algorithms help in generating rich, detailed, and technically optimized designs based on specific performance criteria.

Industry example: Airbus
GenAI model helped design components that aided aircraft weight reduction by 45% and helped reduce GHG emissions.

3

Quality control

Leverages vast datasets for defect detection to enhance precision and minimize discrepancies in production lines.

Industry example: Bosch
GenAI model created training data for an automated optical inspection AI model, supporting an average accuracy of 100%.

4

Reduced downtime

Addresses technical issues and provides step-by-step instructions, reducing machine downtime and expediting issue resolution.

Industry example: Mahindra & Mahindra
GenAI model gives a step-by-step resolution to error codes provided by machine, enabling quicker fix by less-experienced operators.

5

Personalized support

Customizes support and proactive insights for relevant and improved task performance as per requirement.

Industry example: Nike
Gen AI helped Nike curate and personalize shoes based on the athlete's preferences.

Notes: GenAI is generative artificial intelligence. IoT is Internet of Things. AI is artificial intelligence. ML is machine learning. GHG is greenhouse gas.
Source: Kearney analysis

3. Advanced robotics

The advanced robotics industry continues to grow rapidly, carried by demand and advancements in pharma, high-precision, and auto/logistics industries

Market insights

Common types of industrial robots

Articulate: rotary joints, 10+ axes

Cobot: "collaborative" bot designed for human–machine interaction

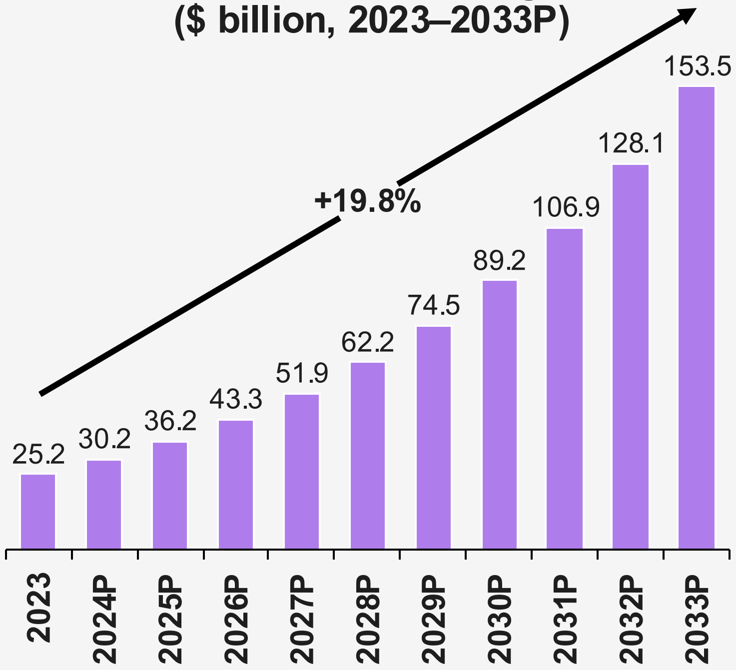
Delta: parallel robot known for speed, precision, and light weight

Other types: SCARA, Cartesian, Polar, Mobile

Digital ↔ Physical

- Connectivity/integration (sensing/sensors)
- Data processing layer
- Visualization and decision-making intervention
- Physical robot

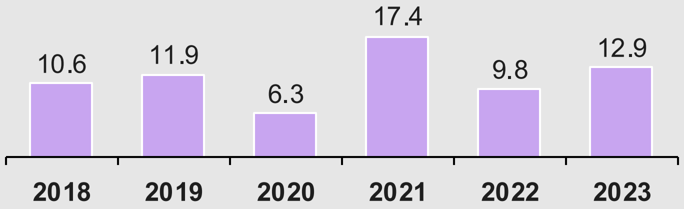
Global market size and growth ($ billion, 2023–2033P)



Sector-specific comments

- Fueled by growth in **human-in-the-loop procedures and pharma-material handling** abilities
- Maturing industry with **stable demand and continued investment**
- High growth due to demand for **electric vehicles**

Recent global investments ($ billion)[1]



– US and China companies received majority of 2023 funding.
– Concentrations in drone technology, autonomous driving applications, surgical robots, and autonomous mobile robots.

[1] Venture capital firms, corporate investment groups, angel investors, and other sources
Sources: Future Market Insights, The Robot Report; Kearney analysis

Firms across industries have found uses in their value stream…

Product design and development

Reduced barrier-to-use in NPI with ability to conduct intricate and complex tasks

Ginkgo Bioworks automation in organism design[1]

Ginkgo Bioworks uses robotics **to automate development** across flavor, fragrance, and agricultural industries, driving **2X monthly output.**

Planning and scheduling

Customizations and quicker changeovers via flexible production lines

Combi custom corrugate erectors[2]

…can manage a **variety of corrugate configurations and orientations,** eliminating **human intervention and tool changes.**

Manufacturing execution

Automation of traditionally manual, repetitive, and/or dangerous tasks

Octinion robotic harvesting vehicles[3]

…monitor quality levels of crops and **automatically pick/sort** into **predefined weight allowances.**

Material handling and warehousing

Storage and retrieval of goods swiftly and without human oversight

Instock AS/RS via robotics as a service (RaaS)[4]

…brings together **incloud locations, physical racking, and robotics** to **automate warehousing** even at micro-fulfillment (<1,000 ft^2) scales.

Maintenance

– Monitoring and reporting equipment condition for predictive maintenance
– Cleaning and maintenance tasks in non-human favorable conditions, like storage tanks or furnaces

Rolls-Royce [prototype] remote boreblending robots[5]

…are **remotely controlled and can perform complicated maintenance tasks**, like repairing compressor blades, improving turnaround time, and reducing specialist travel costs.

Note: AS/RS is automated storage and retrieval system.
Sources: (1) Ginkgo Bioworks, (2) Combi Packaging Systems, (3) Octinion, (4) Instock, (5) Rolls-Royce; Kearney analysis

…overcoming supply chain challenges with advanced robotics

Key challenges

Workforce availability

Workforce shifts in age and job preferences, high turnover

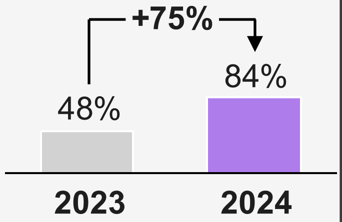
- The **next generation of workers has spurned blue-collar positions** (December 2022 – "65% of durable goods manufacturing roles [remained] unfilled")[1]
- **Manufacturers struggle to attract and retain talent** (~30% workers change jobs annually), investing time and resources into training employees who will eventually exit[2]
- In California fast-food restaurant CaliExpress, **robots by Cucina and Miso Robotics manage food preparation,** allowing humans to focus on customer service and other more people-oriented roles

ESG considerations

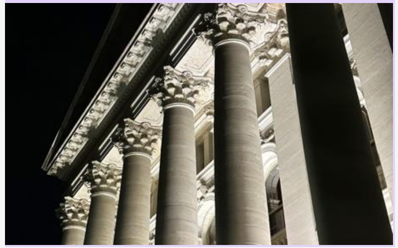
Importance of social risks, health, safety, and human rights has increased; stakeholders and employees demand transparency in value chain

- **Automotive supplier GEDIA recently installed 57 welding robots** to improve working conditions, establish operational flexibility, and create 200 new jobs.[3]

Relative importance of **health and safety** for top executives increased this year[4]



Operational efficiency



Stagnant demand continues to shrink margins; competition continues to optimize

- In the slow growth/high inflationary 2024 environment, companies will continue to use creative methods to drive out costs, while simultaneously future-proofing their operations with step-changes in efficiency.
- New **KR D1200 robot by KUKA operates at cycle time of <0.32sec** (@ 1kg payload) and has up to 6kg payload. With lightweight build, food-safe and hygienic claims, and self-maintaining capabilities, the robot is ideal for FMCG pick-and-place applications.[5]

Note: ESG is environmental, social, and governance.
Sources: (1) Forbes, (2) US Chamber of Commerce analysis and Bureau of Labor Statistics, (3) Fanuc, (4) WTW 2024 Global D&O Survey Report, (5) Kuka; Kearney analysis

We foresee six trends which will shape the near-term robotics market

Robotics-as-a-service (RaaS)

- Involves leasing robotics (by time/task) on a subscription basis.
- Reduces barrier for manufacturers and allows for flexibility to scale up during peak seasons.
- Market is expected to grow by **$1 billion+ (17% CAGR) by 2030.**
- Some example players include **Cobalt, InVia, Locus, and Relay.**[1]

Green improvements

- Development of 3D printing robots using **recyclable materials** from consumer electronics.
- **Self-powered robots** capable of operating on harvested solar power becoming prevalent in the agricultural industry.
- Example players include **OhmniLabs, Solintfec, EcoRobotix, AIGEN.**

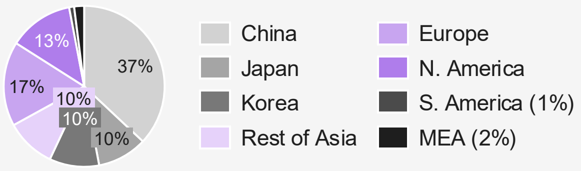
i4.0 tie-ins

- **AI/ML-coded controllers** integrated in modern robotics.
- **Internet of Robotic Things (IoRT)** will integrate sensor data and intelligence to dictate operational steps.

APAC-dominated growth

- Mature supply market with steady and increasing demand.
- Recent company-friendly government policies, like **tax incentives and R&D funding.**[2]

Industrial robots market share



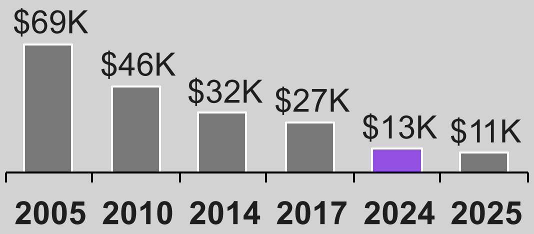
Complementary job growth

- US Bureau of Labor Statistics predicts a **3% increase in engineering positions** this decade (75k jobs) to support robotics growth.[3]

Reduced unit costs

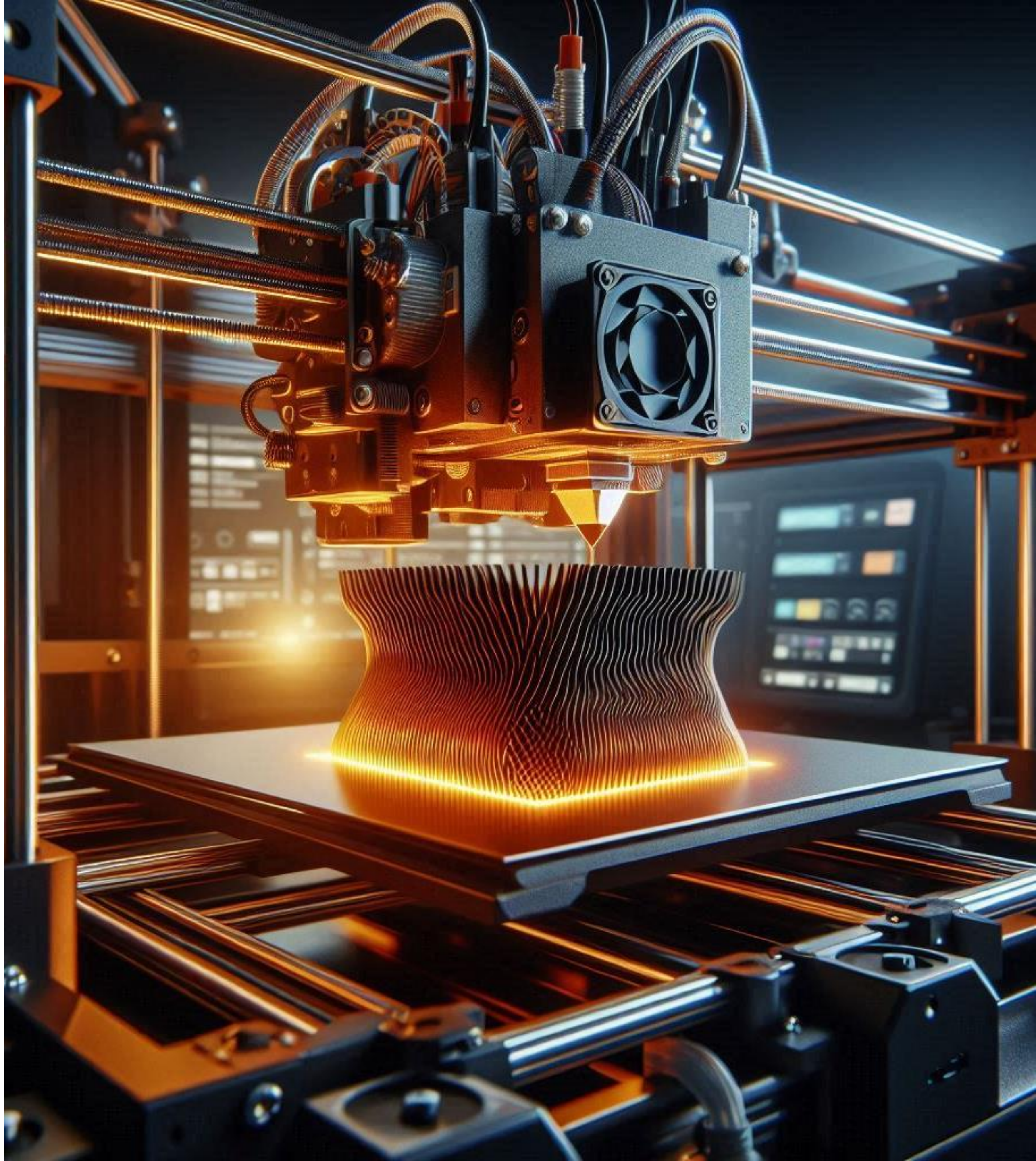
- Driven by industry fragmentation and supplier price competitions.
- Allows **small/mid-sized firms to invest**, keeping pace on production efficiencies.

Average robot cost ($K)[4]



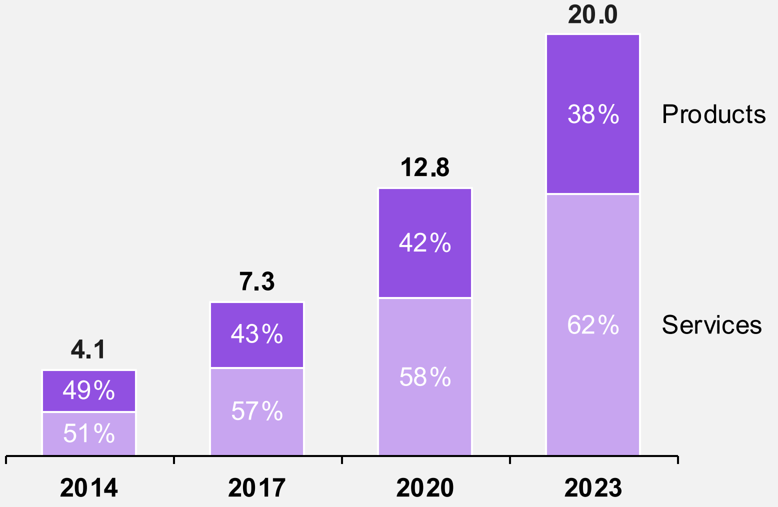
Notes: AI is artificial intelligence. ML is machine learning.
Sources: (1) BuiltIn, (2) Beroe, (3) University of Cincinnati, (4) Signet Global; Kearney analysis

4. 3D printing

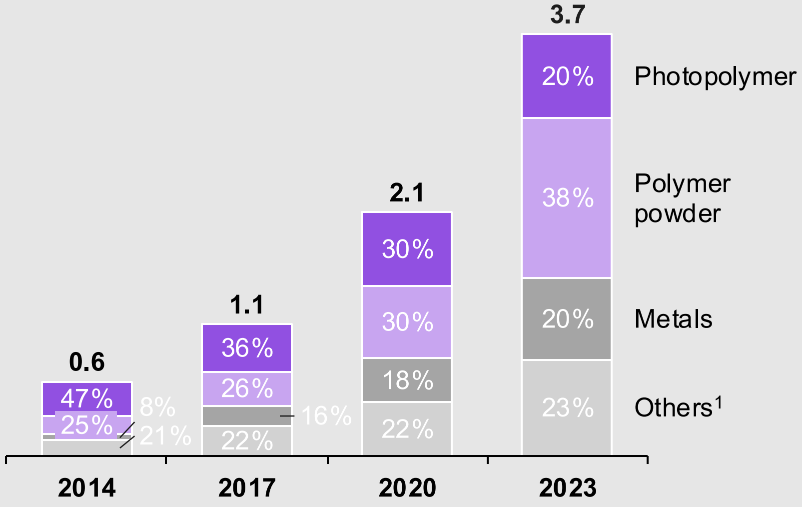


The additive manufacturing (AM) ecosystem is expanding rapidly, fueled by the introduction of new machines, materials, and technological breakthroughs

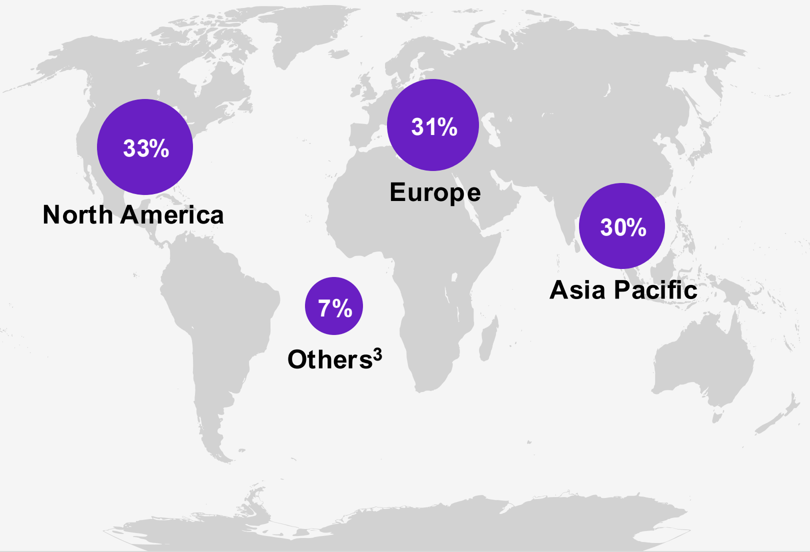
Global AM market ($ billion)



Global AM materials market ($ billion)



Installed AM machinery by region, 2023[2]



- The AM market has surged fourfold in the past decade, driven by a sharp rise in demand for services.
- Companies prefer accessing need-based AM services over investing in costly machinery.
- The AM market will further expand in the future with growth from diverse applications and increased demand for end-use parts.
- For this to occur, AM systems will become faster and material prices will come down, reducing the production cost per part.

- The AM material market has grown more than sixfold in the past decade, at a CAGR of 21.3% between 2014 and 2023, outpacing the general AM market, which grew by 19.3% in the same period.
- While polymer 3D printing still dominates the market, metal additive manufacturing shows rapid growth.
- Various 3D printing materials exist, but few meet industry standards. Challenges like volume issues deter material innovation.

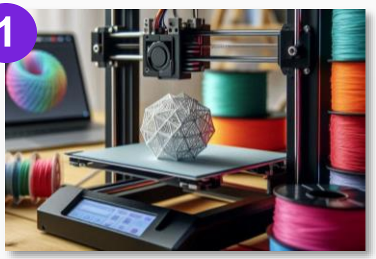
- The highest adoption of AM machinery is in the US, with 31% of installations, followed by China (~12%) and Germany (8%).
- Advanced economies such as the US and EU are better positioned to take advantage of AM as it is a lower labor cost solution to prototyping, whereas the traditional prototyping process requires multiple machine operators and technicians.

[1] Others segment include filaments, ceramics, wax, and materials for binder jetting and sheet lamination.
[2] Percentages may not resolve due to rounding.
[3] Others include Central America, South America, Middle East, and Africa.
Sources: Wohlers Associates; Kearney analysis

Recent technological advancements and enhanced capabilities have significantly increased the scalability of additive manufacturing across a wide range of industries

Current innovations in additive manufacturing

1



Hybrid additive manufacturing

- Combines traditional subtractive methods with additive processes, allowing for greater flexibility and precision in creating complex parts.
- Optimizes material usage, enhances surface finish, and reduces production times compared to conventional methods.

- **Hoedtke GmbH & Co.** utilizes a 3D machine that combines additive and subtractive (5-axis milling) processes in one setup for producing complex parts.
- **MCAM** achieved a 55% reduction in mold production lead time and cut material weight by 60% using hybrid additive manufacturing technology.

2

AI-enabled additive manufacturing

- AI enhances 3D printing by optimizing material dispensation and application methods, ensuring efficiency and precision in building complex structures.
- Identifies and rectifies errors in real time during the 3D printing process.

- **LEAP 71** employs AI-driven design to autonomously create and 3D print high-performance rocket engines, reducing design times from months to just two weeks.
- **FKM** is utilizing AI co-pilot platform in combination with additive manufacturing to expedite engineering speed and improve product quality.

3

Digital light processing 3D printing

- Uses digital light projector and oxygen to cure photosensitive resin layer by layer, enabling rapid and precise printing of intricate objects.
- Ideal for high-end prototyping requiring internal structure visualization, fit validation in assemblies, and low to medium production quantities across diverse applications.

- **Adidas** launched 4DFWD running shoe, which features a midsole created using digital light synthesis (DLS) technology.
- **Ford** uses DLS technology and EPX 82 material to manufacture components on-demand, reducing costs, accelerating time-to-market, and cutting inventory.

4

Multi-materials 3D printing

- Enables the integration of different materials such as polymers, metals, ceramics, and elastomers within the same print job, catering to diverse needs.
- Allows for the fabrication of complex objects with varying properties and textures in a single printing process, enhancing design flexibility and functionality.

- **Glidewell Dental** adopted 3D Systems' monolithic jetted denture solution, leveraging multiple materials to enhance denture durability and aesthetics.
- **Sidus Space** launched a multi-material 3D printing division specializing in multiple composite materials for producing structural support components.

Notes: AI is artificial intelligence. MCAM is Mitsubishi Chemical Advanced Materials.
Source: Kearney analysis

Compared to traditional manufacturing, AM provides significant benefits that solve many pressing concerns for manufacturers

Complex product design

Enables the creation of complex geometries driven by generative design and biomimicry, surpassing the limitations of traditional manufacturing methods.

Industry example: Briggs Automotive Company

Mass customization

Allows creation of mass custom products digitally. Has applications in orthotics, medical implants, footwear, eyewear, handles, and grips, among other things.

Industry example: adidas Futurecraft 3D Shoe

Inventory optimization

Reduces inventory by enabling just-in-time and on-demand operations. Decreased storage requirements and fewer parts reduce costs.

Industry example: Azoth

Sustainability requirements

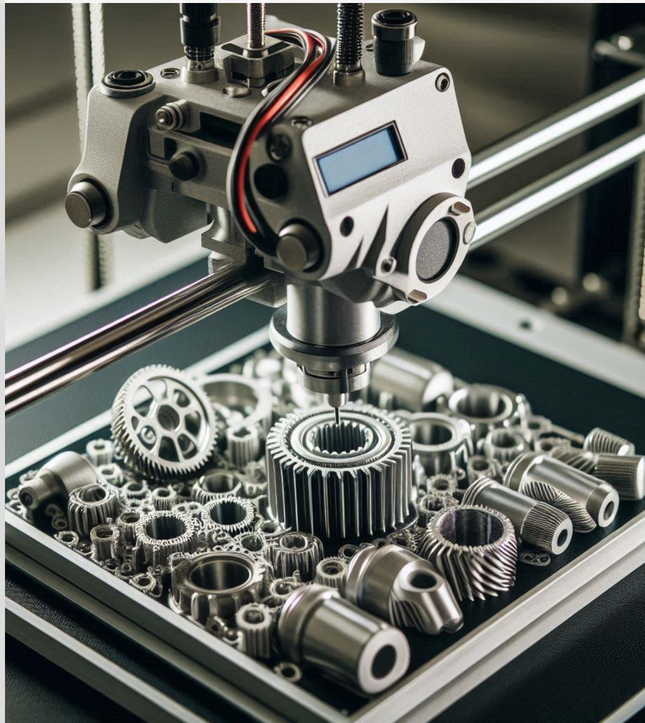
Highly environmentally friendly production process that minimizes material waste, conserves energy, and employs sustainable feedstock.

Industry example: Vestas

Supply chain resilience

Decreases reliance on imports by facilitating localized production schedules, promoting efficiency and resilience.

Industry examples: Model No



Note: AM is additive manufacturing.
Source: Kearney analysis

Despite challenges, companies are increasingly poised to overcome adoption barriers and integrate AM into daily operations

Current challenges

Labor issues
Many manufacturing firms lack skilled workforce required to effectively utilize 3D printing technologies.

High capex and running costs
Industrial 3D printers cost tens of thousands of dollars, with material expenses ranging from $20 to $30 per kilogram for basic materials and exceeding $100 per kilogram for specialized materials and composites.

Slow production speed
Most 3D printers have a moderate production speed, typically printing everyday items at around 50–60 mm/hour (medium quality), which can reach up to 500 mm/hour on higher-end models.

Quality control
3D printing quality control is complicated by interdependent printing parameters and external variables such as environmental conditions, operator skill, and equipment maintenance.

Size limitations
The size of a 3D printer determines the maximum dimensions of printed items, typically restricting the application range to smaller-sized items.

Opportunity

Additional training and education for workers

Improve supply chains and explore new AM-compatible materials to reduce costs

Identify production needs where AM can create maximum value with lower costs

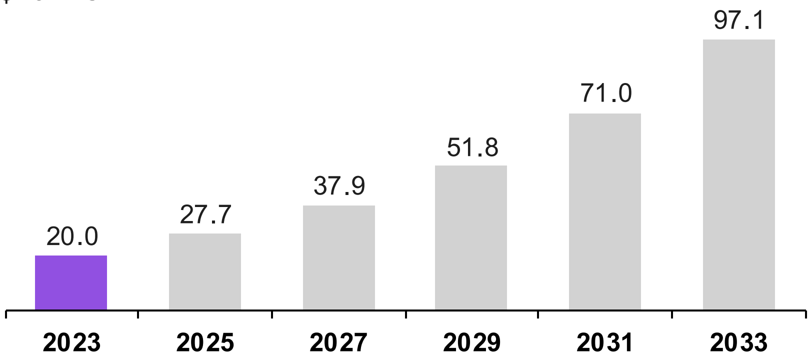
Utilize AI/ML and machine vision to overcome quality concerns

Notes: AM is additive manufacturing. AI is artificial intelligence. ML is machine learning.
Source: Kearney analysis

In the future, AM is expected to go beyond making prototypes, jigs, fixtures, and tooling, moving toward producing fully finished products

Global AM market (Forecast)

$ billion



Future advancements in AM

- 3D printing poised to grow in size, speed, and affordability.
- **Generative designs, ML algorithms, and machine vision** will enhance 3D printers for superior quality output.
- The **accessibility and affordability of AM materials** will expand, opening doors to broader applications.
- AM will **bolster supply chain resilience** while propelling **sustainability efforts.**

Future of 3D printing in prominent sectors

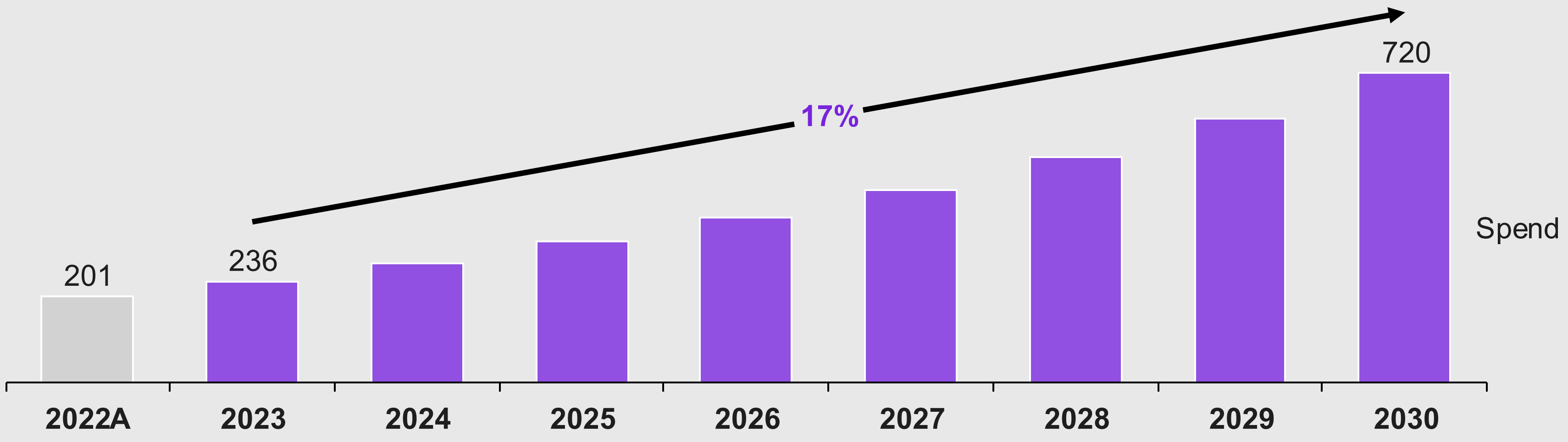
Food	– Moving beyond creation of novel shapes and structures. – Futuristic “digital cooking” gaining prominence. – Meat, fish, and bakery items demonstrate higher applicability.
Pharmaceutical	– Custom drug formulation as per patient’s therapeutic requirements and preferences. – In the future, expect 3D printers in pharmacies and hospitals for on-site, truly personalized medicines.
Healthcare	– Rise of bioprinters using "bio-ink,“ made of living cells, creating human tissue. – Enable mass production of human limbs, joint cartilage, and transplant-ready organs.
Aerospace	– Potential to produce entire 3D-printed jet or rocket engines in future. – Aircraft MRO firms may utilize 3D printers for producing replacement parts, enabling faster turnaround and on-demand production.
Automotive	– Full 3D-printed cars, from concept cars to electric vehicles, even custom models for specific applications. – Auto workshops may shift from parts inventory to 3D printers for on-demand production.
Construction	– Large-scale 3D printers could soon build entire buildings onsite at construction sites. – 3D-printed houses may offer solutions to personalization and affordability challenges in construction.

Notes: AM is additive manufacturing. ML is machine learning. MRO is maintenance, repair, and operations.
Source: Kearney analysis

5. Industrial Internet of Things (IIoT)

Enterprise IoT is expected to be a $720 billion market with more than 4 billion connected devices in manufacturing alone by 2030

Global spending on enterprise IoT technologies[1]



Total IoT devices globally[2]

>55 billion

By 2025

Installed devices in connected manufacturing[2]

>4 billion

By 2030

Terabytes of data generated from IoT[2]

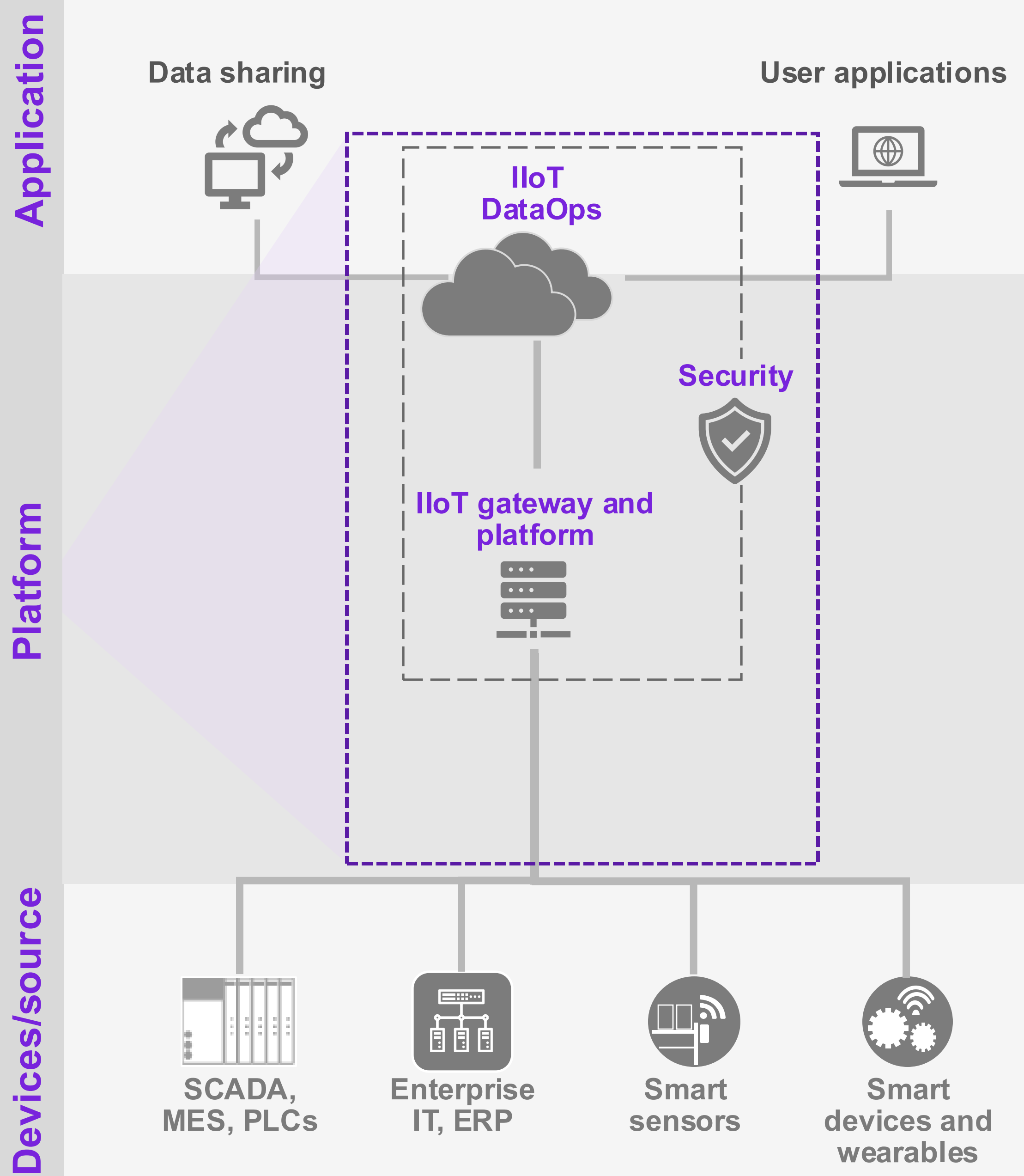
80 billion

By 2025

Note: IoT in Internet of Things.
Sources: (1) State of IoT Spring 2024. IOT Analytics, (2) IoT Global industry Snapshot – Acquisdata (June 2023); Kearney analysis

Kearney XX/ID

A scalable and secure enterprise IIoT platform is the backbone enabling AI, ML, AR/VR, and digital twins



End applications and solutions

– Advanced applications such as AI/ML, AR/VR, and digital twins to generate insights, optimize supply chain and operations, and manage product life cycle end to end.

IIoT DataOps – unified data layer

– Solutions to standardize, normalize, and contextualize data across edge devices and systems for advanced applications.

Security

– ISA/IEC 62443 certified products, zero trust solutions, threat detection, and response and recovery solutions.

Multiprotocol gateways

– Simplified architecture supporting IIoT communication protocols such as OPC UA and MQTT and integration with standard data sources.

Edge devices and data sources

– IIoT protocol enabled (e.g., OPC UA, MQTT, Wireless HART) for secure and scalable deployment.
– 5G enabled for low-cost deployment.
– Edge computing using AI-enabled chipsets to simplify DataOps and architecture for deployment and application development.

Notes: AI is artificial intelligence. ML is machine learning. AR is augmented reality. VR is virtual reality. IIoT is Industrial Internet of Things. SCADA is supervisory control and data acquisition. MES is manufacturing execution system. PLC is programmable logic controller. ERP is enterprise resource planning.
Sources: Simplifying IIoT Technology Stack (ISA), PTC implementing Zero-trust to IoT Solutions, DataOps: Missing Link in your Industrial data architecture (IIoT World); Kearney analysis

IIoT solutions currently being adopted already integrate digital twin, AI/ML, cloud services, and other i4.0 technologies to deliver value

Application	Examples
Predictive maintenance	– Flowserve is using PTC ThingWorx to monitor pumps that undergo intermittent cavitation to improve equipment availability and efficiency and mitigate $16 million cavitation problem.[1]
Sustainability	– Sabic employed IIoT solution alongside AspenTech's Utilities Planner to optimize plant utilities through monitoring real-time plant data and using digital twin simulations to find optimal operating conditions and lower CO_2 emissions by 60k tons per year.[2]
New business models	– Food and beverage OEM is using HighByte DataOps solution with Azure IoT Hub to standardize data across a large and diverse portfolio of products and offer cloud-based machine monitoring and predictive maintenance service to their end customers.[3]
Process optimization	– Logistics Warehouse implemented Samara Site visibility solution combined with AI dashcams to optimize production line workflows and increase daily production by 45%.[4]

Notes: IIoT is Industrial Internet of Things. AI is artificial intelligence. ML is machine learning.
Sources: (1) Flowserve IOT Monitoring – PTC, (2) AspenTech Utilities Planner – customer testimonials, (3) HighByte OEM Cloud Services use case, (4) Samsara Customer Stories– Logistics Warehouse; Kearney analysis

Cybersecurity, costs, and skill gaps are the primary challenges to IIoT adoption and scaling, but can be overcome with the right digital strategy, operating model, and technology road map

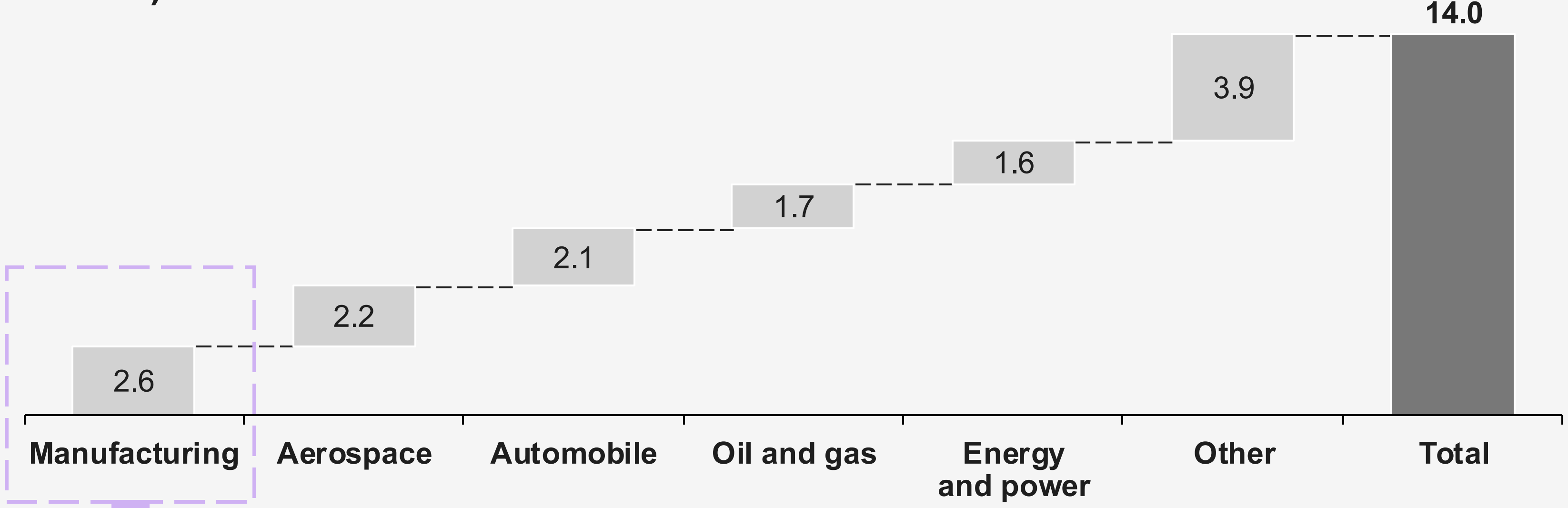
Challenges:	Solutions:
Cybersecurity – In 2023, 70% of all ransomware attacks targeted manufacturing. Secure networks are necessary for broad IIoT solution adoption.	– Zero trust architecture and solutions – ISA/IEC 62443 certified products – IT/OT cyber threat detection, response, and recovery solutions
High capex and opex – High capital requirements for widespread adoption – High operating costs if solutions are fragmented/implemented regionally (or at site level)	– Subscription-based SaaS IIoT platforms, wireless/5G-enabled technology adoption, Ethernet-APL enabled devices to reduce capex for deployment – Global vendor strategy to consolidate and minimize operating costs
Skilled talent to implement and maintain IIoT solutions – Talent shortage to execute and maintain IIoT solutions	– Digital operating model aligned with strategy to implement and sustain IIoT solutions – Leveraging vendor partnerships and managed services to sustain IIoT solutions
Scaling applications and use case – Use cases developed for single plants and processes lack standardization to scale.	– Digital strategy to manage, scale, and maintain applications – DataOps software solutions to standardize, contextualize, manage data across different systems

Note: IIoT is Industrial Internet of Things.
Source: Kearney analysis

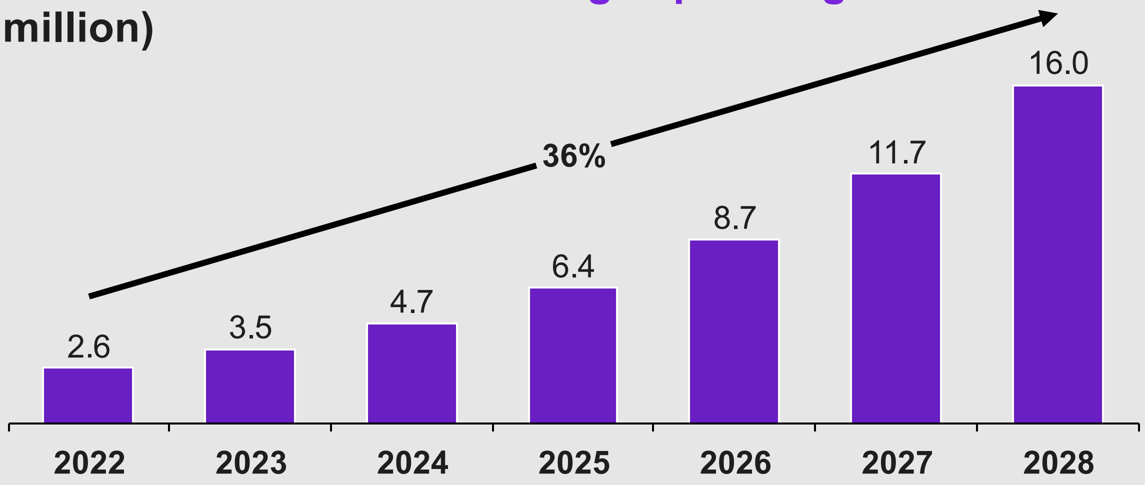
6. Digital twins

The manufacturing sector has emerged as the foremost adopter of digital twins, with its market size projected to surge by 36% by 2028

Digital twin (DT) global market size by application in 2022
($ million)



DT market size in manufacturing expected growth
($ million)



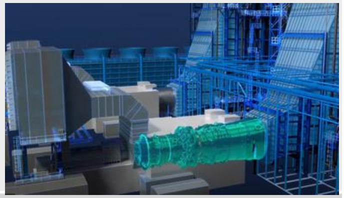
Growth is driven by increasing demand of manufacturers' needs:
- Application of predictive maintenance
- Adoption of Industry 4.0 and IoT
- Reduced time-to-market
- Improved decision-making

(Details to follow)

Note: IoT is Internet of Things.
Sources: Mordor Intelligence; Kearney analysis

DTs have been adopted at different levels in manufacturing, ranging from passive monitoring to interactive virtual factories

Examples of DT in manufacturing

Application	Characteristics	Examples
1 Monitoring	– Tracks and monitors assets. – Integrates into real-time data via IoT.	**John Deere** using virtual operations center – Leveraging Matterport's DT platform to monitor assets – Remotely managing 60 facilities across 4 continents 
2 Maintenance	– Interacts with its physical entity to remain in sync to predict and plan maintenance. – Anomalies are addressed by an external application.	**GE** uses DT in power generation sector – Monitoring health of assets – Performing predictive maintenance 
3 Simulation	– Augments functionality of physical equipment.	**Mevea** simulates machinery before it is built – Testing in different scenarios – Training operators and receiving feedback 
4 Metaverse	– 3D digital twins of production systems to improve manufacturing efficiencies.	**Swinburne University** is building Factory of the Future – Partnering with CWX to create 3D digital twins of factories – Designing new digital manufacturing solutions in metaverse 

Notes: DT is digital twins. IoT is Internet of Things.
Sources: Matterport, Mevea, GE, IEEE, Swinburne; Kearney analysis

In the future, DT may transition from an extension of a physical asset to an independent product/service

Decoupling of software and hardware

- Equipment manufacturers shift from offering DT as an add-on to selling DT as a service
  - Or, third parties specialize in creating and selling DT as a service
- Service is sold in the form of a software package, independent of the physical entity

Generic DT models for sale

- A client buys an off-the-shelf, generic DT model
- Model is refined to match client's physical entity
- DT model acquires "thread" (historical record) of the physical entity
- DT model and the entity are then connected

Customization of the model

- Mechanism to allow clients to:
  - Embed a model and features
  - Add specific knowledge
- Model learns the framework and the do's and don'ts

Enhanced autonomy of the models

- Models have greater level of autonomy as they can take autonomous actions and share them with the environment (e.g., other robots in the assembly line)

There are certain challenges to digital twin adoption…

High cost of deployment and complex infrastructure

- Implementing DTs requires significant investment in technology platforms, infrastructure, and maintenance.
- Complex architecture for DTs requires considerable IT workforce and investments to manage interoperability issues and communication networks.

Talent gaps

- Skilled IT team is required manage the complex integration and maintenance of DTs.
- Successful implementation requires specialized knowledge in IoT, AI, and big data.
- Current workforce supply does not match the rising demand, with the gap between demand and supply widening.

Cybersecurity concerns

- Companies are cautious about adopting new technologies due to the risk of cyberattacks.
- Two threat types:
  - Attack on digital twin: attackers may gain access to company's IP by breaking the infrastructure security.
  - Target physical systems: cyber attackers may access and control the operation of the physical assets.

Ensuring accurate process characterization

- While digital twins can identify correlations within data, distinguishing between correlation and causation remains complex. This can lead to incorrect assumptions about process behaviors and outcomes.
- The human factor continues to play a crucial role. Ensuring that the process is fully and correctly characterized requires human expertise to understand and define critical control points accurately.

Notes: DT is digital twins. IoT is Internet of Things. AI is artificial intelligence.
Source: Kearney analysis

…but rising manufacturers' demands and needs will drive DT adoption growth

Growing demand for:	Digital twins role:
Predictive maintenance – Predicts equipment failure early. – Reduces downtimes.	– 3D digital models relate data from sensors to record KPIs. – Software analyzes real-time data and compares to historical and standard data.
Industry 4.0 and IoT – Improves plant productivity and efficiency. – Facilitates collaboration and knowledge sharing.	– DT solutions allow automation and smart manufacturing process.
Reduced time-to-market – Allows firms to have their product available to customers faster than competitors.	– Virtual twins enable rapid iterations of prototypes in a virtual environment. – Optimizes a product's performance while reducing development time.
Improved decision-making – Enables firms to remain competitive in a dynamic market.	– Digital twin provides consolidated information about assets across different departments and sites. – Dashboards provide a single visualization platform, increasing stakeholder collaboration.

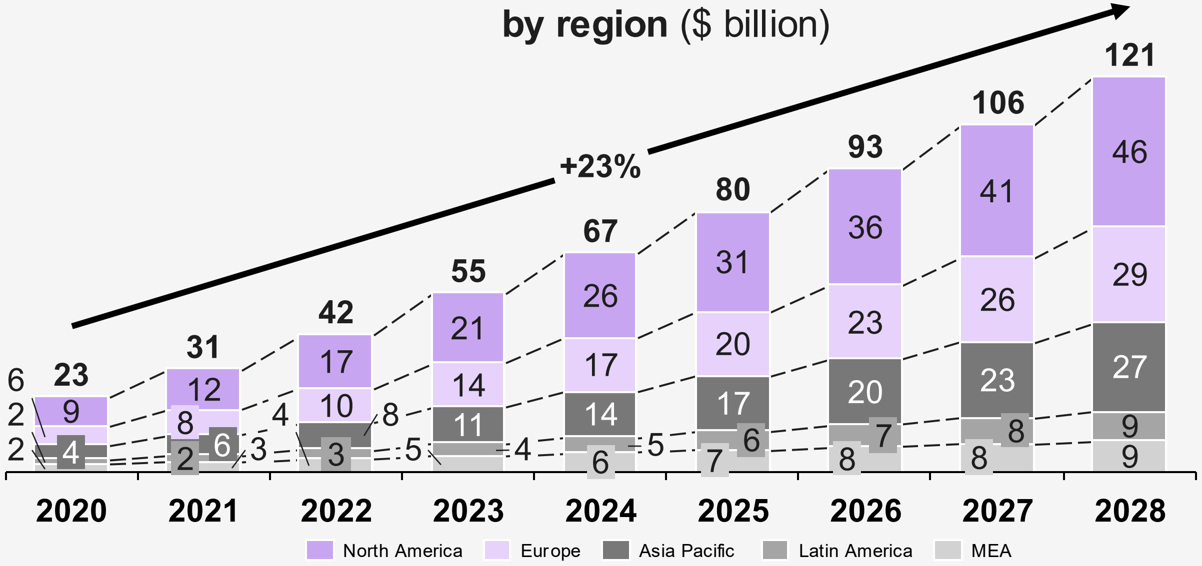
Notes: DT is digital twins. KPI is key performance indicator.
Sources: Technavio; Kearney analysis

Kearney XX/ID

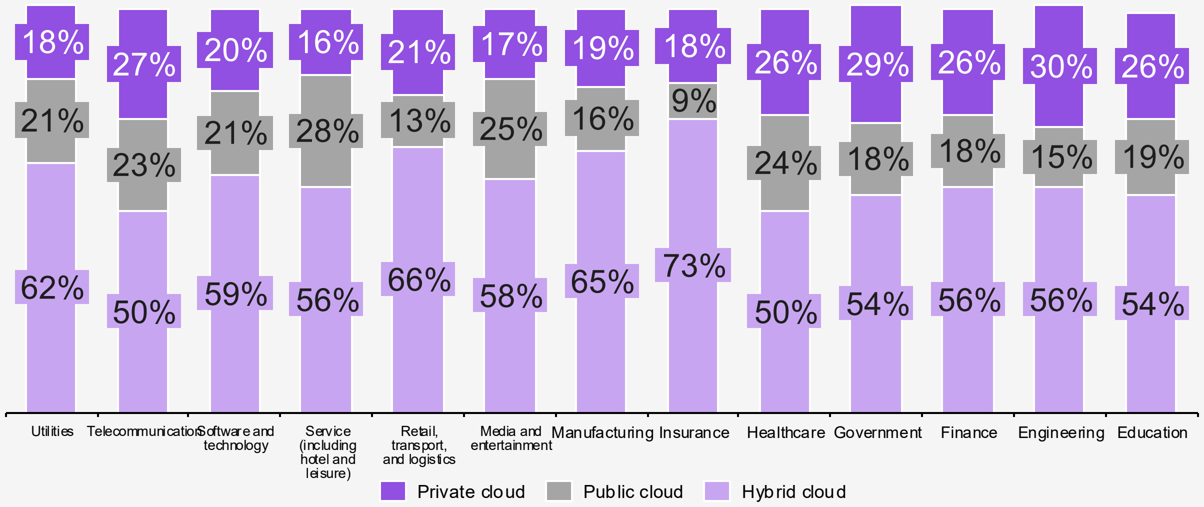
7. Cloud and edge computing

Cloud-based infrastructure growth in manufacturing is driven by modernizing and leveraging technology through tailored cloud services, offering advantages over costly infrastructure investments

Global cloud computing market in manufacturing, by region ($ billion)



Cloud use cases in manufacturing (%)



- Growing use of cloud tech to streamline manufacturing, enhance supply chain management, and boost operational efficiency.
- Cloud service models are poised to offer significant value to manufacturers by incorporating advanced technologies such as AI , ML, and others.
- Hybrid cloud is the top choice for the insurance industry, with 73% adoption.
- The manufacturing industry has a significant inclination toward hybrid cloud solutions compared to private or public cloud. Conversely, the services industry has the highest adoption of public cloud, at 28%.
- The APAC cloud computing market is poised to grow at 24.2% CAGR, followed by Latin America, MEA, Europe, and North America for 2016–2028.

Notes: AI is artificial intelligence. ML is machine learning. Percentages may not resolve due to rounding.
Sources: Grandview Research; Kearney analysis

Cloud computing offers improved scalability, accessibility, agility, security, and energy efficiency

Cost optimization

- Enables cost savings by eliminating upfront hardware expenses associated with on-premises solutions. Also reduces the need for costly infrastructure upgrades.
- MMG used cloud optimization to deliver **20% reduction in costs** with a 20-day ROI.

Data accessibility

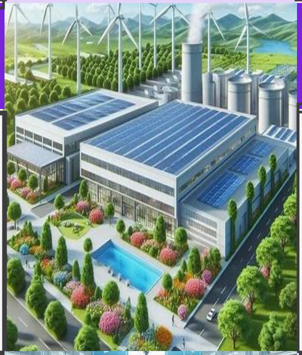
- Manufacturers can instantly and remotely access vital operational metrics such as machine performance and inventory levels for smooth and efficient operations.
- Mueller's cloud-based data lake estimated to save **$8 million** in operational expenses in 5 years.

Scalability and flexibility

- Enables manufacturers to optimize their operations, improve resource utilization, and respond quickly to market fluctuations to meet changing business needs.
- Carlsberg moved all systems to the cloud and **reduced major error incidents from 13 to 5 per month**.

Data security

- Allows use of high-level security measures, encryption, and frequent backups to safeguard data and maintain integrity. Offers disaster recovery solutions for swift data recovery and operational resumption after natural disasters or system failures.
- ADCO leveraged cloud to enable access to secure data **for all its remote employees**.



ESG considerations

- Cloud providers reduce energy usage with efficient data centers, while cloud storage and collaboration tools decrease paper consumption for sustainable manufacturing.
- ABB set up sustainable infrastructure services and **reduced overall test times from 10 to 2 days**.

Agility

- Accelerates product design testing and development, cuts prototype costs, enables quicker market entry, and supports seamless team collaboration.
- Alstom **reduced IT incidents by 62% through automation and infrastructure streamlining, migrating 1,000+ virtual machines** to cloud.

Note: ESG is environmental, social, and governance.
Source: Kearney analysis

Challenges faced by manufacturers while adopting cloud computing technology

Data security and privacy

- Protecting factory equipment from cyberattacks involves connecting as little of it as possible to insecure networks.
- Concerns such as identity theft, data breaches, and malware can erode user trust, leading to potential revenue loss.

Solution

- Manufacturers can decrease risk by implementing cybersecurity standards and limited access rights to central systems.

Legacy IT systems and interoperability

- Outdated IT infrastructure in manufacturing lacks the sensors and Internet connectivity crucial to a smart factory devised for cloud computing and may not integrate with newer production data analysis software, leading to time-consuming retrofitting efforts.

Solution

- Manufacturers can employ integration software to link data center/cloud computers with shop floor machines.

Workforce skills gap

- Cloud work is demanding and requires expertise and ongoing learning due to its complexity.
- The substantial learning curve could lead to issues like late deliveries and overstocking, among others.

Solution

- On-site training benefits factory workers. Manufacturers must consider hiring/outsourcing IT and cloud specialists.

Connectivity and reliability

- Manufacturers in remote areas or with poor connectivity face challenges, leading to potential disruptions and operational delays.

Solution

- Invest in higher bandwidth, train IT staff, and leverage cloud-based production planning, outsource tasks to MSPs to reduce issues.

Source: Kearney analysis

Current and future scenario of cloud in different sectors

Retail

– Helps improve inventory accuracy and reduce wastage, track demand.

– Edge computing for real-time processing for automated operational efficiencies like transport planning.

Oil and gas

– Digitize old equipment, boosts safety by remote operations monitoring.

– Edge and cloud computing help break down data silos, analyze remote data.

Pharma

– Accelerates time to market, modeling and simulation capabilities enhance efficiency.

– Integrated manufacturing IT/OT platforms for production and logistics for novel therapies and customized medicine.

Current challenges

– High cost of transition and stiff competition from retail giants like Amazon deter technology adoption.

– Oil and gas is a capital-intensive sector; hence, cost of upgrading is high.

– Issues like unauthorized access, data breaches, and disruptions may persist.

Automotive

– Visual quality control and early anomaly detection, factory performance analysis.

– Create flexible automated systems for high-quality, precision-engineered products leading to smart manufacturing.

Aerospace

– Aids faster prototyping, sensitive data protection, product design, and production management.

– Enhance key aerospace workflows, testing in immersive environments will reduce the need for costly physical trials.

Current challenges

– High cost of transition, phased implementation may delay production and cause losses.

– High demand from airlines makes it difficult to meet the supply and demand, sidelining innovation.

Source: Kearney analysis

8. AR/VR/wearables

The adoption of AR/VR and wearable technology is rapidly increasing globally, with a current market size of $24 billion in the manufacturing and industrials space

Market size, AR/VR, 2023–2028

CAGR (2023–2028) **23.7%**

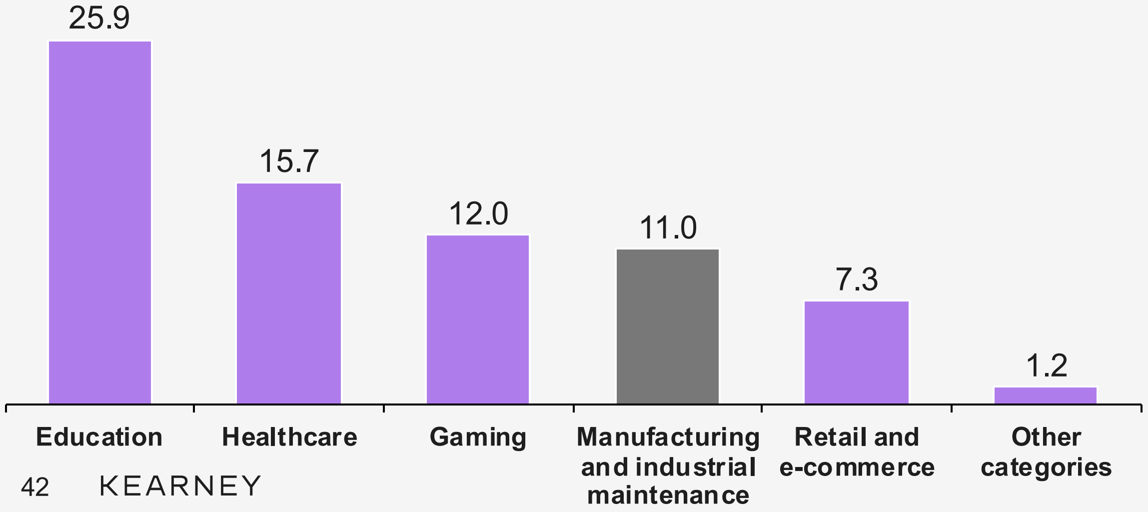
$210.4 billion
Projected market size in 2030

Market size, wearable technology, 2023–2030

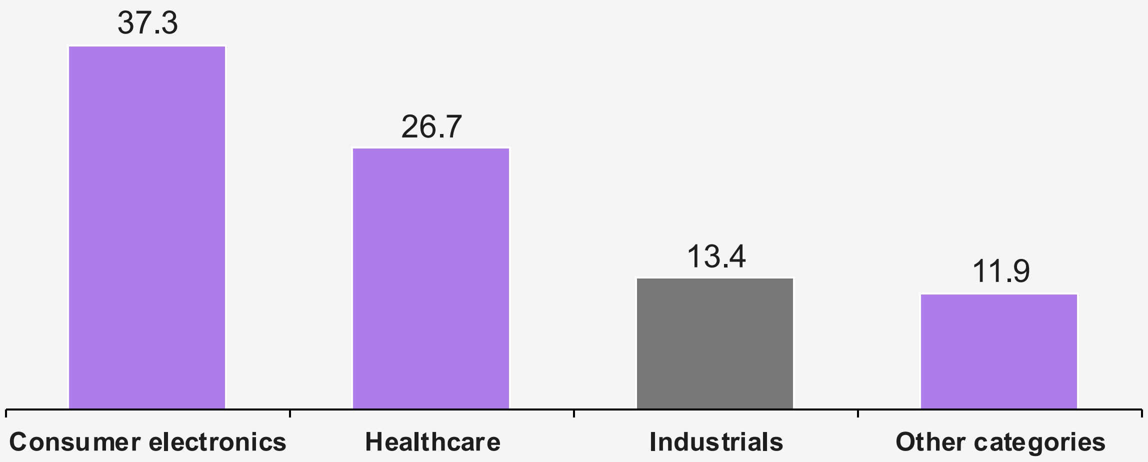
CAGR (2023–2030) **14.6%**

$186.1 billion
Projected market size in 2030

Projected global investment in augmented and virtual reality (AR/VR) technology worldwide in 2024, by industry
($ billion)



Projected global investment in wearable technology worldwide in 2024, by industry
($ billion)



Sources: Prescient & Strategic Intelligence, Fortune Business Insights, Research and Markets, IDC; Kearney analysis

AR, VR, and wearables can be utilized in a wide range of operational applications

Non-exhaustive

Design	Planning	Production	Logistics
Prototyping VR and 3D digital tools for designing new products and their components	**Product planning** Changes in visualized product designs can be tracked in real time	**Workforce training** Virtual training environments for low cost/risk training with real-time feedback	**Order picking** AR solutions can display digital overlays that guide operators through the most efficient routes
Design testing Examine details close up and from all angles and make adjustments in real time	**Plant layout planning** Creates a simulated environment where different plant layouts can be tested before physical changes are made	**Maintenance support** Receive remote support and display information pertaining to operation time, last service date, etc.	**Warehouse management** Display real-time information on quantities, locations, and specific details of warehouse locations
		Quality assurance Examine quality of parts and components in the assembly line in real time	**Safety** Wearables that shut down forklifts or other vehicles if they come too close to personnel or assets

Notes: AR is augmented reality. VR is virtual reality.
Source: Kearney analysis

Adoption of AR/VR/wearables is increasing, with a few industry players at the forefront of the effort…

Example types of AR/VR/wearables applications

1

Metaverse manufacturing process training

- Manufacturers are using the mixed reality (MR) capability of the metaverse to augment manufacturing processes. Augmented manufacturing processes provide a more realistic experience for new operator/engineer training as an alternative to traditional hands-on applications.

2

Mixed reality manufacturing inspections

- Mixed reality goggles are being deployed to complete more thorough inspections in the manufacturing process. MR goggles are superimposing pictures and text onto assemblies to provide written and visual standards as inspections are completed.

3

Augmented reality (AR) manufacturing assembly

- Low-volume, high-tech manufacturers are using AR to communicate work instructions and installation standards. During assembly, the work instructions are shared via AR along with visual standards for correct part alignment and installation.

4

Wearable exoskeletons in operations

- Adjustable exoskeletons are being used to improve operator ergonomics. Exoskeletons replicate body movements to perform necessary tasks with less muscle fatigue and increased speed. The technology leads to an alleviation of physical stress, reduction of ergonomic risk, and sustainment of worker well-being.

Companies leveraging the technologies today

LOCKHEED MARTIN

BOSCH

AIRBUS

gm

Non-exhaustive

Note: VR is virtual reality.

Sources: Volkswagen: Volkswagen | Assembly VR Training | Full-Service VR & AR Agency (vrowl.io), Mercedes: How Mercedes-Benz Uses Virtual And Augmented Reality To Sell Cars, Train Staff, And Create New Customer Experiences (forbes.com) , Lockheed Martin: Lockheed Martin reduces training time by 85% using Augmented Reality Technology! | by InfiVR.com | Medium, Airbus: Mixed reality to meet future challenges | Airbus, General Motors: GM Studying Exoskeleton Tech For Workplace | GM Authority ,General Electric: How Augmented Reality and GE Digital's MES are Bringing Global Expertise to the Factory Floor | GE Digital, Bosch: Artificial Intelligence (AI) in Manufacturing | Bosch Global; Kearney analysis

…but challenges remain for implementing and leveraging these technologies effectively across an organization

Financial justification

- **The cost of purchasing AR/VR and wearable devices**, as well as the associated software and infrastructure, **can be substantial.**
- **Justifying the investment in wearable technology can be challenging**, especially if the benefits are not immediately apparent.

Complexity and scalability

- Wearable technology **needs to seamlessly integrate with current manufacturing systems**, which can be difficult due to compatibility issues with legacy systems.
- **Deploying wearable technology** across a large workforce with multiple sites and use cases **can be complex.**
- Customization to environments and applications **can require specific skill sets that are uncommon in manufacturing.**

Human factors

- Workers may be **resistant to wearing new technology**, particularly if it is uncomfortable or perceived as intrusive.
- Workers need **comprehensive training to effectively use wearable devices.**
- To willingly adopt the technology, workers must feel that the technology adds direct value to their positions, without adding complexity.

Privacy concerns

- **Wearables can track workers' movements** and activities, raising concerns about privacy and surveillance.
- Ensuring that personal data collected by wearables is handled in compliance with privacy regulations is a significant challenge.

Notes: AR is augmented reality. VR is virtual reality.
Source: Kearney analysis

The evolution of AR/VR/wearable tech has laid the foundation for future applications in the manufacturing sector

Future innovation in VR/AR/wearables

Neuro-wearables

- Brain computer interfaces
- Monitoring cognitive states
- Training and skill enhancement
- Predictive maintenance
- Enhanced safety
- Quality control
- Worker well-being and ergonomics
- Data analytics and optimization

Biometric sensors

- Visual instructions and guidance
- Remote assistance and collaboration
- Interactive equipment visualization
- Training and onboarding
- Real-time data integration
- Enhanced safety
- Cost savings and efficiency

VR factory floor planning

- Simulation and visualization
- Design review and collaboration
- Training and skills development
- Safety assessments
- Maintenance and operations

AR remote assistance

- Real-time support
- Reduced downtime
- Training and knowledge transfer
- Quality assurance and inspection
- Cost savings and efficiency
- Safety and compliance

AR worker training

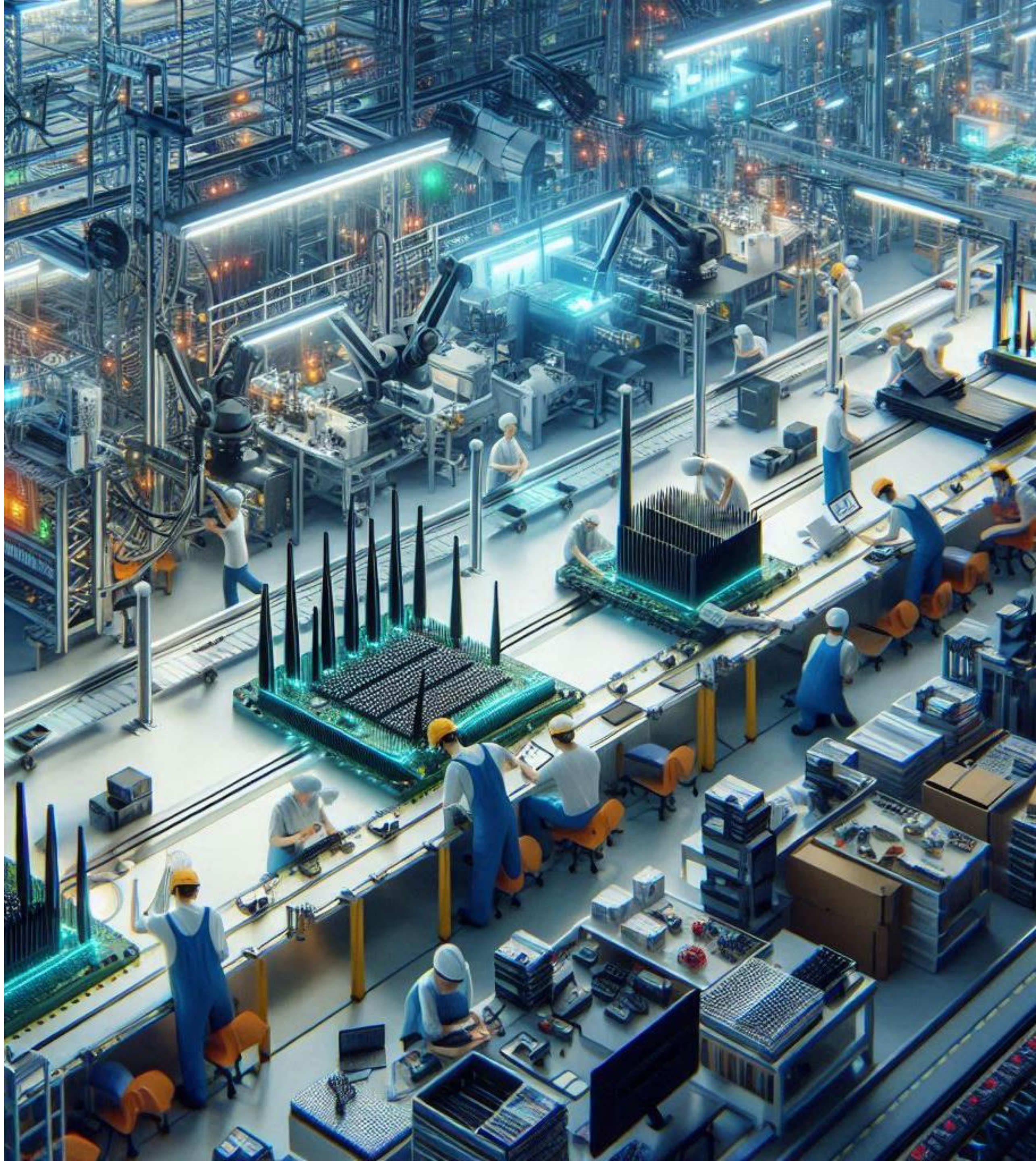
- Interactive learning experiences
- Realistic simulations
- Remote expert assistance
- Complex equipment familiarization
- Consistency and standardization
- Cost and time efficiency

AR routine maintenance

- Hands-free operation
- Interactive training and guidance
- Digital twins and simulation
- Workflow optimization
- Documentation and reporting
- Inventory management and parts identification

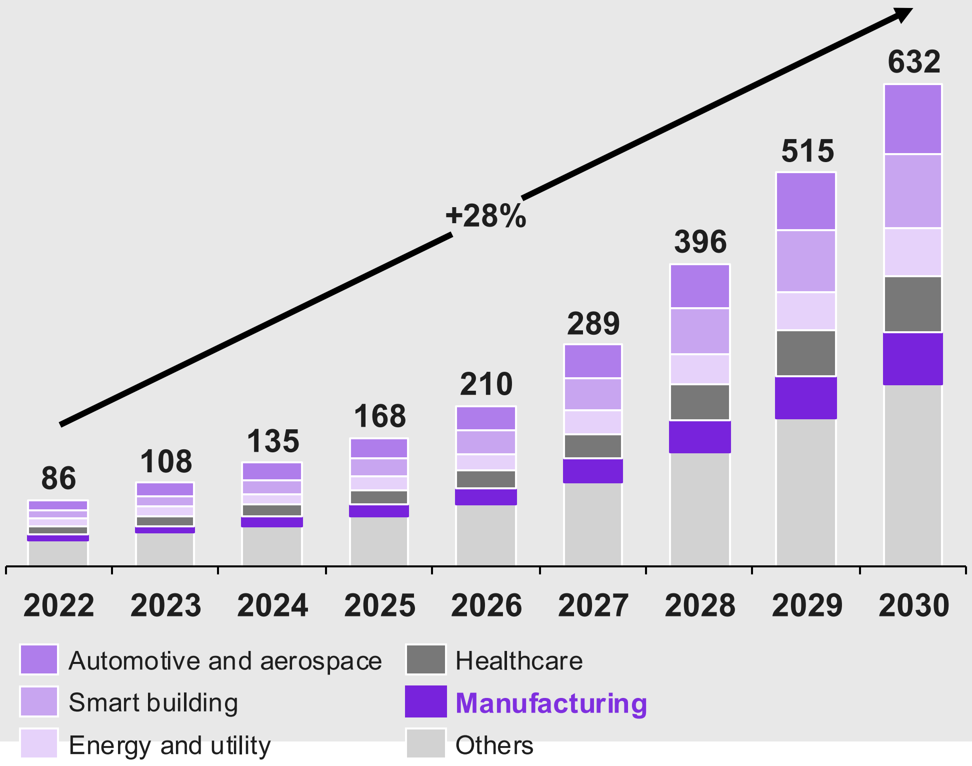
Notes: AR is augmented reality. VR is virtual reality.
Source: Kearney analysis

9. 5G

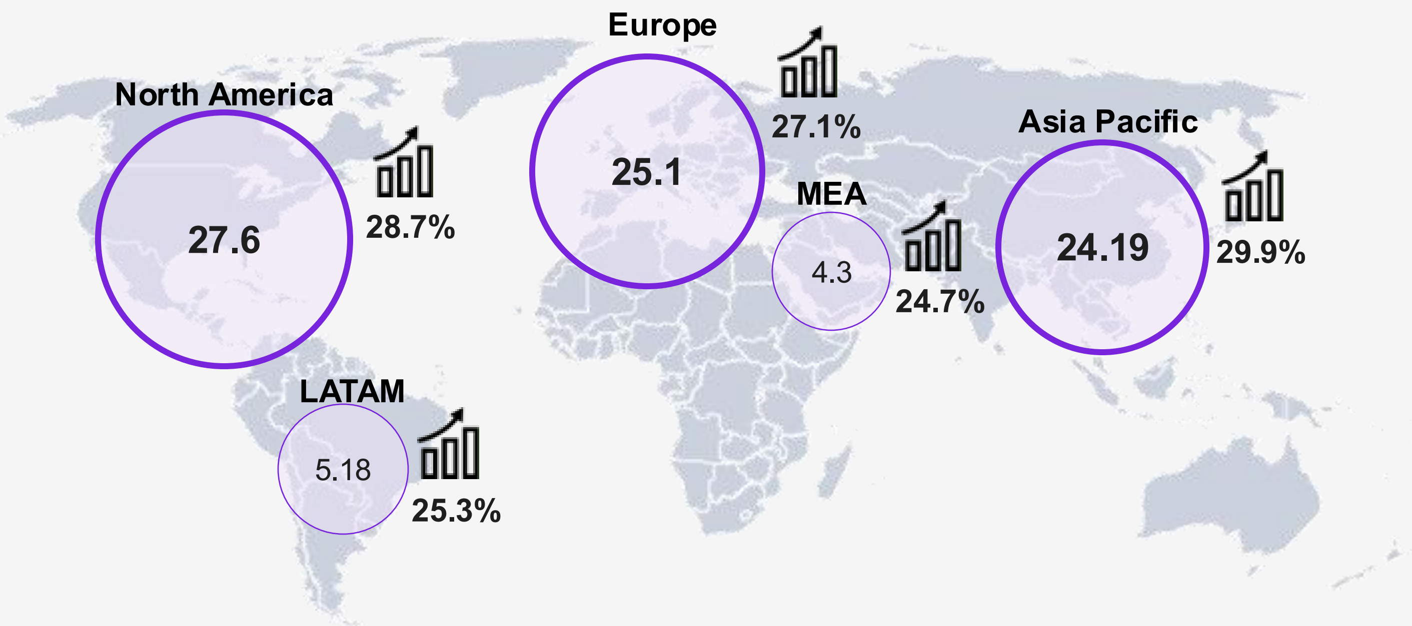


5G industrial applications to grow by 28% CAGR through 2030, primarily driven by smart building, automotive and aerospace, healthcare, and manufacturing

5G market size by industry verticals ($ billion)



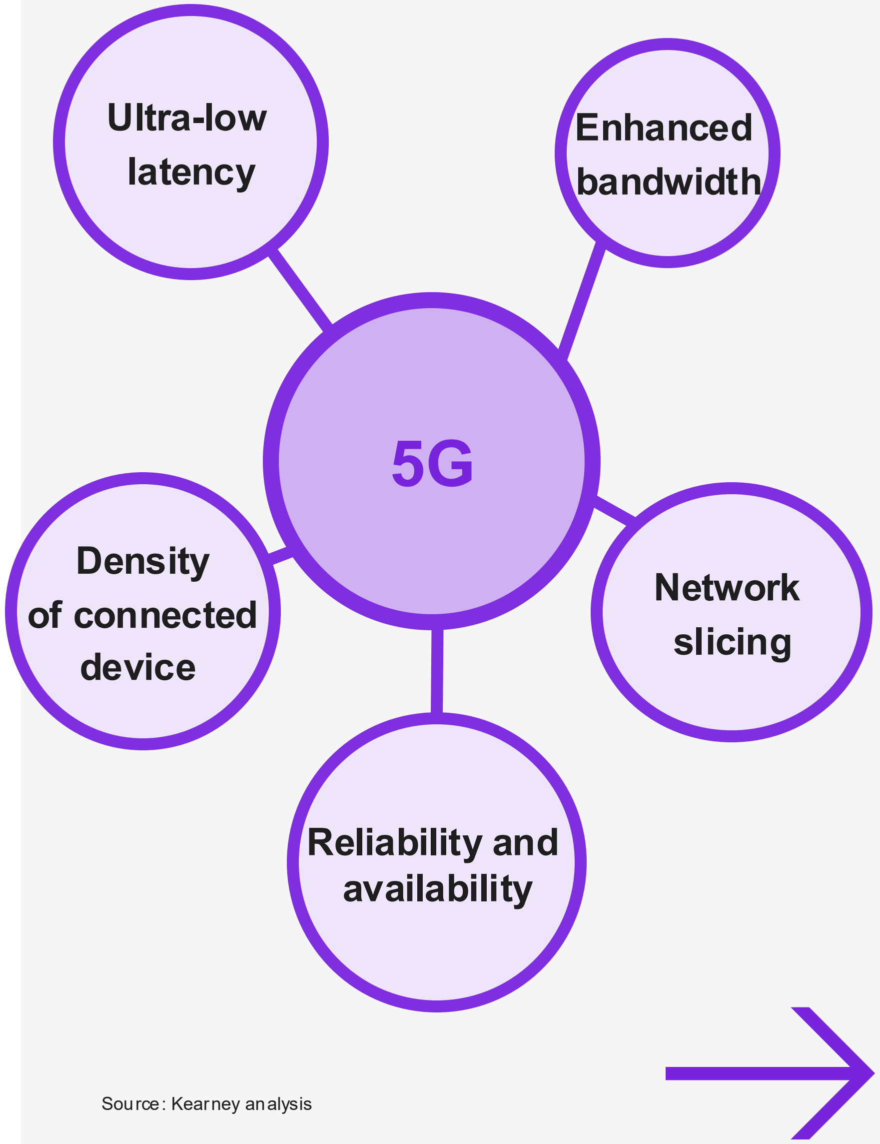
Adoption of 5G applications by region, 2022 ($ billion)



Sources: Mind Commerce; Kearney analysis

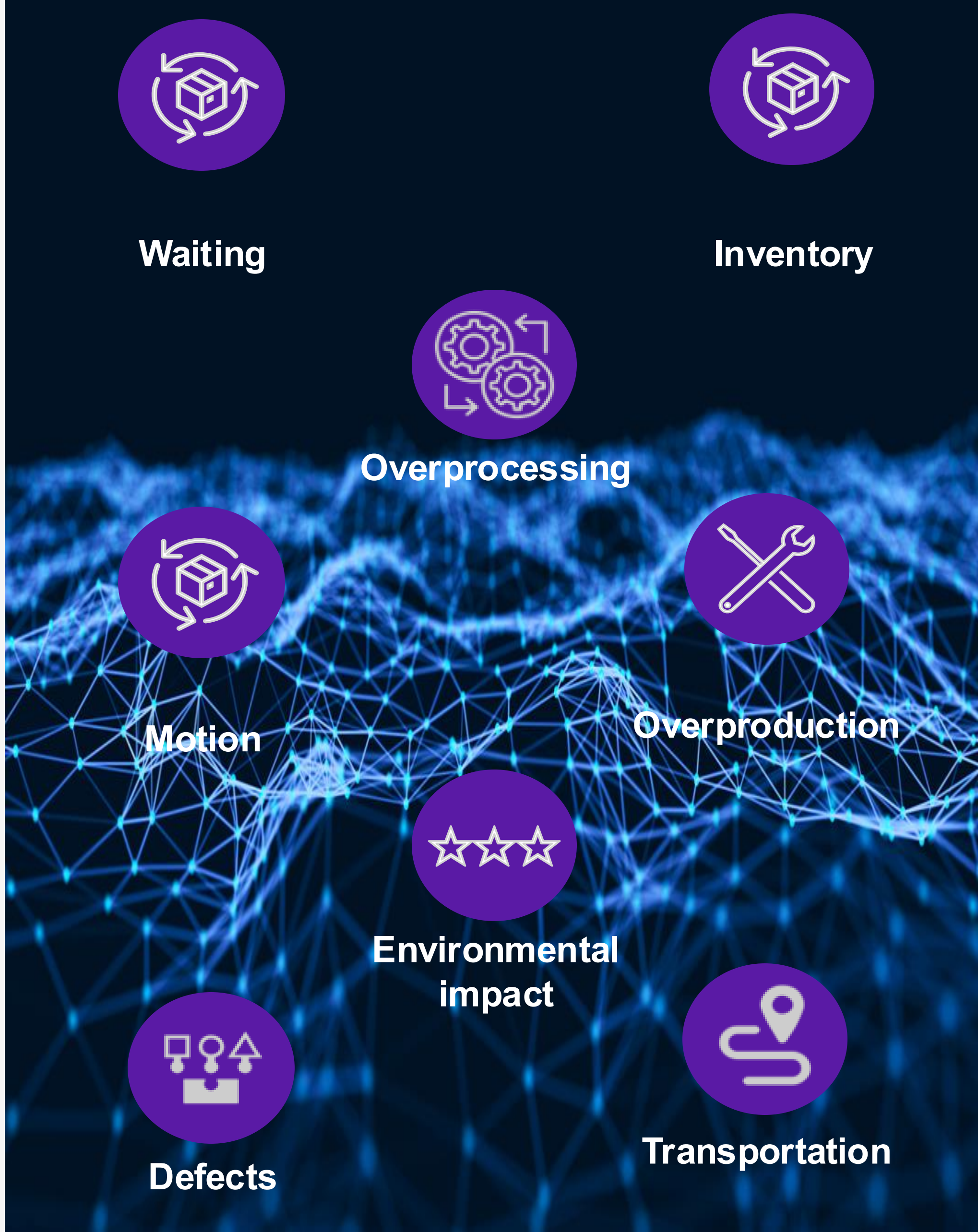
5G helps reduce environmental impact by addressing all seven types of waste that hinder leaner operations

5G value add



Source: Kearney analysis

Wastes in operations



5G technology can significantly enhance manufacturing efficiency, reduce costs, and streamline operations across all stages of the value chain

5G use case in manufacturing framework

Non-exhaustive

	Product design	Supply chain	Manufacturing	After-sales
Waiting and inventory	Reduces time through seamless sharing of compute-heavy resources	Automated stock optimization through massive device connectivity	Real-time machine synchronization, reducing downtime, increasing throughput	Real-time and reliable spare-part visibility enables timely information on inventory levels
Defects		Continuous data flow enhances quality control and early identification of errors		Remote configuration and product feature updates reduces need for recalls or field visits
Over-production	Optimizing specification with real-time insights in product usage		Dynamic production scheduling based on real-time data from multiple sources, e.g., CRM, MES	

Audi

Audi, partnered with Verizon, is using 5G on its test track for smart vehicle testing, for real-time data exchange for more efficient testing.

Toyota

Toyota Material Handling uses private 5G for its production operations, enabling real-time monitoring and automation for improved efficiency.

AIRBUS

Airbus is using a private 5G network to enhance production facilities, enabling faster connectivity for critical manufacturing processes.

BOEING

Boeing plans to use 5G to enhance aircraft maintenance, focusing on faster data transmission and real-time diagnostics.

Notes: CRM is customer relationship management. MES is manufacturing execution system.
Source: Kearney analysis

Evolution in 5G technology will incrementally add value to Industry 4.0 to achieve autonomous factory

5G and Industry 4.0 evolution

Autonomous factory

E2E process digital twin
Self-regulating operations

Integrated value

Supply chain optimization
Digital twin of key assets
Remote/OTA equipment management

Discrete use cases

Improved OEE with real-time monitoring
Faster cross-functional collaboration
Inventory tracking

Long-term (2030–beyond)

Medium-term (2026–2029)

Short-term (2023–2025)

Short-term (2023–2025)	Medium-term (2026–2029)	Long-term (2030–beyond)
Deployment of enhanced mobile broadband	Rollout of massive machine type communication at scale	Fully operational private 5G network for factories
Early stage of ultra-reliable low-latency communications	Ultra-reliable low-latency communications maturity	Convergence of AI and 5G for real-time decision-making
Basic network slicing	Advanced network slicing	Third-party applications ecosystem for network slicing

Notes: OEE is overall equipment effectiveness. OTA is over-the-air. E2E is end-to-end. AI is artificial intelligence.
Source: Kearney analysis

Key challenges include demonstrable ROI, data overload, integration with legacy systems, and security vulnerabilities

High initial investment

- 5G infrastructure requires substantial upfront investment, which can be prohibitive.
- The return on investment may not be immediately clear, causing hesitation.
- Smaller enterprises may struggle to justify the costs of 5G deployment.

Solution

- Implement 5G incrementally, starting with high-impact areas to demonstrate ROI.

Complex integration with legacy systems

- Integrating 5G with existing, outdated systems can cause significant technical issues.
- Integration may lead to temporary operational downtime and quality issues.
- Managing a hybrid of old and new systems adds layers of complexity.

Solution

- Utilize middleware to facilitate seamless, phased integration while minimizing operational risks.

Security vulnerabilities

- More connected devices means more entry points for cyberattacks and data breaches.
- Critical manufacturing data could be at risk of theft or sabotage.
- Critical operations may be targeted, leading to costly downtimes.

Solution

- Implement robust cybersecurity measures, including encryption and AI-based threat detection, to secure the network.

Data management and overload

- 5G enables a vast number of connected devices, sensors, and machines, leading to exponential growth in data volume.
- The ability to process, analyze, and act on real-time data can become a bottleneck, particularly if the infrastructure is not adequately scaled.

Solution

- Implement edge computing to process data closer to source, reducing latency and bottlenecks.
- Utilize AI and machine learning to prioritize and manage data effectively.

 Source: Kearney analysis

10. Conclusion

Manufacturers are leveraging intelligent automation, data analytics, and bandwidth capacity to improve supply chains, reduce environmental footprint, and empower workforces

AI adoption drivers include big data, robotics, and computer vision capabilities, as well as predictive analytics and real-time optimization.

AI-enabled predictive maintenance applications are expected to grow by 25% over five years, with quality control and production planning applications expanding by 16% and 18%, respectively.

Enterprise IoT offerings are expected to comprise a $720 billion market by 2030, with more than 4 billion connected devices in manufacturing alone.

AR/VR and wearable technology adoption continues to grow, with a current market size of $24 billion.

AI-enabled solutions enhance efficient, sustainable, lights-out production.

The advanced robotics industry continues to grow rapidly, carried by demand and advancements in pharma, high-precision, and auto/logistics industries.

3D printing is fueled by the introduction of new machines, materials, and technological breakthroughs.

Scalable and secure enterprise IIoT platforms are the backbone enabling AI, ML, AR/VR, and digital twins.

Cloud-based infrastructure offers advantages over costly infrastructure investments.

AR, VR, and wearables can be utilized in a wide range of operational applications.

Evolution in 5G technology will incrementally add value to Industry 4.0 to achieve autonomous factory.

Workforce challenges include shortages and skills gaps in areas critical to deploying and managing digital solutions.

There are security concerns surround emerging digital technologies that are by definition vulnerable to exposure.

Integrating digital solutions with legacy systems can be complex, disruptive, and expensive.

Continued investments, strategic planning, and incremental deployment can address existing challenges.

Notes: AI is artificial intelligence. IoT is Internet of Things. AR is augmented reality. VR is virtual reality. IIoT is Industrial Internet of Things. ML is machine learning.
Source: Kearney analysis

Thank you

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