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UNLOCK-CEI

Cloud-Edge-IoT Demand Landscape

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D1.1 – Cloud-Edge-IoT Demand Landscape

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Glossary of terms

Item	Description
AD&D	Application Development and Deployment
AI	Artificial Intelligence
API	Application Programming Interface
AR/VR	Augmented Reality/Virtual Reality
ASIC	Application Specific Integrated Circuit
CAGR	Compound Annual Growth Rate
CDN	Content Delivery Networks
CEE	Central and Eastern Europe
CEI	Cloud-Edge-IoT
CIS	Center for Internet Security
CPU	Central Processing Unit
CRM	Customer Relationship Management
CSP	Content Security Policy
CT	Communication Technology
DACH	The region that includes Germany, Austria and Switzerland
DDoS	Distributed Denial-of-Service
DSL	Digital Subscriber Line
EU	European Union
FPGA	Field Programmable Gate Array
GDP	Gross Domestic Product
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
GSM	Global System for Mobile Communications
HVAC	Heating, Ventilation and Air Conditioning
IaaS	Infrastructure as a Service
IoT	Internet of Things
IP	Internet Protocol
ISV	Independent Software Vendor
IT	Information Technology
LED	Light-Emitting Diode
LOB	Line of Business
LTE	Long-Term Evolution
LPWAN	Low-Power Wide-Area Networks
MEC	Multi-access Edge Computing
MPLS	Multiprotocol Label Switching
MRR	Monthly Recurring Revenue
NB-IoT	Narrowband IoT
NFC	Near Field Communication
ODM	Original Design Manufacturer
OECD	Organisation for Economic Co-operation and Development
OPEX	Operating Expense
OT	Operational Technology
PaaS	Platform as a Service
PoC	Proof of Concept
POTS	Plain Old Telephone Service
RF	Radio Frequency

RFID	Radio-Frequency Identification
ROI	Return on Investment
RTU	Remote Terminal Unit
SaaS	Software as a Service
SDN	Software-Defined Networking
SD-WAN	Software-Defined Wide Area Network
SI	System Integration
SOC	System on Chip
VNF	Virtual Network Functions
WLAN	Wireless Local Area Network
WP	Work Package

Keywords

Cloud, Edge, IoT, Demand landscape, Use case, Market adoption, Operational technology, Drivers and barriers

Disclaimer

Executive Summary

The present document (D1.1) is the first report of WP1 of UNLOCK-CEI project covering the demand landscape analysis. UNLOCK-CEI's ambition is to UNLOCK the potential for accelerating the deployment of the Cloud-to-Edge-IoT (CEI) computing continuum in Europe. The focus is on demand-side drivers and challenges that can help identify technology-driven innovation and business opportunities that will stimulate demand value chains. To this end, UNLOCK-CEI deals with several technological concepts surrounding cloud, edge and IoT. This report provides a comprehensive overview of the main technologies that are the core of UNLOCK-CEI, analysing these from a demand market perspective and providing insights on their evolution and maturity, their current and future uptake, the key use-cases, and the main drivers and barriers for the adoption. This report is generated leveraging IDC research on the CEI market and other major public sources.

The cloud, edge and the Internet of Things (IoT) are three major, interconnected technology trends enabling the digital transformation of European organisations and economies. Together, they are forming a foundation of data collection and processing upon which a new generation of solutions can be developed to transform operations and prepare European organisations for the next decade of innovation. Europe's adoption and deployment of these technologies will be crucial for continuing to strengthen Europe's economies, meeting its sustainability objectives, and continuing to improve its social well-being.

This report demonstrates that these technologies serve prominent roles across all industries. They are utilised in a variety of ways to create many individual solutions. These solutions are targeting the unique needs of individual industries, such as hospital bedside telemetry or manufacturing automation, as well as general needs across all industries, such as vehicle tracking and video surveillance.

Each use case is assembled from a wide range of components, including end devices and sensors, computing infrastructure, software platforms, analytics, applications, professional services and many others. Many of these feature large numbers of mobile items, like vehicles, or widely dispersed assets like vending machines or manufactured smart appliances. Such use cases often employ central computing resources in the cloud, as a means of efficiently collecting, analysing and acting on data from the remote sensors. Many other use cases, however, feature assets concentrated in one location, such as within a factory, and they may require real-time data processing and analysis to enable contextual system automation. These cases are likely to see benefits in deploying edge-computing solutions and relying less on more distant cloud infrastructure.

CEI adoption is already at high levels across European countries and industries. In a 2022 survey, 83% of European organisations surveyed use public cloud services, to varying degrees[1]. Edge is a somewhat newer technology theme, and as such, adoption has not yet reached the same levels as cloud. In a 2021 IDC survey, one in three European organisations surveyed were using edge solutions in their daily business[2]. As for IoT, according to a 2022 survey, 48% of European organisations surveyed were using IoT, while another 37% were planning to do so[3]. And adoption was well distributed across all verticals.

The drivers for use of these technologies are varied, which reflects their different roles in organisational IT systems. Among the key benefits driving cloud are the desire for agility and flexibility with IT resources; increased availability; reduced total cost of ownership; and easier IT management. Key benefits driving edge usage are low latency and real-time analytics, reduced data transmission volumes and costs, and potentially increased privacy and security by keeping data locally. IoT is used in many ways across industries, with companies deploying it to increase efficiency and productivity; to improve customer experience; to improve product quality; reduce operational costs; and for many other purposes.

[1] *IDC, European Multicloud Survey, September 2022*

[2] *IDC, European Emerging Technologies Survey, 2021*

[3] *IDC, European 5G and IoT Survey, June 2022*

However, these technologies still face challenges that impact adoption rates. Some of the key challenges slowing cloud migrations include security concerns about turning over sensitive applications and data to a third party for management; concerns about lock-in to a specific cloud provider; a shortage of skills needed for utilising cloud systems; and challenges integrating with existing systems. Among the challenges slowing down the adoption of edge technologies are a lack of qualified workforce and skills; lack of funding; difficulties adapting current systems to edge solutions; and a lack of adequate supporting infrastructure. The biggest challenges slowing down IoT deployments were reported in IDC surveys to be costs, security and complexity. Industry is making great progress in addressing these challenges, but the fragmentation of customer needs across so many different use cases makes this process a gradual one.

The next version of this report will be submitted in M12 (May 2023) under D1.2 and will include the results of a custom survey, currently underway, to tackle the CEI market dimensions indicated in the previous paragraphs. The survey will involve a representative sample of European business users, with 700 interviews, in five selected verticals of manufacturing, energy, mobility, healthcare and agriculture. Moreover, the next deliverable (D1.2) will include the results of deep dive interviews with industrial stakeholders in terms of emerging business opportunities driven by the paradigm shift towards CEI.

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1. Introduction

Creating a seamless, secure, sovereign, and sustainable continuum of data collection, storage and processing beyond the central cloud will be an essential component of a globally competitive, trusted and dynamic data-agile economy in Europe. Cloud, edge and the Internet of Things (IoT) represent three major, interconnected technology trends that are enabling the digital transformation of European organisations and economies. Together, they are forming a foundation of data collection and processing upon which a new generation of solutions can be developed to transform operations and prepare European organisations for the next decade of innovation.

Next-generation edge computing and data technologies and infrastructures must not only be developed, but also deployed and adopted by European organisations to enable the European single market for data and a Europe that is fit for the digital age. Europe's adoption and deployment of these technologies will be crucial for continuing to strengthen Europe's economies, meeting its sustainability objectives, and continuing to improve its social well-being.

However, the speed of technology change is so fast that industrial stakeholders are struggling to adapt to a multi-cloud infrastructure environment and to deal with the paradigm change created by a Cloud-Edge-IoT (CEI) scenario. Many European organisations, particularly SMEs, may choose to rely on global providers such as cloud hyperscalers to manage this transition, with a high likelihood of customer-lock-in situations.

In order to accelerate and facilitate the adoption of IoT use-cases in the computing continuum of cloud-to-edge, it is crucial to have a clear and realistic view of the actual and potential demand for CEI and their adoption status.

The present report aims to provide this overview, leveraging IDC's global CEI research and other main public surveys. In the lifetime of the project, two other reports regarding "demand landscape analysis" will be generated. The second report will include the results of a custom survey, which is currently ongoing to tackle the CEI market dimensions indicated in the previous paragraphs. The survey will be a representative sample of European business users, with 700 interviews, in five selected verticals of manufacturing, energy, mobility, healthcare and agriculture. Moreover, it will include the results of deep dive interviews with industrial stakeholders in terms of emerging business opportunities driven by the paradigm shift towards CEI. The final report will analyse the CEI demand-supply dynamics in-depth, mapping the demand requirements versus the supply status and trends to identify actual and potential gaps in performance and service offerings. Eventually it will highlight the main gaps between CEI demand and supply landscapes.

This report is structured as follows. In Chapter 2, the methodology of the study is described including the approach to select target verticals and EU member states for the study. Chapter 3 describes the main technological aspects of CEI as well as their history and evolution during time. It also provides insights on why and how these three main technologies are interdependent to drive the industrial use-cases. Chapter 4 provides detailed information about the current and future adoption of CEI in Europe and the key use-cases in the 5 verticals of manufacturing, energy, transportation, healthcare and agriculture. Chapter 5 describes the main drivers and inhibitors to uptake CEI technologies. In Chapter 6, we provide some final remarks about the business and strategic relevance of CEI for Europe and the next actions. The annex provides more detailed technology taxonomies of CEI markets and solutions.

2. Methodology

The present report is generated based on the extensive existing IDC studies on CEI in particular IDC's spending guides on cloud, edge and IoT; Market forecast and taxonomies. In order to provide more specific insights in the next report regarding CEI demand landscape, primary data will be collected through a custom survey, which is under progress. The scope and main dimensions of the survey are described in section 2.3. The results of the survey will be included in the updated report due in May 2023.

2.1 Selection of Industry Sectors for Study

2.1.1 Criteria for Selection

While every sector is making use of cloud, edge and IoT technologies, this project has slightly narrowed the focus. The project needs to balance the desire for completeness on one hand with a need to efficiently manage resources on the other. Whereas the project aims to cover the full breadth of all sectors, it would not be able to provide the desired depth of analysis. Therefore, the project is focusing on five industry sectors.

The sectors have been chosen based on the following criteria:

- The scale of the industry's spend on CEI
- Strong examples of current CEI use cases
- Strong examples of future CEI use cases
- A desire to examine diverse sectors
- Importance to the European economy; for example, levels of employment, share of GDP or other measures
- Importance to European security; for example, a need for European self-reliance or technology leadership in strategic areas
- Importance to sustainable development and renewable energy objectives; for example, helping to reduce carbon emissions or introduce new energy sources as Europe implements its Fit for 55 climate plan.
- Importance to European society, such as healthcare, employment, cultural heritage, or other factors
- Diversity of examples; they should represent quite different parts of the European economy

2.1.2 Analysis and Choice of Sectors

Few of the above criteria are readily quantifiable. As a result, the selection is necessarily based on some qualitative assessments. Below is the assessment of the choices of industries.

- **Manufacturing**: The manufacturing industry is the largest segment of the overall European CEI market, with spending in 2022 estimated to be EUR 49.6 billion, more than twice that of the second-largest industry[4]. Manufacturing is the largest employer in Europe, and it accounted for 15% of GDP in 2021, according to the World Bank[5]. Manufacturers are embracing a wide range of CEI use cases, ranging from energy management and asset monitoring to autonomous vehicles and production automation. With such a large significance to the economy and society, widespread usage of CEI, and a diverse set of use cases, the manufacturing sector is a top candidate for examination.
- **Energy and Utilities**: The European energy sector, as a subject of geopolitical threats, is undergoing significant transformation, diversification and digitalisation. The industry is transforming rapidly, coping with energy insecurity and a need to decarbonise. It is also an industry that is geographically dispersed with many remote assets (offshore oil platforms and wind farms; pipelines; extensive powerlines). The industry is ambitiously adopting automation and remote management using IoT. It's strategic nature, rapid transformation and distributed assets make it a strong candidate for analysis in the context of CEI.

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[4] *IDC, various Worldwide Spending Guides, May 2022*

[5] *https://data.worldbank.org/indicator/NV.IND.MANF.ZS?locations=EU*

- **Transportation**: This study is examining multiple linked components of the transportation sector, including both passenger transport (vehicles, public transport) and logistics. The passenger transport industry is migrating from manually controlled vehicles with internal combustion engines toward electric vehicles that are connected, intelligent, and increasingly autonomous. This migration also involves upgraded smart infrastructure and charging stations. Meanwhile, on the logistics side, transport vehicles are also becoming smart and eventually autonomous, while fleets are tracked and optimised, freight conditions are monitored, and assets are tracked continuously across borders and oceans. These use cases are developing rapidly. The combination of mobility, remote connectivity, simple existing use cases (like fleet tracking) that are widely deployed now, highly advanced future use cases (such as autonomous vehicles) that will drive strong investment in the future, and distributed computational needs make this sector a strong example for CEI.
- **Healthcare**: The healthcare industry is very different from the other industries examined. This sector has a large public-sector presence throughout Europe. It features significant regulatory guidance and intervention. It is critical for European society's well-being. The industry has many large and small healthcare facilities, with data-sharing needs among them, as well as unique privacy concerns. It also has a large amount of mobility of staff, patients, medications, dangerous materials, and valuable hospital assets that need tracking, coordination, and control. This sector is making extensive use of connected devices, asset tracking, patient monitoring and analytics; healthcare facilities make good candidates for deploying local edge computing resources for the purposes of security, privacy, and efficiency. In sum, healthcare is critical for society, a strong candidate for diverse CEI use cases, a subject of significant regulation and policy attention, and a very different example than the other industries discussed, all of which make it an important sector to analyse in the context of CEI.
- **Agriculture**: The agriculture industry is far smaller than the others in terms of employment, but it is strategically important, critical for European society's well-being, and it accounts for the largest share of land use in Europe, amounting to 39.1% of total EU land in 2018, according to Eurostat[6]. The distributed geographical nature and low density of workers in the agriculture industry are a key reason this industry needs to make use of CEI solutions. This sector makes extensive use of animal tagging and increasingly uses field monitoring to optimise yields. Agricultural machinery is connected and smart, and it is moving toward autonomous operations. But much of the agricultural land has limited cellular network coverage. As a result, this industry is continuing to develop IoT use cases, making use of edge computing (such as systems on-board farm machinery) for automation and local analytics, as well as connecting to cloud resources for analysis across territories and asset fleets. The unique nature of the industry and strong adoption of CEI solutions make agriculture a strong candidate for evaluation in the context of CEI.

2.2 Selection of Member States for Study

2.2.1 Criteria for Selection

This study aims to investigate the demand trends in the European market for cloud, edge and IoT solutions, including adoption plans, drivers and inhibitors. In order to capture market trends across the EU's diverse markets, this study includes survey results from several Member States that feature diverse market characteristics. The characteristics that were considered in selecting Member States for inclusion in the survey were the market size, geographic distribution, and diversity of market characteristics.

2.2.2 Analysis and Choice of Member States for Study

The Member States chosen for inclusion in the survey are, Germany, France, Italy, Spain, Poland, Romania and the Nordics. The first six of these markets are the largest Member States in order of population, and they represent wide distribution geographically and in terms of GDP per capita. The Nordics were included as a

[6] *https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Land_use_statistics*

group to capture insights from another geographic region that is the higher end of the income spectrum and that was not among the six largest countries by population.

2.3 Primary data collection: UNLOCK-CEI Survey

A survey is being conducted in order to provide deeper understanding of the adoption of CEI technologies and the drivers and inhibitors to adoption. This survey includes a sample of 700 businesses across Member States.

The respondents are selected from the five vertical industry segments described above:

- Manufacturing
- Energy and utilities
- Healthcare
- Transportation
- Agriculture

The survey is exploring the following topics:

- Awareness of CEI technologies
- Adoption and deployment of CEI
- Maturity of CEI projects
- Benefits of CEI projects
- Challenges inhibiting deployment of CEI projects
- Preferences for cloud, edge or traditional IT infrastructure
- Data sovereignty
- Preferences when selecting CEI technology providers

Upon completion of the survey, this report will be updated with the results in May 2023.

3. Introduction to CEI

3.1 What is CEI?

Cloud, Edge and The Internet of Things (IoT) represent three major, interconnected technology trends that are enabling the digital transformation of European organisations and economies.

Cloud computing emerged as a way to enable multiple applications and even organisations to more efficiently use and share centralised computing resources. It has steadily become a core part of the modern technology landscape.

Meanwhile, the Internet of Things has developed rapidly over the past decade. IoT involves autonomous sensors and devices ("things") that generate data in many disparate locations and send that data to centralised resources (in the cloud or otherwise) for processing. However, many of these devices produce large volumes of data that requires a level of aggregation, processing or filtering before sending it to the core computing resources in the cloud or data centre. Moreover, many of those "things" need to act on that data, requiring quick analysis and automated response that are better served by avoiding the long round-trip of data from the edge to the core and back again. The degree to which this speed (latency) is critical or not varies according to the domain in which it is deployed.

Thus, edge computing has emerged in more recent years as a way to put computing resources closer to those many devices at the edge, and to increase the utility of those edge devices.

Altogether, organisations are utilising a combination of cloud, edge and IoT to enable a wide range of new solutions that organisations can use to transform processes, automate operations, and launch new products and services.

What is emerging is an integrated environment that incorporates and blends together sensors, automated devices, edge computing, and centralised cloud computing in a way that is tailored to the specific needs of a use case and organisation. These CEI environments form the foundation for modern information and operations technology. Organisations then utilise a mix of complementary technologies, such as robotics, big data, analytics, drones, and artificial intelligence, to achieve their complete technology solutions.

Creating this CEI environment—a continuum of data collection, storage and processing from edge to cloud—will be an essential component of a globally competitive, secure and dynamic data-agile economy in Europe. European organisations must adopt and deploy these technologies to maintain economic leadership, increase security and resilience of our economies and societies, and to achieve sustainable development objectives.

As the world embraces these technologies, Europe has the opportunity to help shape and possible lead their development. European companies can create value while building resilience of the European economy, and defining technologies, standards and practices that comply with European ideals. European institutions can implement policies that assist this process and position Europe to thrive in the next generation of technological and economic development.

A detailed definition of the CEI Continuum has been defined in Deliverable 4.1. The following sections provide initial definitions of the three component technology domains, cloud, edge and IoT.

3.1.1 Cloud Definition

Cloud services refers to the provision of software or infrastructure in a flexible manner that allows organisations to purchase them as a service, rather than as a one-time license fee. These services are typically easily scalable up and down via self-provisioning. And the services are commonly based on shared use of the software or infrastructure on a multi-tenant basis. Cloud most commonly refers to **public cloud services**, in which service providers support multiple customers within the same infrastructure or software instance and dynamically provision resources to those customers as needed. Unless otherwise noted, this report uses the terms "cloud" and "public cloud" interchangeably.

The cloud model goes well beyond prior online delivery approaches — combining efficient use of multitenant (shared) resources, radically simplified "solution" packaging, self-service provisioning, highly elastic and granular scaling, flexible pricing, and broad leverage of Internet standard technologies — to make offerings significantly easier and generally more cost-efficient to consume.

In addition to public cloud, the term "cloud" is sometimes used in reference to other types of IT resource deployments:

- **Dedicated (private) cloud:** Dedicated (private) cloud services utilise cloud principles of dynamic scaling and resource allocation in a manner that dedicates resources specifically for one organisation or workload. Dedicated (private) cloud services may be deployed by a cloud service provider or deployed in a company data centre.
- **Hybrid cloud:** In cases where an organisation uses a combination of public and dedicated (private) clouds, the organisation is said to be using a **hybrid cloud** environment that may also include traditional on-premises IT resources.
- **Multi-cloud:** As companies increase their cloud adoption with applications/workloads spread across various public clouds, multi-cloud strategy becomes more common among users.

For more detail on cloud taxonomy and terminology, see the annex.

3.1.2 Edge Definition

Edge — Everything Between the "Core" and "Endpoints"

Historically, IT deployments have relied on significant centralised resources, such as data centres, to drive key business decision support systems. However, the data utilised by those IT resources are typically generated far from the core. Increasingly, newer use cases, such as those comprising the Internet of Things, are resulting in large numbers of additional data-generating devices being added to enterprise networks far from the data centre, at the edge of the network. And many of these remote devices can utilise data to take action, such as closing a valve, activating a machine, or operating an autonomous vehicle. Thus, with more data generated at the edge, and more opportunity to make use of that data at the edge, technology vendors are turning attention to new IT solutions and architectures that can support new use cases by putting computing resources closer to where they are needed, at or near the network edge.

The "edge" is the intermediate space between the data collecting endpoints and the core that supports all key business decision support systems. Depending on the usage, an edge can have a different meaning for each business. An edge device is typically connected to multiple endpoints to aggregate or process data.

Edge is typically a distributed computing paradigm that includes the deployment of infrastructure and applications outside of centralised data centre and cloud infrastructure, and placing them closer to where data is generated and consumed.

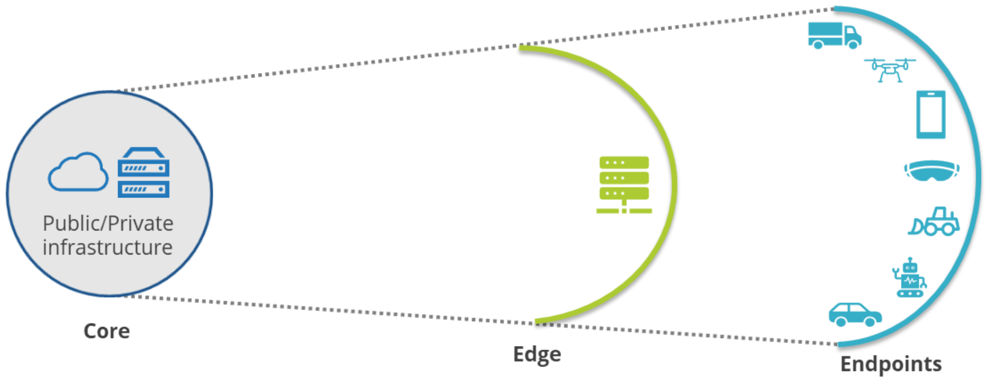


Figure 1 Edge Definition (Source: IDC European Edge Practice Research, 2022)

Characteristically, the edge is distributed, software-defined, and flexible and is the foremost technology infrastructure that extends and innovates the capabilities found in core data centres (DC), whether they are enterprise or service provider oriented.

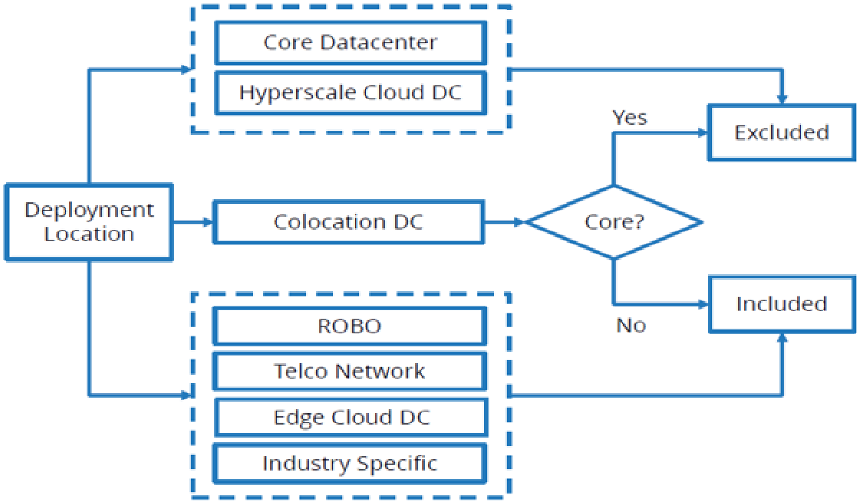


Figure 2 Edge Inclusions (Source: IDC European Edge Practice Research, 2022)

For more detail on edge taxonomy and terminology, see the annex.

3.1.3 Internet of Things

The Internet of Things (IoT) refers to a network of uniquely identifiable endpoints (or "things") that autonomously connect bidirectionally using IP connectivity. Thus, in a narrow sense, IoT refers to sensors and devices that collect data and the connectivity between them.

IoT also has a broader definition, beyond the connectivity of sensors and machines. In a broader sense, IoT refers to “an ecosystem in which applications and services are driven by data collected from devices that sense and interface with the physical world.” This ecosystem establishes end-to-end solutions that leverage those connected devices and the data they generate to obtain new insights, transform and automate systems and processes, provide new products and services, and bring a host of benefits to users, organisations, economies and societies.

The technologies that are used to assemble IoT solutions are discussed in more detail below.

Examples of IoT Features

IoT is used widely across all industries. The ways in which IoT is used vary greatly, with technology vendors targeting hundreds of different use cases with complete solutions. However, there are many capabilities that are common across many of those use cases. Some common features include:

- **Location tracking**: Many IoT use cases make use of sensors to track the location of key assets. They may use global navigation satellite systems (GNSS), such as Galileo or GPS, or other systems to determine location and then relay that data to a remote application. They can then use that data to locate assets, optimise routing, obtain more affordable insurance policies, or various other purposes.
- **Condition monitoring**: Many IoT solutions incorporate sensors for condition monitoring. They may track temperature, vibration, humidity, noise, light levels, atmospheric pollution or other conditions. With that data, an organisation may build a use case for ensuring temperatures during transport, preventing theft, measuring inventory, or many others.
- **Cameras and imagery analysis:** Cameras are proving to be among the most useful sensors. Due to mass production of cameras and advanced capabilities of AI-powered imagery analysis, cameras can be used for many IoT use cases. Instead of replacing an obsolete analogue pressure gauge or water meter, a camera can be pointed at the gauge, and analytics used to determine the reading. Cameras

also allow automated entry control systems for people and vehicles. They enable surveillance systems for physical security. And they enable quality control systems that check the quality of welding or that the correct components have been installed to on an automobile assembly line.

- **Smart and autonomous assets:** Many use cases begin with contextual information on location and conditions and then add smart devices and autonomous systems that can act on that data. Smart streetlights turn on after sunset or during a storm; Refrigerators activate if temperature gets too high; road signs display warnings if an accident occurs; alarms are sounded, and fire suppression systems activate if smoke and excessive heat are detected; farm fields are watered when sensors determine the soil is too dry; and so on.

For more detail on IoT taxonomy and terminology, see the annex.

3.2 History and Evolution of CEI

3.2.1 Intro

Cloud, edge and IoT have emerged in recent years as separate but linked technology trends. Cloud and IoT were largely distinct trends for many years, with cloud being an evolution and outgrowth of traditional IT systems, while IoT leveraged the emergence of small, connected devices and wireless connectivity. However, the two trends became complementary. Cloud became an enabler of IoT solutions, simplifying IoT deployments. And IoT has begun to drive usage of cloud resources.

However, as more and more IoT solutions are emerging with advanced capabilities, especially automated systems, there is a tension rising that is pulling computing resources closer to the edge devices. This tension led to the emergence of what is becoming a robust edge computing market. Vendors are developing various edge solutions, cloud players are developing an edge-to-cloud computing continuum, and IoT solution developers are developing a variety of new solutions with these technologies.

This section discusses the emergence of cloud, edge and IoT markets in greater detail.

3.2.2 Cloud: Evolution, Ecosystem and Maturity

Emergence of Cloud Computing

Cloud services represented one of the most dynamic areas of the IT market in Europe in 2021, expanding several times faster than most of the traditional IT categories year on year.

From the beginning, cloud services were not directly meant to eradicate traditional IT but add a new way of delivering IT resources to organisations. With time, this delivery model gained a lot of traction and in some areas (e.g. collaboration and communication software), cloud-based model started to dominate to make up more that 50% of the market value.

Today, it is becoming common to perceive cloud as an enabler of more digital transformation projects; hence, cloud appearing in the context of Internet of Things (IoT), advanced data analytics projects, workforce reengineering programs, and artificial intelligence/machine learning initiatives.

Cloud Ecosystem

Both international IT vendors and local players are present in Europe's cloud market, as are global and local pure-play cloud providers. In addition, telecommunications and data centre operators have launched cloud offerings, enhancing their positions in the European cloud market.

The top 5 vendors accounted for 40% of the European public cloud market share in 2021, showing how fragmented the rest of the market is. Leader Microsoft covers all public cloud services to a different extent, 40.9% of its income comes from IaaS and PaaS while 59.1% is generated by the SaaS service. The second position is held by Amazon Web Services (AWS), which has 13% of a public cloud market share and YoY growth at 37.6%. Salesforce.com completes the podium with 5.4% of public cloud market and a constant growth of 26.4% YoY. The remaining companies in the top 5 are Google and SAP. Five out of the top 10 public cloud vendors in Europe have consistent revenues in all three categories: IaaS, PaaS, and SaaS.

Data centre providers are very active in developing as-a-service offerings, primarily in infrastructure, and offer various delivery models for their resources. OVHcloud is one example of a traditional data centre provider that has been developing a cloud offering and building new business in the cloud.

Telecommunications operators continue to build presence on the cloud market, taking different approaches that create various results. Some focus on data centre services and establish and leverage their IT services subsidiaries (OBS or T-Systems), that develop various as-a-service products (backup, digital signage, malware, etc.). Operators try to set up marketplaces for partners' apps. Many continue to look for the right way to utilise their resources.

Deliverable 3.1 of UNLOCK-CEI provides an extensive view of the CIE ecosystem, including players focusing on cloud solutions within each major vertical.

Cloud Maturity

Out of all three technologies in the report, cloud is the most mature with most European companies using some form of cloud services in their everyday operations.

Organisations rarely stick to one cloud model and embrace multiple cloud to focus on environments that are best for a given workload or application. A recent end user survey showed that only 17% of organisations prefer to run their application exclusively on-prem or in a collocation space. Most companies opt for a mixed model combing own data centres resources with various cloud models. Cloud adoption differs depending on companies overall digital maturity and growth strategy, but also needs to take into account organisation's financing model or skills availability.

3.2.3 Edge: Emergence, Ecosystem and Maturity

Emergence of Edge

Until a few years ago, the edge was still an enigma, with players in the European technology and communications markets trying to find a coherent and cohesive terminology. At that moment, the edge was on a trajectory clearly defined by the hype: a few vendors had structured true edge offerings based on their own innovative but proprietary architectures. Many were repurposing existing products and solutions to be part of the game. Meanwhile, end users were asking themselves, "What is edge? And am I already using it or not?"

More than 20 years ago, the term "edge" appeared to address several technology objectives that were emerging at that time, such as improving response times, saving bandwidth, and reducing costs. These goals are still relevant, and they continue to address some of the biggest challenges many companies face in their technology infrastructure.

Fast forwarding to the present, the situation is changing. The widespread deployments of connected sensors, endpoints and IoT devices are generating a huge amount of new data, enabling new capabilities like real-time analytics for instant decision-making and automation. These new volumes and uses of data are driving a new need for low latency, making local data processing capabilities more critical than ever.

Complemented by cloud technologies, edge has become one of the most attractive technologies due to its major advantage that places computing resources near where much of the data is generated, consumed and distributed.

In this way, edge infrastructure has the overarching role of facilitating the processing of time-sensitive and/or bandwidth-heavy applications close to the data source, while cloud provides the necessary computing and storage capabilities to aggregate data from disparate sources, and to allow solutions to scale in sise and geographical coverage.

Storing, protecting, and analysing data at the edge helps end users and applications to access it more quickly than if it were sent to distant, centralised clouds or data centres. Local applications running on edge devices are also more resilient to network communications service interruptions. From a use case's perspective, edge environments ensure low latency and continuity when the connection to the core or cloud is unstable or intermittent. All these factors also help to contain costs for ongoing IT operations across distributed environments.

Decentralised architectures can combine remote edge infrastructure with centralised public cloud services, applying cloud or edge where they are most useful. Such combinations will see greater adoption and popularity moving forward, being the key to ensure agility, performance, and scalability.

Edge computing is also bridging the gap between cloud and other emerging technologies as AI, IoT and 5G, enabling a continuum of computing and storage capabilities from the cloud to the most remote parts of the networks, where endpoints are located.

Even though it is still an emerging market, the edge market has expanded significantly in the last couple of years, with new solutions developed to address specific industries and use cases as more organisations have started to understand the benefits and opportunities behind edge.

Compared to few years ago, edge adoption has become much more widespread. Both edge and public cloud have increased their share of infrastructure spending, at the expense of core data centres. This has been driven by most organisations' increasing need for manufacturing or business process automation and optimisation, improving customer experience, optimised asset management, or for automated threat-intelligence monitoring and prevention.

Moreover, many European organisations will continue to increase their edge investments if several factors will be resolved.

Figure 3 Factors Driving Investments in Edge IT Resources (Source: IDC's Future Enterprise Resilience & Spending Survey, 2022)

According to *IDC's Future Enterprise Resilience & Spending Survey (January 2022),* European organisations stated they will increase their edge investment if:

- They have proof that edge will increase profitability, efficiency, and sustainability.
- They can rely on a partner able to simplify their edge journey.
- Edge can improve safety and health of people.
- Edge can support with data sovereignty efforts.

Addressing all these requirements will be the foundation on which edge market will continue its expansion and establishment across Europe.

European Edge Ecosystem

The European edge landscape is continuously developing and, compared to few years ago when building an edge ecosystem required a very complex approach, now different edge players are applying a more structured approach, making the process simpler and faster.

The build-up of the edge value chain now sees different types of global technology vendors (service providers, infrastructure providers, telecom providers, system integrators, etc) at the epicentre of edge evolution in Europe. Most players moving into the edge market are specialised in a limited set of edge related areas. There is no player able to work across the four categories essential to edge architectures: hardware, software, services, and communications.

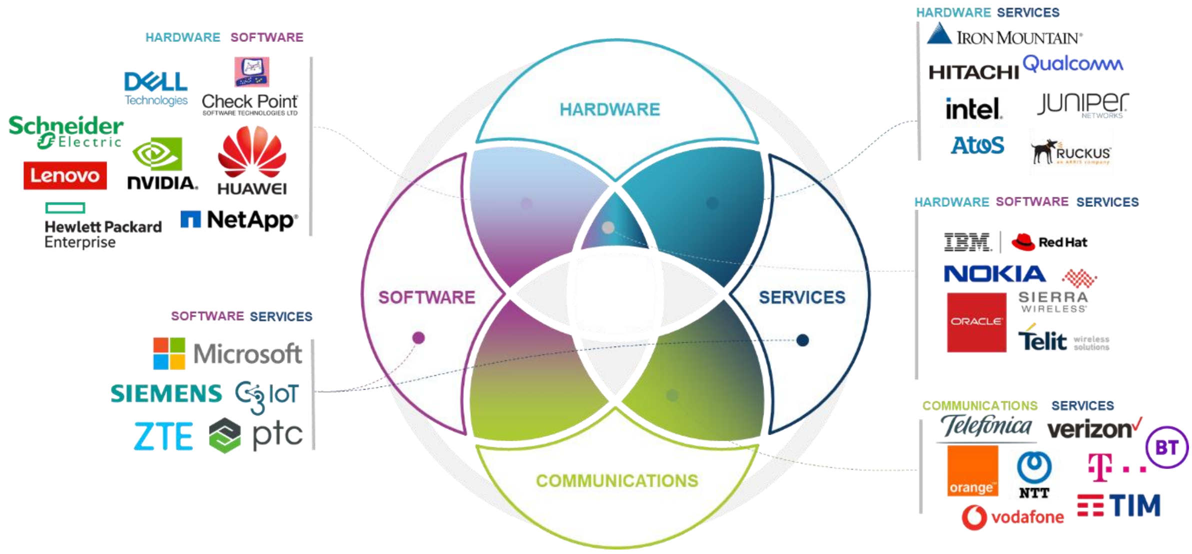


Figure 4 European Edge Ecosystem – Technology Overlap Analysis (Source: IDC European Edge Practice Research, 2022)

Edge remains a highly fragmented ecosystem where two-thirds of the suppliers play in only one of four key solution segments of hardware, software, service, or communications, and fewer than 10% play in three of the four. As a result, edge solutions tend to be led by a service engagement that brings in hardware, software, and communications services to provide an end-to-end edge solution.

To support the full stack of edge solutions, from infrastructure to applications, tech vendors are expanding their horizon and are starting to build their edge partner ecosystem.

The aim of the edge ecosystem is to expand their capabilities, to shape a common edge go-to-market approach, with a dedicated portfolio, and joint messaging, bringing to the table a different mix of capabilities, such as technology, regional know-how, industry, and use-case expertise.

Usually, hardware and software providers are building partnerships and alliances with systems integrators or telecoms providers to optimise their edge solutions' time to market and consistency. Telecoms providers partner with public cloud providers to implement edge cloud to bring the edge cloud closer to data. The aim is to focus on the entire use case solution to add value to the customer and avoid becoming a commodity provider.

Due to the highly distributed and complex edge type of solutions, customers require ongoing support and maintenance. In this case, consumption-based models, and managed services approaches for edge solutions to help customers avoid large upfront investment and to optimise long-term operational costs will be critical.

The largest edge vendors in the European market are based outside of Europe, but they have shaped their offering and capabilities to address European requirements. They are partnering with European vendors that can better understand the emerging European edge technology scenario and address specific demands from their clients.

Several European vendors, such as Schneider Electric, Orange Business Services, Deutsche Telekom, Telefonica, and others, also have a significant role in developing the edge ecosystem and environment across Europe.[7]

For example, Deutsche Telekom offers various edge computing solutions. In 2017, the company founded MobiledgeX , building a marketplace for edge resources and services that connects developers with the world's largest mobile networks to power the next generation of applications and devices. Then in 2019, Deutsche Telekom subsidiary T-Systems announced its edge computing platform, EdgAir, tailored to various industries such as production, logistics, building automation, automotive, and energy. T-Systems focuses on ad hoc custom-made digital solutions, offering fully managed edge services often in private network scenarios. More recently, they have partnered with Dell to develop solutions that will make it easier for enterprises and government customers to embrace the 5G and edge computing era.

Another example comes from Telefónica, its edge strategy leveraging the transformation of its network and infrastructure assets, developing an edge platform and edge networking capabilities. Telefónica offers data connectivity and ultra-broadband access capabilities (fibre and 5G) to third parties through network APIs to enhance edge services. Telefónica is working on IaaS services in partnership with leading hyperscalers to market their edge services while developing high-value use cases with them. The operator is also extending its own cloud services to the edge, with the launch of Virtual Data Centre Edge (VDC-Edge). Telefónica currently has different edge nodes across Europe, where it provides its VDC-Edge service, with further expansion of services and additional nodes over its geographic footprint planned for the next few years.

Deliverable 3.1 of UNLOCK-CEI provides an extensive view of the CIE ecosystem, including players focusing on edge solutions within each major vertical.

3.2.4 Internet of Things: Market, Ecosystem and Maturity

Emergence of IoT

The Internet of Things is an evolution of the Internet and the IT industry, in which IP networks interconnected virtually all personal computing devices and enterprise IT systems since the 1990s. Already during the 1990s there were some discussions of the widespread connection of things to the Internet, and the term was reportedly coined by Kevin Ashton in 1999. During the 2010s, the term became widely used and was embraced by technology vendors aiming to position themselves in this emerging space.

IoT's emergence happened in parallel to developments in industrial control systems. Industrial control systems have long utilised remote data collection on physical devices that sent data over a network to a control room. However, industrial control systems and IP-based information technology systems remained largely separate ecosystems until recently. Only in recent years are industrial control systems incorporating IP networks, integrating with IT systems and becoming Industrial IoT.

IoT Ecosystem

IoT was one of the early innovation accelerators that were built upon the foundation that mobile, cloud and big data created. Today, IoT interfaces or supports many emerging technologies such as artificial intelligence, edge computing, and operational technology (OT). IoT provides the capability to connect endpoints, collect information, and transmit the data to be computed, enabling organisations to make quicker decisions, observe deviances from norms, change business processes, and drive efficiencies — thus allowing other technologies to leverage the information as an input.

A diverse IoT ecosystem has emerged to make all of this possible. IoT solutions are comprised of many different components across the technology spectrum.

[7] *IDC, European Edge Vendors Coverage Analysis, December 2020*

IoT Hardware includes vendors of chipsets, connectivity modules, edge gateways, network routers and switches, servers, storage and many other components. Though some vendors are active in multiple areas, each component has its own competitive environment and key players. For example, the chipset market includes major players from North America, Asia and Europe, such as Qualcomm, Intel, arm, ST Microelectronics, Fujitsu, Infineon, and many others. IoT connectivity modules vendors include several Chinese vendors (such as Quectel and Fibocom), European players (ublox and Thales), and North American players (Sierra Wireless and Telit). Infrastructure vendors offering gateways, networking, servers and storage include companies like Cisco, Dell, Hewlett Packard Enterprise, Huawei, Eurotech and others.

IoT Software includes a wide range of submarkets and vendors. IoT platform vendors include many different types of vendors targeting various customer needs, such as application development, connectivity management, device management, and other features. Vendors include the likes of Bosch, Amazon Web Services, IBM, Oracle, Nokia, Ericsson, Cisco, SAP, Vodafone, Pelion, PTC, and many others. IoT security software includes many different types of offering, and a variety of vendors in each area. Some key vendors include Fortinet, Check Point, Cisco, Trend Micro, Kigen, Giesecke and Devrient, Symantec, Thales, and many others. IoT software also includes many analytics tools from companies like SAS, Amazon Web Services, Google, IBM, Software AG, and others. And there are also various embedded software vendors crucial to IoT, such as ARM, Canonical, Red Hat, Microsoft, and others. Throughout these software segments, there is a fierce competition taking place, in which vendors are rapidly developing and evolving their products, attempting to build a strong position in what remains a nascent market.

IoT connectivity includes a variety of communications service providers. Because of the immense infrastructure requirements and complex regulatory environments, network operators tend to be fragmented geographically, and there are many strong European players, such as Orange, Deutsche Telekom, Vodafone, Telefonica, and others. There are also many virtual network operators (such as Wireless Logic, EMnify, BICS, 1NCE, or Eseye) that utilise wholesale access to other companies' networks and compete on various factors, such as offering seamless connectivity across networks or offering lower-cost connectivity.

A variety of **professional services** is also required to make IoT possible. These services include consulting, solution design, hardware design, application development, installation, integration, management, and others. This market includes a variety of players, including smaller local players and large global companies, such as Atos, Capgemini, Accenture, EY, Cognizant, Logicalis, HCL, Tech Mahindra, Orange, Vodafone, and many others.

Finally, the IoT ecosystem also includes many companies focused on specific **industry solutions**. These include ABB, Honeywell, Schneider Electric, Bosch, Philips, Rockwell Automation, Samsara, SAP, Siemens, and many others.

Deliverable 3.1 of UNLOCK-CEI provides an extensive view of the CIE ecosystem, including players focusing on IoT solutions within each major vertical.

Market Maturity

The IoT market has evolved over the last decade, but it is not yet a mature market. The market's maturation is slowed by the extremely fragmented nature of the market. In practice, IoT is not really one market, but rather a combination of markets for every individual use case. For example, the industrial automation market has very little to do with the smart home appliance market, or the smart utility meter market. As a result, every industry, and often individual use cases, require the development of a specific partner ecosystem, standards, value chains and packaged offerings. And in each of these submarkets, the key players must develop a unique value chain, integrate with partners, educate the market, refine the offerings, optimise operations, and scale up the business. This maturation process has proven to be a slow.

While the market for various use case solutions remains highly fragmented, there are some horizontal technology layers that are crucial for many or all vertical use cases. For example, cloud infrastructure, application platforms and analytics are widely used across verticals and use cases for running various IoT applications. Likewise, many types of connectivity (cellular, LPWAN, Wi-Fi, Bluetooth, and others) are standard components for a variety of solutions. The same applies for modules, gateways, sensors, security software, and other components. So although the market is highly fragmented and immature, there are many technology areas that are maturing rapidly and enabling the solutions vendors to efficiently mix and match components to develop their end-to-end solutions.

3.2.5 Why CEI?

The cloud-edge-IoT continuum is emerging as a new foundation for building the next generation of digital organisations. Its origins, however, can be found in separate cloud, edge and IoT market dynamics of the past decade or more.

Cloud services emerged as a means for organisations to tap into external computing resources in a way that was complementary to traditional IT, as well as a means for data centre operators to optimise their assets, increase efficiency, and make use of their excess capacity. However, over time, cloud services have moved toward becoming the primary choice of delivery model for enterprise IT applications, platforms and infrastructure. Their enormous scale of operations and scalability of services make cloud services a strong candidate for providing the backbone of many IoT solutions. Furthermore, the scale of the business has allowed hyperscale cloud providers to develop wide portfolios of services and partners that together can make it easier for an organisation to develop and deploy an IoT solution.

IoT has largely emerged in parallel to cloud computing. The drivers differ; IoT was enabled particularly by the emergence of small, smart devices, wireless connectivity, and the merger of IT systems with operations systems. Yet as the two technologies have grown toward maturity, they have become an effective pair. Cloud hyperscalers see IoT as a likely driver of data and applications for cloud resources in the future. To enable easier use of cloud for IoT, Microsoft and Amazon Web Services have developed services tailored for IoT devices and solutions, while Google relies more on partners to fulfil those functions.. Those improved cloud-based services have made it easier for organisations to develop and scale their IoT solutions.

However, cloud and IoT are not always a perfect fit. Many IoT use cases require rapid response and automated control systems. Such use cases have sensors and actuators in one place, while the cloud computing may be hundreds or thousands of kilometres away. It is not logical to place control systems so far from the device. It also may introduce additional costs (network transmission and cloud resources), security concerns (as the data unnecessarily leaves the premises), and other risks (in the event the connection is lost, and the controls fail to operate correctly). Furthermore, operating the system via distant cloud resources may risk service degradation to the point that the use case cannot be deployed at all.

As IoT matures and organisations develop more and more advanced solutions, there is a growing need for computing solutions that put resources close to where the data is generated and consumed, at the edge. This need explains the emergence of edge computing solutions.

Despite the move of some computing needs to the edge, there is unlikely to be a battle between cloud and edge but more of a complementarity. The market is evolving to put computing resources where they make the most sense – sometimes at the edge, sometimes in the core, and often a combination of the two.

4. Current and Planned Uptake of CEI

This chapter discusses the level of adoption of CEI in Europe, as well as the future forecast. It will also discuss perspectives on the complementary technologies such as AI, robotics, 5G, etc. It includes a brief description of selected use-cases, as well as the leading use-cases per vertical (3 per vertical).

This chapter currently utilises existing IDC research and analysis. Upon the completion of the survey dedicated to the UNLOCK-CEI project, this chapter will be updated with the survey results.

4.1 Cloud Adoption

Awareness and Adoption

Cloud services are adopted and used by companies in all industries, although not all invest in cloud at the same level. In 2021 in Europe[8] distribution and services sector accounted for 33.8% of the total public cloud spending, followed by manufacturing and resources at 22.2% and financial sector accounting for 17.8%[9].

According to the IDC's Multicloud survey, companies see cloud as a technology platform supporting their businesses: 40.3% of European organisations using or planning to use cloud claim cloud helps them save costs, and the same share of companies states that cloud helps modernise their applications.

For European companies, cloud provides a platform to develop new products and services and set the foundation for new business models and new revenue streams. Increasingly, cloud is leveraged to deal with the IT skills shortage and to achieve sustainability goals.

Cloud adoption is no longer perceived as just a technological initiative. Much more often, a platform is adopted for business reasons to improve an organisation's business resiliency or accelerate business transformation. As technology that changes the way companies operate, cloud drives cultural and organisational change.

There are certain business benefits that companies expect to achieve with cloud adoption. Organisations want to achieve higher business and IT productivity, enable remote access and hybrid work, improve customer experience and increase customer loyalty. Cloud is also seen as a way to reduce risks related to data security and achieve better regulatory compliance. Many users reach for cloud platforms to enable efficient and rapid software development and deployment and enhance agile organisational platform.

Cloud strategy approaches have also started to shift. For a long time, companies looked for "cloud first" or "cloud only" as a way to introduce cloud into their IT platforms. "Cloud first" has often been the strategy of choice for companies starting or accelerating their cloud journeys. Some companies have adopted a pragmatic "cloud also" strategy, wherein they use cloud in areas where it makes sense. After several years of discussions about the best cloud strategy, companies are increasingly aware that the problem is not in using cloud per se; rather, the challenge lies in skilfully matching cloud solutions to individual processes and to the applications and IT systems that support those processes. Consequently, organisations are moving to a "workload first" approach, whereby the requirements of business processes and supporting applications and systems determine the appropriate cloud strategy.

Planned Usage

In terms of cloud use, most companies in Europe have some exposure to public cloud. However, not all companies are equally open to using cloud.

In a 2022 survey[10], 17.0% of European organisations surveyed still preferred to run things on premises or collocate exclusively, while another 34.8% preferred to run things on premises or collocate, but used public

[8] IDC Public Cloud Spending Guide
[9] Worldwide Public Cloud Services Spending Guide
[10] IDC, European Multicloud Survey, September 2022

cloud where they needed to. However, 34.9% of respondents said they take a balanced approach between on-premises/co.-location and public cloud, while 9.4% generally preferred to use public cloud and use on-premises/colocation where they needed to. Only a tiny group of 1.8% used public cloud exclusively. This high usage of on-prem/co-location results from the fact that most companies already have their own IT resources. Cloud is more common as a new environment or a replacement of decommissioned resources rather than a completely new IT platform for the whole organisation. Companies relying exclusively on cloud usually are new, digital native organisations with limited or no legacy IT to deal with.

From a spending perspective, in 2021, European organisations spent most on their core data centres (28.2% of an organisation's total infrastructure spending), followed by public cloud IaaS (18.8%) and public cloud PaaS (18.3%). Edge spending has been growing most dynamically in recent years accounting for 15% of total infrastructure spending in 2021. European companies spent least on third-party data centre services in 2021 – 16.5%.

Public cloud is not the only cloud model used by European companies. In 2021 67.8% of companies run a private cloud environment (customised on-prem private cloud; standardised cloud stack, such as AWS outposts, AzureStack, Google Anthos, Red Hat Openshift, etc.; or hosted private cloud). The increasing complexity of the IT environment is reflected in the growing share of customers running hybrid IT platforms (i.e. a combination of private and public cloud often integrated with local resources) or even multicloud (multiple public clouds).

Maturity

European organisations differ significantly with regard to how mature their usage of cloud is. In a recent survey[11], the largest share of European cloud users (30.5%) declared their approach to cloud as "opportunistic". For such organisations, their use of cloud may be requested by internal stakeholders with no significant training/certification and limited ability to share resources or create scalable and repeatable implementations.

The second largest group describes their cloud maturity level to be "repeatable". They make a consistent effort to leverage and reuse best practices and resources across multiple projects and business units (24.1%).

Another large share of organisations have a cloud strategy that they consider to be "managed". For them, cloud is offered across the business and supported by proactive business leadership driving decisions about strategy, growth, and investments (22.4%).

Only 12.2% of European companies describe their cloud maturity level as "optimised". Such organisations have implemented a substantial cloud team that is proactively managed, resourced well, and clearly driving business growth.

Still, 10.1% of organisations deals with cloud in an "ad hoc" manner. They focus primarily on pilot projects and validation activities driven by the needs of individual projects or business units.

The figure below shows how companies see their cloud maturity.

[11] *Ibid.*

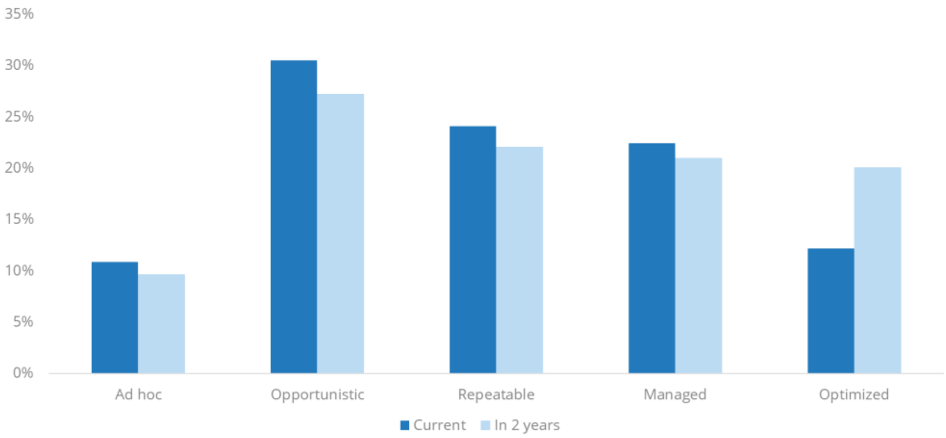


Figure 5 Cloud Maturity (Source: IDC's Multicloud Survey, September 2022 n = 1077)

Market Forecast

In 2021 the European public cloud market reached $86.9billion[12].

From a geographic perspective, the DACH region (led by Germany) is the leader and accounts for 26.5% of the total public cloud market in 2021, to reach 27.5% by 2025. The U.K. and Ireland (UKI), the second-largest region in Europe, is the only region in Western Europe, which share is predicted to decrease from 23.9% to 22.6% in 2026. The share of France, the third-largest region, is predicted to slightly increase from 13.1% in 2021 to 13.4% in 2026. The Nordic region also has a significant share of 11.2% and will remain quite steady over the next five years. Finally, Benelux and southern Europe are the smallest Western European subregions with 9.5% and 9.1% shares in 2021, respectively. The Central Eastern European (CEE) region is the smallest (6.7%) in Europe and with the slowest growth (18.9%).

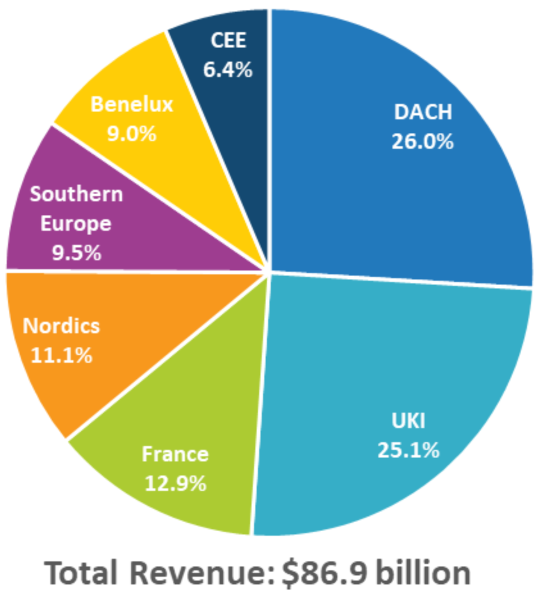


Figure 6 European Public Cloud Revenue Share by Region, 2021 (Constant $M) (Source: IDC 2022)

The European public cloud market is estimated to reach $109.5 billion in 2022 and forecasted to grow to over $232 billion by 2026, with a five-year compound annual growth rate (CAGR) of 21.8% for 2021-2026[13]. This

[12] *IDC, Worldwide Public Cloud Software Tracker, May 2022*
[13] *Ibid.*

forecast is based on assumptions, market trends, and top-down view of the market in May 2022 and considers macroeconomic events that recently occurred in Europe such as the war in Ukraine, inflation, or supply chain disruptions.

Public cloud continues to be the number one cloud solutions service especially for its cost effectiveness capability, which has become critical at this stage. Indeed, with the pandemic crisis, European organisations carefully weighted their investments and optimised their costs. However, to a smaller extent, IDC sees major interest in other cloud computing models, such as private cloud, hybrid cloud, multicloud, as well as in containers or serverless solutions as not all business applications and services can be fit in the same cloud.

In the next five years, IDC predicts that many European organisations will invest in public cloud and its models to continue the shift from on-premises to cloud solutions. The main cloud services include:

- **IaaS + PaaS.** Accounting for 34.3% of 2021 public cloud revenue and growing at a 28.8% five-year CAGR through 2026, IaaS + PaaS will achieve a revenue of $105.9 billion by 2026. Please note that in this IDC Market Forecast, the IaaS and PaaS markets are covered as one space.
- **SaaS.** Accounting for 65.7% of 2021 public cloud revenue and growing at a 17.3% five-year CAGR, SaaS is the largest public cloud service, but also the slowest growing one. It will achieve a revenue of $126.9 billion by 2026.

4.2 Edge Adoption

Edge Adoption

Despite the very unpredictable environment in Europe, firstly due to the pandemic and then to Russia-Ukraine War, inflation, high energy prices, and supply chain disruption, the edge market proved to be resilient and continued its evolution, though at a lower growth rate.

Edge computing is now seen as part of the solution as many organisations are starting to understand the benefits and opportunities that edge could bring, such as reducing costs, boosting performance, improving privacy and data security, and enhancing scalability and reliability, all very important benefits in such a volatile environment.

The edge landscape across Europe looks better than a few years ago, with European organisations now investing approximately 15% of their total infrastructure spending on edge workloads and solutions[14].

Both edge and public cloud significantly increased their shares of infrastructure spending, at the expense of core data centres, driven by the increasing need for process automation and optimisation, improving customers/users experience or for automated threat-intelligence monitoring and prevention.

According to a 2021 survey on emerging technologies, one in three European organisations are implementing edge computing solutions in their daily business, with this number expected to double over the next two years.[15]

The level of adoption also depends to the different organisational dimension, with large enterprises outperforming smaller organisations in adoption edge solutions in a more structured way.

Edge Maturity

However, despite the interesting level of adoption across Europe, maturity remains low. Most of these organisations are implementing edge solutions in a pilot or educational phase, with only a small share of them adopting these solutions in a more structured way.

[14] *IDC, European Infrastructure Survey 2022, N=928*
[15] *IDC, European Emerging Technologies Survey, 2021*

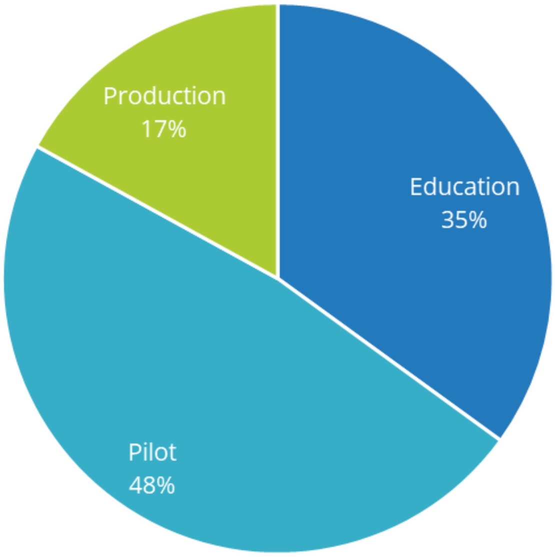


Figure 7 Distribution of adopters of edge across maturity phases (Source: IDC's European Emerging Technologies Survey, 2021)

Around 35% of respondent companies are in the education phase, building awareness and familiarity with the technologies. A larger share (48%) is in early-phase pilots of edge solutions, with most of these limited to smaller pilots in a single business unit, rather than at company-wide scale. As often happens with emerging technologies, making the case for shifting from a pilot to a fully deployed solution (production use) is complex. As a result, only 17% of European companies having done so, with less than half of those having deployed those solutions to the full company.

Germany, France, and Italy show the highest maturity. Overall, Western European countries are more advanced compared with Central and Eastern European peers. Distribution, infrastructure, and manufacturing/resources are the leading sectors, with more than one in five adopters already beyond the pilot phase.

According to *IDC's Future Enterprise Resilience & Spending Survey*[16], organisations find it difficult to extract meaningful insights from data gathered at edge locations. Almost half have gathered a large amount of data - but they don't extract insights from it yet. Only a quarter are using data gathered at the edge to gain meaningful insights.

This creates a larger structural problem: organisations need the right resources (people, tools, and infrastructure) to be able to extract data insights and to base the decision-making on them, and while the tools and infrastructure are available and can be built, people with the skills to design, build and operate edge solutions are in short supply, and expensive.

Despite the many opportunities and benefits edge could bring to European companies, adoption is still hampered by several barriers, such as lack of know-how and skills specialised on deploying the technology, still having old infrastructure, unclear return of investment, concerns related to initial implementation costs, or even privacy and security concerns.

However, deployed correctly and with the necessary guidance, edge is a technology able to drive significant value to various industry sectors.

[16] *IDC, Future Enterprise Resilience & Spending Survey, 2022*

In this case, the role of technology providers is essential, as they need to understand that technology itself is not the only aspect driving the conversation about edge but also the edge use cases, the different features that may need a personalised approach.

Some of these edge use cases that are emerging and driving the spending and adoption across Europe were indicated as most important for European organisations, according to *IDC's European Infrastructure Survey 2022*, *n=928*, as seen in the following figure.

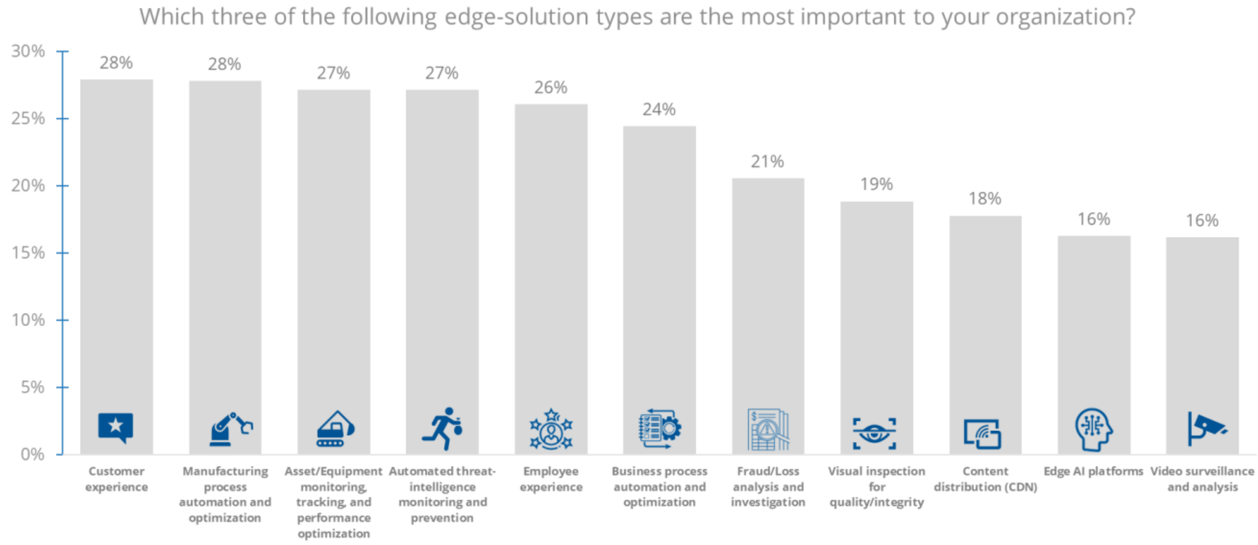


Figure 8 The Most Important Edge-Solution Types for European Organisations (Source: IDC's European Infrastructure Survey 2022)

As cloud is already mature and established, another way to approach the edge conversation is through thinking about the cloud-to-core-to-edge continuum and to emphasise the complementary nature of both. Now cloud represents a strong opportunity for edge as cloud players are expanding their presence to the edge with new infrastructure and communications capabilities and partnerships, building up the service providers value chain for delivering the hybrid edge for the "millisecond war" by leveraging new types of purpose-built edge infrastructure combined with 5G networking capabilities.

Moreover, edge is often the architectural choice supporting and enabling other emerging technologies and this will expand even more its adoption in the next couple of years. For example, edge supports a range of IoT and robotics deployments in managing large amounts of data, reducing time to action, and enabling processes to remain active even when disconnected. Another case is for AI, where inferencing is increasingly performed at the edge, reducing latency as well as keeping bandwidth use down. Also, the critical role of low latency and high bandwidth in retrieving real-time data makes edge the perfect candidate for AR/VR deployments. As for communications side, 5G heavily relies on distributed computing and storage capabilities, with edge being a critical component in both public telecom networks and private network deployments.

Edge Spending Outlook

Looking ahead at the edge market landscape in Europe, there are significant developments that will drive the edge spending in the region:

- European edge spending will grow from nearly $38 billion in 2021 to $75 billion in 2026, with a five-year compound annual growth rate (CAGR) of 14.6%. Edge is one of the key technologies on which organisations are relying to unlock new digital capabilities for innovation and performance.
- Compared with Central and Eastern Europe (CEE), Western Europe sees a more established and developed edge scenario. Nevertheless, edge adoption in CEE is expected to gain traction over the forecast period, despite being impacted by the continuous crisis in Eastern Europe, albeit at a slower pace than Western Europe.

- Within the three main edge technology segments, services (including professional and provisioned services) will continue to make up the biggest part of the total market. Services will grow at a faster pace compared with the other technology groups. Hardware is the second-largest market, driven by spending on light-edge deployments.
- In the enterprise area, edge is key in supporting a wide array of emerging technology markets, which are driving the overall edge market and generating value outside core data centres. Internet of Things (IoT) is the largest domain within the European edge market, followed by artificial intelligence (AI), which presents vast capabilities on real-time data processing. Augmented reality/virtual reality (AR/VR) is the fastest-growing domain while robotics and drones have a lower share.
- Within enterprise industries, the distribution and services sector along with manufacturing and resources have the largest share of European enterprise edge spending; these sectors will account for more than half of the market. Edge use cases linked to the IoT and AI domains will drive developments in this sector, especially in manufacturing.
- The largest investments linked to service providers delivering edge services to enterprises will stay within content delivery networks (CDNs) and virtual network functions (VNF) use cases, making the service providers' domain the fastest-growing spending area through 2026.

The Russia-Ukraine War still represents a critical geopolitical crisis across the world; its effects are no longer restricted to Eastern Europe and have already spread across the entire region, heavily impacting trade, supply chains, capital flows, and energy prices on a broader level and ultimately affecting how consumers and businesses are behaving in such an uncertain and volatile environment.

In this scenario, it is difficult for the European edge landscape to escape the consequences of this crisis. However, the edge market remains resilient as its development is expected to continue and new specific edge use cases will increasingly be addressed by the European edge ecosystem. European edge spending is expected to reach $43 billion by the end of 2022 and increase to $75 billion in 2026, driven by demand from organisations seeking to reshape their investment plans and shift toward improving their innovation, automation, and optimisation capabilities as well as customer experience, which can be critical in challenging situations.

Regardless of the spill-over effect from the ongoing geopolitical and macroeconomic issues affecting Europe, edge will continue to gain momentum over the next few years, with spending estimated to still reach a 14.6% 5-year CAGR by 2026.

Being aware of how edge can change the traditional approach on how data is managed and used to increase efficiency and performance, one in three European organisations will increase their spending in their own edge environments, workloads, and solutions, while 40% will keep the same spending pace as last year[17].

With data and information expanding beyond core IT environments, edge will provide many businesses great opportunities and applications such as data creation, processing, and management at the edge; improved real-time decision-making process; high network availability, speed, and efficiency; advanced data analytics and automation; and improved security and privacy.

Edge Market by Technology Categories

In terms of technology spending, the services market (including provisioned and professional services) is the largest category in the European edge market and is expected to remain a key component of the edge scenario, even in the geopolitical and macroeconomic context in Europe.

The cloud portion (cloud services delivered from edge locations, such as infrastructure as a service - IaaS, software as a service - SaaS, and platform as a service - PaaS) of edge services spending represents a minor portion of the services component at the moment but will play an ever more important role in edge services,

[17] *IDC's European Infrastructure Survey, May 2022, n = 928*

driven by the acceleration of revenue-generating and return-to-growth projects that combine remote edge deployments with cloud to support greater automation and performance.

The edge professional services market promises to be of high interest for service providers and technology vendors, as there are great opportunities for addressing organisations' requirements for low-latency edge services that can improve processes, support new consumer applications, comply with data sovereignty, and deal with security threats.

Despite the spill-over effect of the COVID-19 pandemic, geopolitical conflicts, and macroeconomic issues across Europe, IDC expects hardware edge spending to remain more resilient than overall core data centre spending, evolving quickly to adapt to new requirements coming from enterprises. Distributed and specialised hardware will continue to play a critical role in data processing in specific physical locations.

Hardware spending will be led by significant investments in edge gateways linked to light-edge deployments and heavy-edge computing platforms as new generations of edge-specific hardware come to market.

Hardware remains a critical part for IoT deployments at the edge, being the underlying infrastructure responsible with controlling data flow, collection, and processing of valuable data at the network edge.

The edge software market is expected to slightly decline over the forecast period, due to the accelerated shift to as-a-service deployments. Software used for data management, integration and orchestration, application development, software quality and life cycle, and application platforms together make up for the largest part of the edge software market.

Edge Market by Industry

In terms of industry spending, the uncertainty about the macroeconomic and geopolitical situation across Europe and other countries may lead organisations in some industries to limit some investments or reprioritise spending to protect themselves against additional disruptions. However, the benefits of edge still will encourage European industries to keep the pace of adoption or even increase in some cases, driven by the interesting capabilities that edge can enable across various verticals and use cases.

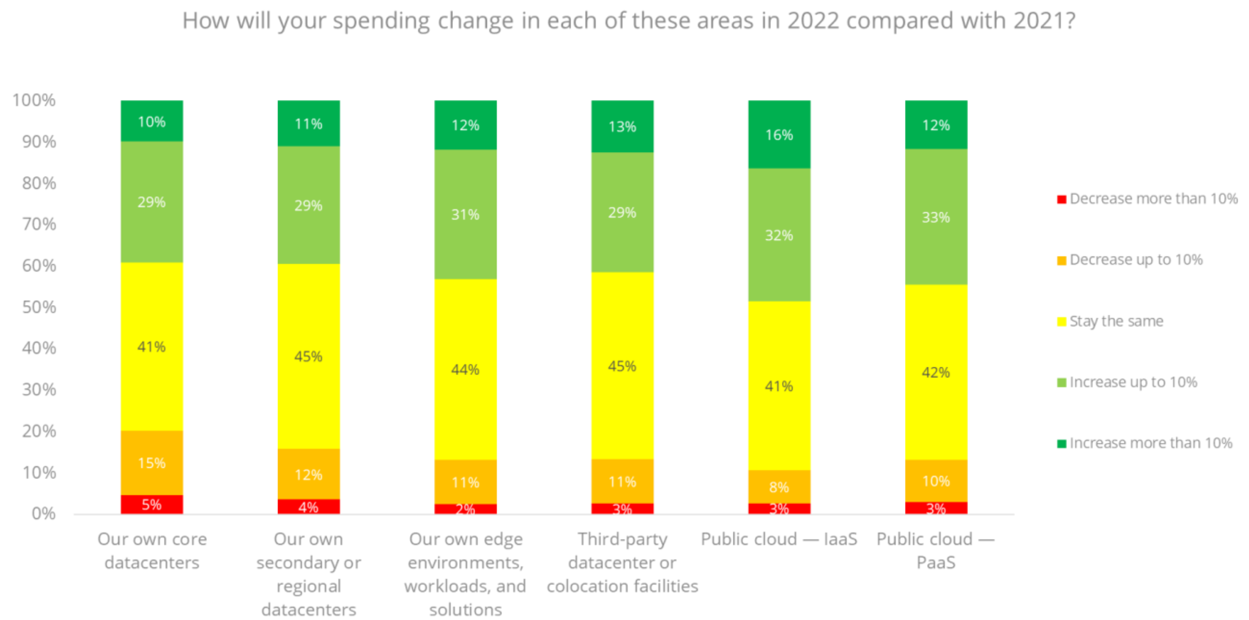


Figure 9 Investments in Edge 2022 vs 2021 (Source: IDC's European Infrastructure Survey 2022)

Many industries will benefit from the development of edge, starting from manufacturing, resources, distribution, or infrastructure, where capabilities such as real-time supply chain monitoring, inventory management, asset remote monitoring, or enhanced virtual experiences can make edge a technology able to drive significant value.

The service provider sector is the fastest-growing area within the European edge scenario, capturing spending from providers that deliver edge services to any of the previously mentioned enterprise industry sectors. The service provider sector includes the delivery of edge-related hardware, software, and services technologies and spans across use cases such as content delivery networks (CDN), multi-access edge computing (MEC), and virtual network functions (VNF).

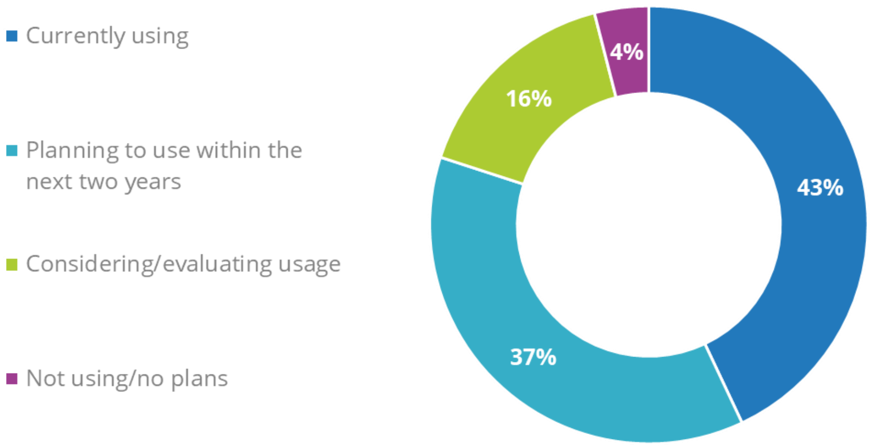
The service provider sector represents one of the most interesting areas for the European edge market, as many organisations that lack of in-house edge expertise skills will seek for a trusted provider that can simplify their edge journeys by delivering a full-edge technology stack and responding to their demands in a timely manner. Skills shortage being one of the major challenges for European organisations, the development of service providers area will be critical to support organisations fill this gap and to help them build their edge journey.

Overall, despite still being an emerging market, the rapidly maturing edge computing ecosystem represents one of the most attractive technology areas for investment, having tremendous applications for IoT and other underlying technologies (such as AI, AR/VR, robotics etc) by bringing computation closer to the data source, significantly reducing the response time, improving bandwidth utilisation, and reducing the overall operational costs. In a world where massive amounts of data are being generated every second, it will be critical for organisations to be able to act upon the data as fast as possible.

4.3 Internet of Things

IoT Adoption

The Internet of Things is now a well-established and well-understood concept across the public and private sectors. All industries have indicated that they are well aware of IoT and that the intend to use it. Very few organisations have no plans to use IoT. For example, in a recent IDC survey of European organisations with more than 100 employees, 43% said they are currently using IoT. Another 37% said they plan to do so within two years. Together, that means that 80% of organisations are planning to use IoT. Most of the rest are unsure, stating that they are considering or evaluating IoT. As a result, only 4% of respondents said they have no plans for IoT.



Question: Does your organisation use or plan to use the IoT within its own business activities?
N=987 (all respondents)

Figure 10 European Usage and Plans to Use IoT (Source: IDC, European 5G and IoT Survey, June 2022)

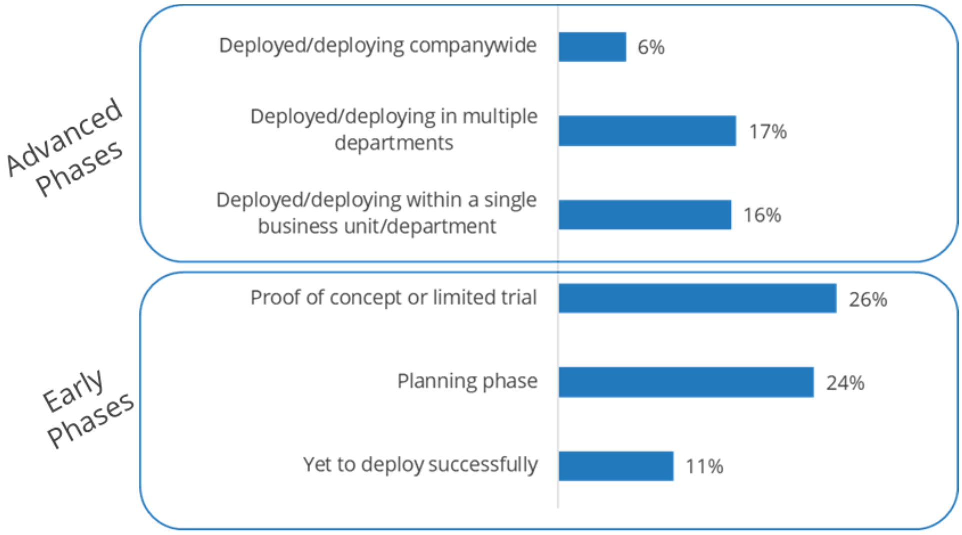
All industries are committed to IoT. The level of adoption differs slightly across industries, with public sector deployments lagging slightly behind commercial sectors. However, a large majority of organisations in every segment is committed to IoT within two years.

Results also vary by the size of the organisation, with smaller companies reporting lower levels of IoT adoption (33.6% of those with 100 to 249 employees, compared to 45% of those with over 5000 employees). Yet here again, every segment has strong plans to deploy IoT, with 71% of those smaller organisations either using or planning to use within two years, compared to 74% of those larger organisations.

Overall, European organisations across all verticals understand IoT and are committed to utilising IoT within their organisations.

IoT Maturity

Though IoT adoption plans are optimistic, the market remains in an early phase of development. In addition to the fact that nearly half of those organisations committed to IoT have not yet deployed an IoT project, those projects that have been deployed are often in early phases. For example, in that same survey, those who have deployed at least one IoT project were asked about the maturity level of their projects. Most respondents said that the majority of their projects are in early phases of development, such as planning, proof of concept, limited trial, or simply not yet successfully deployed. Far fewer organisations reported that the majority of their projects were deployed and fully operational. And those that were deployed were more likely to be within a single department, rather than deployed widely across the organisation.



Question: What best describes how mature the majority of your organisation's IoT projects are today?
N=426 (those currently using IoT)

Figure 11 European IoT project Maturity (Source: IDC, European 5G and IoT Survey, June 2022)

As the above data shows, IoT is being widely embraced throughout European organisations. However, the market is still early in its development. Many more organisations are expected to add IoT projects. Furthermore, many of those already using IoT are expected to add more projects and to scale their projects more widely within their organisations.

This growing demand is expected to continue, even if the wider economy faces challenges. Organisations tend to consider IoT to be important in a variety of market conditions. IoT is often considered to be a key part of long-term digital transformation initiatives, which will be needed for organisations to thrive in the long-term. Additionally, many IoT use cases are oriented toward increasing efficiency, which can help organisations to cope with challenging economic environments. As a result, IoT adoption and project implementation are expected to continue to grow rapidly.

The expected growth in IoT adoption, deployment and scaling is reflected in forecasts of European spending on IoT. According to IDC, European IoT spending will reach EUR 176 billion in 2022. That figure will grow at a compound annual growth rate of 10.0% to 2026, reaching EUR 258 billion.

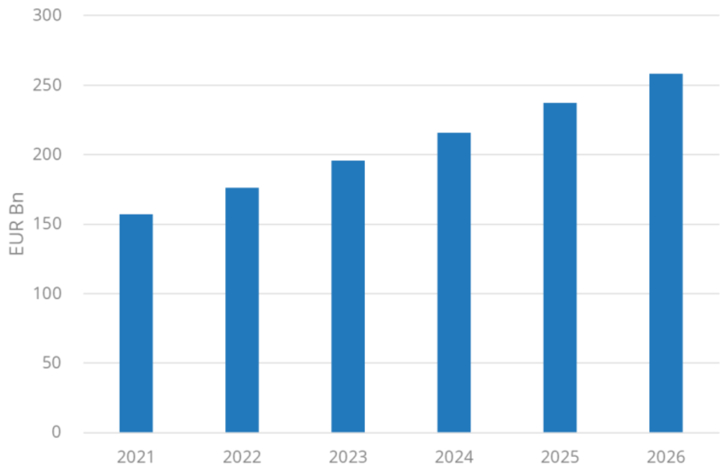


Figure 12 European IoT Spending Forecast 2021-2026 (Euro Billion) (Source: IDC, Worldwide Internet of Things Spending Guide, May 2022)

4.4 Key CEI Use Cases

This section reviews some of the most common use cases observed in the key verticals discussed in this study. Among these use cases, many are highly specific, tailored to unique needs of a given industry, while others are more generally applicable, used across multiple industries. Additionally, these use cases feature a wide variety of technology requirements.

In terms of network connectivity requirements, some are mobile, requiring the use of mobile networks, while others are stationary and on-premises, making them suitable to LAN connections over cabling or short-range radio. Some use cases are stationary but located on a third-party's premises (such as a vending machine), which often requires mobile connectivity. There are also large differences in the volume of data being sent over the networks, from large video files to small amounts of sensor data. And there are also significant differences in the tolerance for network congestion, with some use cases comfortably allowing for intermittent connectivity, while others may require constant connectivity with the guaranteed highest quality and reliability. All these factors influence the types of computing infrastructure that a use case will require.

In addition to network and data requirements, other factors also influence the ultimate decisions about computing infrastructure. Cost is a key factor. Costs may be affected by hardware decisions, management requirements, network connectivity requirements, and others. For example, a use case sending large volumes of data at the highest possible reliability will face significant costs for using cloud services, but those costs might be reduced via local edge computing. Another use case might feature low data volumes with modest quality requirements from many different distributed endpoints. Thus, edge computing may bring limited benefits, with most compute located in the cloud. Or such a use case might benefit from the use of light-edge gateways to aggregate endpoint data and send it to the application in the cloud.

Thus, there is not one specific architecture or infrastructure decision that is right for all use cases. This section highlights selected use cases and some of their typical requirements that might lead to various decisions about the cloud-edge compute continuum.

4.4.1 Manufacturing

Manufacturers are expected to make significant use of edge computing. This industry has concentrated facilities, makes large investments in IT and operations technology, and often has significant staffing of engineers and maintenance workers on-site. With the use cases and support teams all in one location, there is a strong case for keeping the compute infrastructure in that same location. Furthermore, many manufacturing use cases require high reliability and low latency, which also point to keeping the compute infrastructure close to the endpoints.

However, manufacturers also commonly manage multiple facilities, supplier networks, distribution networks, warehouses, and their smart connected products themselves. These widely dispersed data sources point to the need for some centralised computing resources, which may include a combination of traditional IT and cloud-based systems. As a result, manufacturers are expected to be among the leading innovators and adopters of CEI technologies.

Typical use cases seen in manufacturing include:

- **Manufacturing operations automation**: This use case includes significant use of sensors, automated operations systems, robotics and autonomously guided vehicles (AGVs) to automate factory operations. Such solutions are concentrated on-site and are likely to utilise heavy edge infrastructure.
- **Smart connected manufactured products**: Smart products are distributed regionally or globally to commercial or private customers. They often use mobile network connectivity back to central applications. Such use cases are likely to rely on central cloud-based compute infrastructure.
- **Quality control using cameras and imagery analysis**: Quality control systems are being automated with the use of cameras and AI-based image analysis. Such systems often sit on the factory floor, where edge compute resources are available. However, they may also rely on cloud resources for the imagery analytics.
- **Other**: Manufacturers also utilise many other use cases, including many that are common across verticals, such as energy monitoring and optimisation, smart buildings, video security and surveillance, and many others.

4.4.2 Energy and Utilities

Energy and utilities comprise a broad sector that includes many component parts with their own CEI requirements. For example, it includes upstream energy production (such as oil and gas exploration and extraction); mid-stream pipelines and refineries; retail filling stations; electric vehicle charging infrastructure; power stations; power grids; and local power, water, and gas utilities.

Despite the variety, these organisations bear many important similarities. They operate complex critical infrastructure; their assets are widely dispersed, often in difficult locations; they require extensive use of IoT and industrial control systems for monitoring and operating their systems; these control systems require very high reliability, despite being widely dispersed and often in locations with poor network coverage.

This combination of features leads to extensive reliance on various kinds of IoT, with some of it linked to extensive edge computing solutions in key locations, and others managed at a distance via centralised computing infrastructure.

Among the use cases seen in this vertical are:

- **Smart grid management and control systems**: Smart grid management includes devices to control and optimise power flow to ensure efficient, safe, and reliable service. It applies to a distribution grid including line sensing, substation automation, feeder and line equipment control, and optimisation.
- **Smart meters**: These are located at customer premises and connect back to central systems via direct cellular connection, or via a gateway used as an aggregator.

- **Connected drilling and extraction operations**: Oil drilling and extraction makes extensive use of high-value machinery that requires continuous monitoring and maintenance. Much of the sensing, alerts and predictive maintenance must be managed locally with edge computing, while being connected over limited satellite connection to central computing resources.
- **Drone-based network and pipeline observation**: This use case utilises drones to travel along networks and pipelines to observe leaks or encroachment of vegetation that requires action. AI-based image analysis can automate the process. Such a use case is most likely to utilise centralise computing resources.
- **Sensing for closed wells and other decommissioned infrastructure**: IoT devices can monitor decommissioned assets and facilities for safety and security.
- **Other**: This sector also makes extensive use of cross-vertical use cases, such as fleet management, condition monitoring and video surveillance.

4.4.3 Transportation

The transportation industry includes public passenger transport systems, private vehicles, freight logistics, transport infrastructure, and other components. Within this sector, many assets are mobile, moving throughout a country, region or globally. They may also travel in and out of terrestrial network coverage, such as during transoceanic shipping. And many of these mobile assets are increasingly intelligent and expected to operate autonomously in the future. This combination of high levels of functionality and automation, combined with high mobility and intermittent network coverage suggest a combination of on-board computing resources and centralised monitoring and management.

Common use cases in this vertical include:

- **Fleet tracking, monitoring and management**: These solutions allow vehicle fleets to be tracked. Their location is monitored, enabling optimised routing, as well as prevention of theft. They also allow predictive maintenance, freight condition monitoring, driver safety monitoring, and other benefits. These solutions can operate with relatively simple endpoints connected over cellular networks to central computing.
- **Freight tracking and monitoring**: This use case is similar to fleet management, but it focuses on tracking the freight items themselves.
- **Port operations**: Ports are highly complex operations with very large, expensive machinery that is monitored and managed and gradually moving toward autonomous operations. These assets must interact with continuous flows of ships, trucks, trains, containers, and workers. Ports must manage this complex environment, moving freight and vehicles in and out, while ensuring worker safety. Ports are increasingly deploying private mobile networks (4G and 5G), combined with local heavy edge computing to manage these port operations.
- **Autonomous vehicles**: Most vehicle categories are moving toward autonomous operations. These vehicles need extensive on-board sensing, computing, and analytics systems, as well as powerful connections to central systems to share data on road conditions, enable the continuous training of analytics models, and update the on-board software.
- **Other**: This industry also uses many cross-vertical solutions, such as surveillance systems, employee safety systems and predictive maintenance.

4.4.4 Healthcare

The healthcare industry operates very differently than the other sectors. It has many large and small healthcare facilities, with data-sharing needs among them, as well as unique privacy concerns. It also has a large amount of mobility of staff, patients, medications, dangerous materials, and valuable hospital assets that need tracking, coordination, and control. These characteristics drive healthcare facilities to deploy CEI solutions, with a combination of local edge and central cloud computing.

Common use cases in this vertical include:

- **Remote health monitoring**: This use case uses IoT to improve quality of life and care through accurate and focused medical home/remote monitoring for chronic diseases (e.g., asthma and diabetes). Typical devices considered are glucometers, blood pressure cuffs, oximeters, heart monitors, and data gateways. These devices provide patients with remote clinical support via coaching and intervention when necessary. Such devices may use a local light-edge gateway, but most computing is likely to happen at central resources, such as a hospital's data centre or the cloud.
- **Hospital asset tracking**: Hospital asset tracking is a solution that locates high-value medical assets within a medical facility enabled by pervasive wireless LAN networking, beacons or active RFID (RTLS) associated with each piece of equipment, person, or tracked item (i.e., high-value inventory like medicine … or a baby!). The solution typically integrates with ERP, hospital inventory management, and work management. Capabilities are used to create intelligence for the central maintenance and tracking (audit) of high-value assets to improve quality of patient care, reduce costs, and improve service quality.
- **Bedside telemetry**: IoT systems support hospitalised patients whose physiological status requires close attention. In this use case, the patients can be constantly monitored using IoT-driven, non-invasive monitoring. This type of solution employs sensors to collect comprehensive physiological information and uses gateways and the cloud to analyse and store the information and then send the analysed data wirelessly to caregivers for further analysis and review — providing a continuous automated flow of information. In this way, the solution simultaneously improves the quality of care through constant attention and lowers the cost of care by eliminating the need for a caregiver to actively engage in data collection and analysis.
- **Other**: This industry also uses many cross-vertical solutions, such as video surveillance, smart building systems and energy monitoring.

4.4.5 Agriculture

The distributed geographical nature and low employment levels in the agriculture industry are a key reason this industry needs to make use of CEI solutions. With widely distributed and valuable assets that need monitoring, tracking, analysis and planning, this sector is increasingly using connected devices and machinery. As a result, this industry is continuing to develop IoT use cases, making use of edge computing (such as systems on-board farm machinery) for automation and local analytics, as well as connecting to cloud resources for analysis across territories and asset fleets.

Common use cases in this industry include:

- **Agricultural equipment management**: As farm machinery becomes increasingly smart, connected, and automated, these machines are monitored and managed remotely. Sensors allow predictive maintenance, and machines can be operated as a service, such as being paid by the hour of usage.
- **Animal tagging**: Livestock can be monitored with animal tags to track location and health conditions. These systems can utilise cellular, LPWAN or satellite connectivity and cloud-based applications for distant tracking, as well as local connectivity and compute resources at the agricultural facilities.
- **Agricultural field monitoring**: This use case may use a variety of sensors and data inputs, including drone imagery, satellite imagery, weather data and local sensors to drive actions. Based on analysis of the data, which is likely to be done centrally in a service provider's cloud-based solution, key actions can be scheduled, such as irrigation, planting, harvesting, and pest control, all of which are intended to optimise yield.
- **Other**: This industry may also use various cross-vertical solutions, such as fleet management and employee safety systems.

Manufacturing

- Manufacturing operations/automation
- Food traceability
- Process automation and optimization
- Smart connected manufactured products
- Quality control using cameras and imagery analysis
- Asset monitoring
- Autonomously guided vehicles (AGV)

Energy and Utilities

- Smart meters
- Smart grid management
- Pipeline management
- Remote workforce/field service technicians' monitoring/automation
- Connected drilling and extraction operations
- Drone-based network, pipeline and facilities observation
- Process automation and optimization

Transportation

- Fleet tracking, monitoring and management
- Freight tracking, monitoring and management
- Port operations management
- Passenger traffic flow
- Autonomous vehicles
- Vehicle and infrastructure inspection

Healthcare

- Remote Health Monitoring
- Hospital Asset Tracking
- AI-enabled Diagnosis and Treatment Systems
- Bedside Telemetry
- Robots or augmented-reality-assisted surgery

Agriculture

- Agricultural equipment tracking, monitoring and management
- Process automation and optimization
- Autonomous vehicles – Agricultural
- Livestock monitoring
- Agriculture Animal Tagging
- Agriculture Field Monitoring

Common Cross-Vertical Use Cases

- Asset condition monitoring
- Predictive maintenance (Sensor-based asset diagnostics and maintenance)
- Asset command and control
- Regulatory compliance
- Visual inspection (quality/integrity)
- Smart building (e.g., lighting/HVAC/elevator/ other)
- Video security and surveillance
- Employee safety monitoring
- Asset location tracking
- Drone-based observation
- Fleet tracking, monitoring and management
- Energy monitoring and optimization

Figure 13 Common CEI Use-cases by Industry (Source: IDC, 2022)

5. Drivers and Barriers for The Adoption of CEI

This chapter discusses the main drivers and inhibitors of adoption of cloud, edge and IoT technologies.

This chapter currently utilises existing IDC research and analysis. Upon the completion of the survey dedicated to the UNLOCK-CEI project, this chapter will be updated with the survey results.

5.1 Cloud Drivers and Challenges

5.1.1 Benefits of Cloud

European companies reach out to cloud for multiple reasons focusing on both optimizing current operational models as well as seeking tools to drive new business value creation:

Drivers:

- **The Need for Agility and Flexibility:** The changing business environment requires companies to adapt their business operations and adjust their resources, including IT. The agility and flexibility of cloud services make them especially applicable to changing market conditions.
- **High Availability of Resources:** The failure of an IT platform can result in operational disruption, and considerable costs may be incurred. Public and private cloud delivery models make IT resources readily available, which a recent IDC study revealed as a key driver of cloud uptake among organisations.
- **Mobility and hybridisation of work:** The growing penetration of mobile devices in the workplace has led to increasing demand for the development and implementation of mobile business applications, as well as the need to integrate mobile devices with existing IT infrastructure. Cloud facilitates remote access to company resources, which increases work efficiency.
- **A Focus on Core Competencies:** Some companies often cannot afford extensive dedicated IT departments. These companies tend to use cloud services because this approach enables them to obtain the services they need at a lower cost than via traditional on-premises IT. Some cloud providers offer business processes as services, thereby enabling organisations to focus more on their core business activities.
- **Reducing the Total Cost of Ownership:** Many companies expect a significant reduction in the total cost of ownership as a result of migrating to cloud-based solutions.
- **Increased energy efficiency:** Though cloud data centres use large amounts of energy, their shared resources can increase efficiency of IT resources and decrease an organisation's CO^2 footprint.
- **Easier IT Management:** Cloud offers a greater degree of IT automation, which helps businesses simplify IT management and lower costs.
- **Disaster Recovery:** Many companies are turning to cloud-based solutions for their disaster recovery plans. Cloud enables them to mitigate risks by, for example, allowing them to utilise a redundant data centre using the capacity of a cloud services provider or having a third party manage their data centre requirements entirely. Public cloud, private cloud, or a combination of the two can be used for this. Hybrid models can be formed if cloud is combined with on-premises solutions.
- **Temporary Capacity Shortages**: Business dynamics sometimes result in a company needing to manage peaks in computing capacity demand. These situations are difficult to handle with traditional onsite infrastructure. Companies that face this dilemma will be more open to cloud-based IaaS solutions.
- **Security Requirements:** Most end-users have insufficient budgets to secure their on-premises environments using advanced security solutions. Using cloud solutions can offer a high level of security that is also shared by a large number of users, allowing the achievement of economies of scale.
- **Skills shortage:** with IT departments striving to meet business demand for IT solutions, cloud often becomes a quick and easy way to access IT functionalities companies would be able to develop internally.

5.1.2 Cloud Challenges

Most challenges in cloud adoption are related to security and governance.

Challenges:

- **Security Concerns:** Security has a twofold impact. Although companies start to appreciate the level of security offered by cloud providers, many still have concerns, especially when it comes to sensitive data and critical applications.
- **Regulatory Framework**: Many public cloud providers, particularly the global ones, are unable to guarantee where user data will be stored. This situation conflicts with the internal policies of many companies and most government institutions in terms of maintaining data within the country. Furthermore, it contravenes legislation. Organisations that must store their data within the borders of the country or within the borders of the European Union will be more concerned about going to the public cloud.
- **Provider Lock-In:** A change of provider and the associated data migration can become a costly and lengthy endeavour. As most cloud services are still not standardised in a way that allows smooth move from one IaaS provider to another. For PaaS, provider lock-in seems most probable due to the specific application programming interface (API), database, and programming languages supported by the platform. In terms of SaaS, provider lock-in is very frequent; however, thanks to integration through API and possible data exports, a change of SaaS provider is generally possible, but at additional cost.
- **Job Security Concerns:** When it comes to deploying a cloud solution, IT department personnel have many reasonable concerns, including the security of their own jobs. IT managers are unlikely to embrace cloud, as they fear it would lead to net job losses and/or diminish their roles. This cloud-inhibiting factor may be very strong, especially in organisations where IT departments are responsible for IT procurement and the development of IT strategy. In fact, while the role of IT staff/departments will change with cloud adoption, operational management from skilled staff will still be required.
- **Skills Shortage:** Although cloud is often perceived as a technology delivery model that is less demanding in terms of skills, growing complexity and sophistication of cloud offering requires a certain level of cloud competencies in the organisation. Companies often declare that their adoption of cloud is limited by the insufficient number of experts in-house.
- **Existing Investments:** Although the promise of flexible costs is one of the main drivers of cloud adoption, a significant group of users will opt not to shift costs to OPEX, as they have relatively recently invested large sums in IT, and these investments must depreciate before new ones can be made.
- **Integration of Cloud-Based Solutions with Existing Systems:** CXOs are often concerned that cloud-based solutions may not function well with their existing systems. This is compounded by the fear that difficulties in systems integration and users' unfamiliarity with cloud will, together, have a significant negative impact on business objectives and efficiency.
- **Sustainability concerns:** Cloud data centres use large amounts of energy, which can generate substantial amounts of atmospheric CO^2. With increased focus on sustainability, cloud service providers may face pressure to reduce carbon footprints.

Despite relatively high adoption on cloud, the success rate of cloud projects is still far from ideal. In a 2022 survey, 55% of European companies declared that their cloud projects were not successful[18]. The main reasons mentioned for projects being unsuccessful were security and trust issues, inability to integrate well with on-premises applications, other cloud services, and/or edge and lack of skills. Research show that companies also struggle with the lack of cloud culture and face performance and reliability issues.

[18] *IDC, European Multicloud Survey, September 2022*

5.2 Edge Drivers and Challenges

5.2.1 Drivers and Benefits for Edge Adoption

As analysed in previous sections, edge market's development in Europe is driven by tremendous benefits and business goals the technology brings on various organisations that want to unlock more value from data and achieve greater business outcomes.

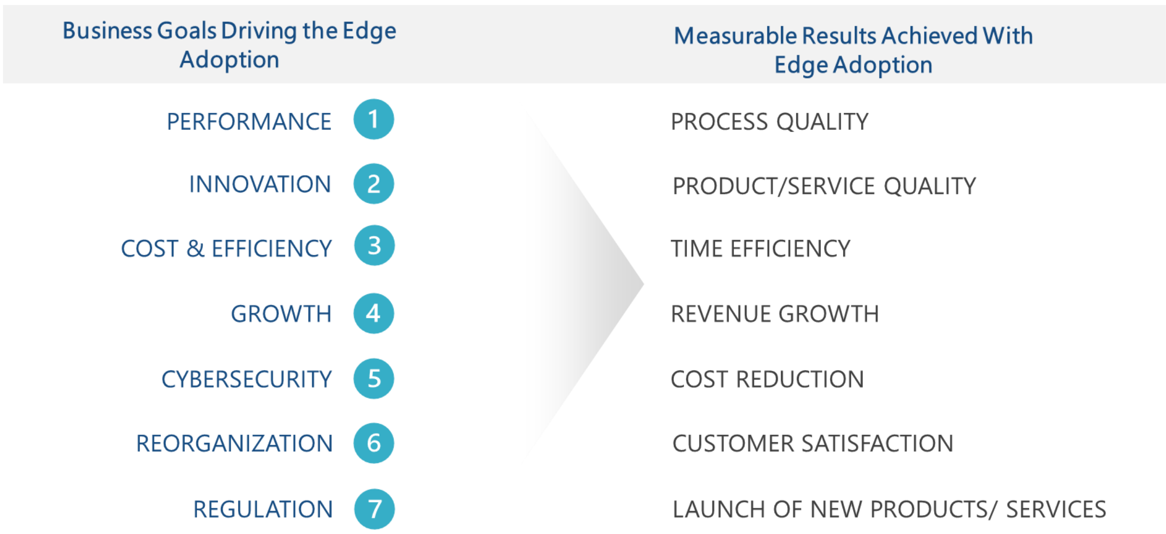


Figure 14 Reasons behind edge adoption (Source: IDC European Edge Practice Research, 2022)

According to the IDC European Emerging Technology Survey's results related to the business goals driving the edge adoption and the underlying measuring results, edge is often considered for enhancing performance due to the synergy it creates with other emerging technologies. By bringing previously established procedures and processes to the next level, edge and IoT can lead to significant cost reductions by helping organisations across all sectors send only pertinent information to the cloud or core, minimizing the need for data transfers or longer-term storage on the network.

Another important driver behind edge computing adoption is the push for innovation. Edge represents the foundation of several innovative ways of conducting old processes in a new and more efficient way, as well as allowing for completely new processes which were not available before. Remote asset tracking is a clear example of the first type of innovation: edge solutions enable real-time asset tracking and increased visibility across the supply chain, analytics driven procurement, and real-time inventory management for an efficient and transparent value chain. On the other side, edge computing can be leveraged to achieve the next level of production automation, by facilitating it in the last mile of the whole production process.

The pandemic and the war in Ukraine have put enormous transformational pressures on organisations and industries, and this is being exacerbated by high inflation, increasing energy costs, supply chain disruption and so on. Edge computing can play an important role in supporting companies by allowing digital agility and scale while also driving cost reductions.

Many organisations consider edge computing as an enhancement for cloud computing capabilities (which in some cases is characterised by higher latency and costs associated with data transmission) when it comes to IT-OT environments convergence, enabling both the centrally managed and monitored infrastructure that IT teams need, while still being on the factory floor under the control of the OT teams.

Regarding time efficiency, this is mainly linked to the key advantages that edge is bringing to its adopters, such as reduced latency, faster operational responsiveness and the possibility to establish new data-driven processes. By locating key processing tasks closer to end users, edge computing can reduce the time needed for data to move across the network, thus delivering faster and more responsive services.

Moreover, organisations are adopting edge technology also to achieve other results, such as providing enhanced data security and privacy protection as data is stored and processed at the edge and not in core data centres. Edge also supports different regulation requirements as, again, data remains stored and processed in one single place only.

In conclusion, edge is continuously seen as the solution for improving organisations' processes and operations, as well as an innovative tool that may bring, maybe in new use cases and together with other emerging technologies, new revenue streams and growth opportunities, both for technology buyers and technology providers.

5.2.2 Challenges Hampering Edge Adoption

Along their adoption journey, organisations sometimes face several challenges which are hampering their innovation and transformation process.

According to the *IDC Europe Emerging Technologies Survey*, the lack of qualified workforce and skills is the major barrier organisations face, as almost one third do not have, or are not able to find, the right specialised and technical workforce to implement and properly use edge technologies. Hence, receiving support from service providers, as well as train and specialise the workforce will be critical for many organisations

The other three major barriers that organisations face in their adoption journey are related to the lack of funding, difficulties adapting established processes to new technologies and lack of adequate IT infrastructure, as organisations still find it difficult to let go of legacy systems and consolidated work processes, or simply to adapt to new technologies.

Another major concern refers to privacy and security as organisations understand that in a highly distributed environment, risks related to cyberattacks could be increasingly higher. In this case, securing the entire distributed infrastructure and proactively detecting any vulnerabilities is essential.

Also, another barrier that usually limits not only edge adoption but other technologies that could drive transformation and change in organisations is culture resistance, coming either from leadership, lines of business and even IT departments. This is an undergoing major challenge, especially in the case of smaller organisations, and could be resolved by continuous market education and increased awareness on regards to the greater benefits that a new and modern technology could bring to the organisation.

All these challenges related to the deploying and managing edge IT services are also confirmed by respondents to *IDC's Future Enterprise Resilience & Spending Survey*, as presented in following Figure.

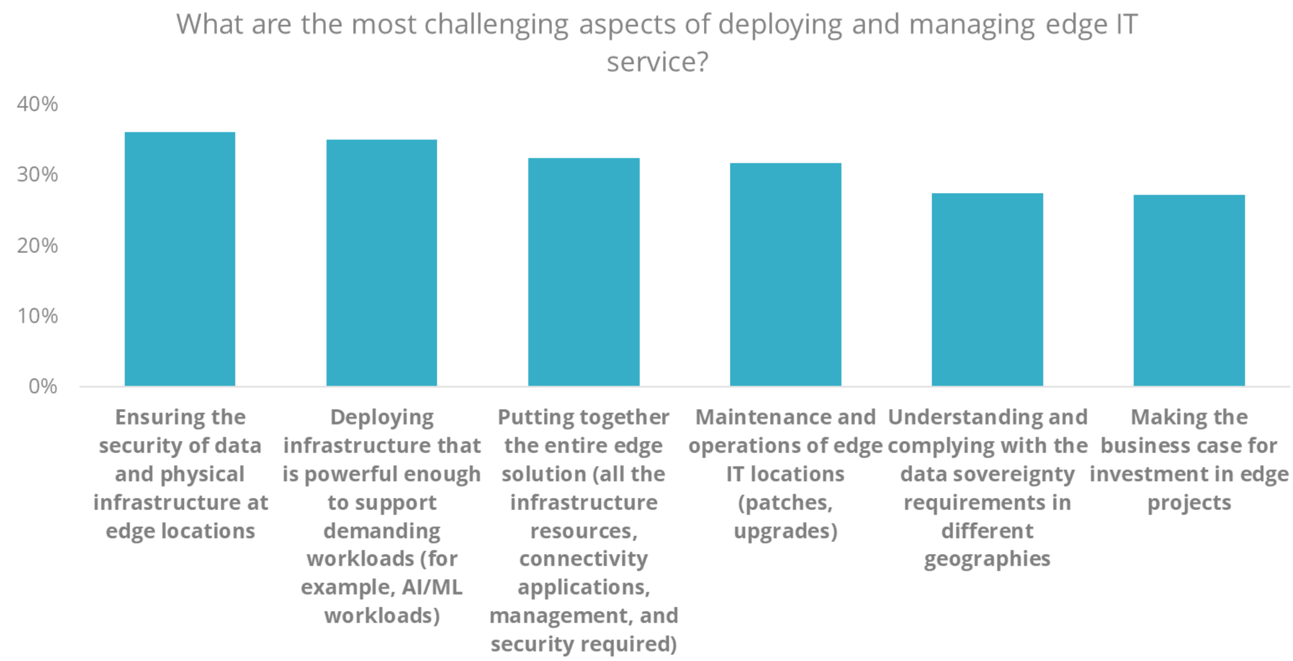


Figure 15 Challenges related to edge IT service deployment and management (Source: IDC's Future Enterprise Resilience & Spending Survey, 2022)

Lastly, there is an underlying challenge that could indirectly impact the adoption of edge in Europe, such as the macroeconomic uncertainty, as IDC expects demand for edge solutions in Europe to be somehow affected by the Russia-Ukraine War's broader impact on trade, supply chains, capital flows, and energy prices. As stated in the IDC's European Enterprise Infrastructure Survey (n=928), 13% of European organisations will decrease their investments in their own edge environments, workloads and solutions, while 44% are keeping the same investment pace as in 2021.

Thus, organisations must redesign their investment mindset and start thinking of technology as an opportunity to transform and enhance their operations, rather than as a barrier for development. In this case, the edge ecosystem will have a critical role in highlighting edge and its benefits as a key enabler of innovation, performance and operational efficiency. Moreover, edge vendors must guide their clients to ensure resiliency and security in edge locations, as well as expanding the edge-cloud story to help them understand the advantages of both technologies.

5.3 Internet of Things

5.3.1 Drivers of IoT Usage

Organisations utilise IoT for many reasons. It can help organisations control costs, thereby contributing to the bottom line. But it also helps organisations to improve the top line by improving customer experience, improving product quality or introducing new products and services. It also has other benefits that may be less visible in financial results, such as increasing employee safety or ensuring regulatory compliance.

A survey conducted in November 2020 inquired about what benefits European organisations seek from IoT. Though the IoT market is fragmented across hundreds of individual use cases, there are several general benefits that are common across most IoT projects. The figure below shows the top reasons European organisations stated for investing in IoT.

Figure 16 Reasons for Investing in IoT Projects (Source: IDC European IoT Decision-Maker Survey, October 2020, (N=964))

It is worth exploring several of these benefits and discussing some examples.

- **Increased productivity and efficiency**: These are the most commonly sought benefits. For example, a key benefit of utility smart meters is that they drastically cut the cost of meter reading. Likewise, smart garbage cans allow increased efficiency by routing garbage collection only to the bins that are full. Smart lighting cuts energy costs. Asset tracking increases utilisation rates while reducing loss and theft. Smart vending machines increase efficiency by notifying when stock must be replenished. Agricultural field monitoring increases efficiency and yield by optimizing water, fertiliser and harvesting operations. Warehouse automation reduces staffing requirements. And fleet management systems can increase efficiency in routing and save costs on fuel.
- **Improved customer experience**: Many use cases include improved customer experience as one of their aims. Manufacturers add connectivity to appliances to enable remote management. Logistics companies track packages to reduce delays and losses, which results in happier customers. And healthcare providers use remote health monitoring to deliver high-quality health results at lower cost and trouble to the patient.
- **Improved product quality**: IoT improves the quality of products and services in many ways. Auto manufacturers use IoT systems for quality assurance. Manufacturers add device connectivity to add new features and to enable predictive maintenance, thus reducing maintenance costs and downtime.
- **Reduce operational and maintenance costs**: For example, manufacturers use production asset management to monitor assets and conduct predictive maintenance before they break down and require more expensive repairs.
- **Competitive differentiation**: Many companies embrace some IoT solutions for competitive differentiation. For example, many appliance vendors add connectivity as a differentiating feature for high-end models, and automobile manufacturers feature their connected car platforms as a key selling point and differentiator. Similarly, automobile insurance companies differentiate their offerings with insurance telematics services, often called usage-based insurance (UBI). In UBI services, the insurer uses a device to monitor the vehicle's usage, in order to understand how much the vehicle is in use, and potentially how safely it is driven or whether speed limits are violated.

With that information, the insurer can then offer lower fees for those who drive safely or infrequently.

- **New revenue streams**: By adding connectivity to products, many vendors aim to add features and services that can generate further revenue. These include selling maintenance services and reordering consumed supplies. For some companies, these new services may change the business model, resulting in selling their products as a service. Rolls Royce is one of the earliest examples, as the company has offered aircraft engines as '"Power-by-the-Hour'" since 1962. Modern IoT systems create the opportunity for far more businesses to adopt a similar product-as-a-service model. Sierra Wireless, an IoT module maker, has promoted a similar use case for industrial washing machine companies to offer their products as a service.
- **Improved physical security**: Home and building security systems are among the most popular IoT use cases, and they clearly focus on physical security. Others focused on this objective include public safety and emergency response services using surveillance cameras, body cameras and vehicle cameras; vehicle safety systems; roadside infrastructure; and various industrial safety systems.
- **Improved employee safety**: In industrial settings, employees must often work in dangerous environments, such as working on construction sites, electricity networks, factory floors or oil rigs. In such environments, numerous automated systems can enhance safety. For example, they can ensure workers have cleared space around an industrial machine; they can manage traffic around emergency response or road construction workers; and they can monitor and control air quality and temperature. The recent COVID-19 pandemic has led to new safety use cases to ensure physical distancing (see more on COVID-19 below).

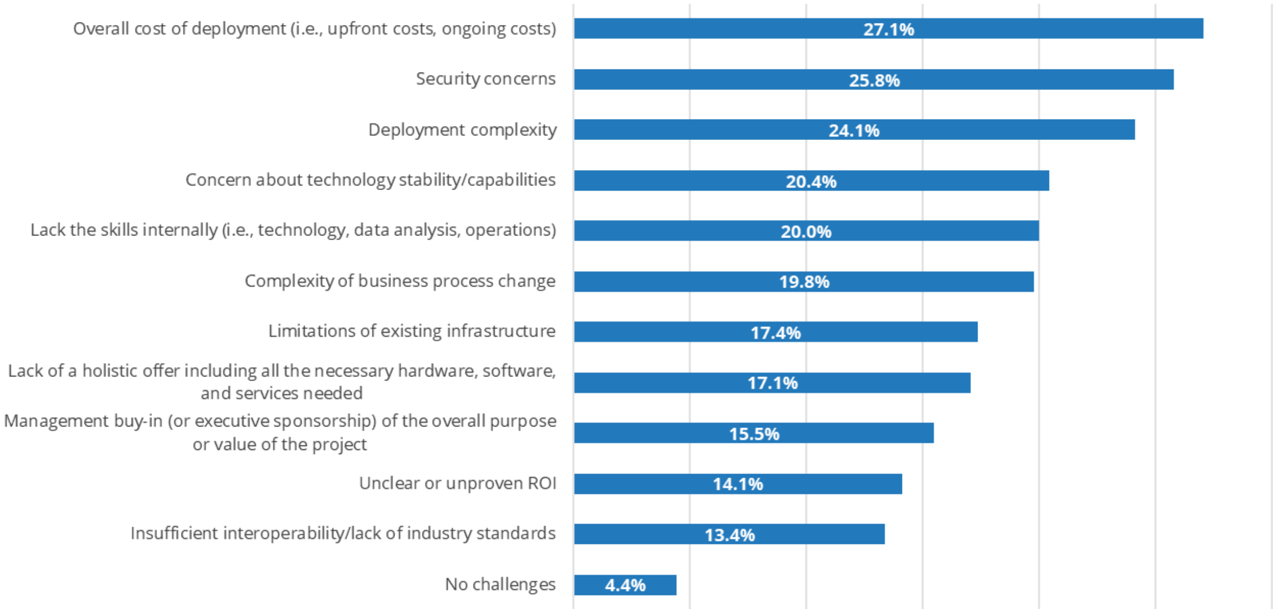
One may note that the various benefits of IoT often overlap. For example, improved customer experience and product quality are often competitive differentiators. Many use cases bring multiple benefits in terms of efficiency, product quality, customer satisfaction and others. The French retailer Decathlon presents a useful example. The company switched to RFID-based inventory tracking and checkout using radio-frequency identification (RFID). That allowed faster checkout, saving employee costs and increasing customer satisfaction. It allowed full-store inventory to be checked as frequently as weekly, reducing lost and misplaced products, driving increased sales, and reducing logistics costs. And in 2019, the company announced it is adding scan-and-go checkout allowing customers to avoid the checkout line entirely.

While the benefits of IoT for individual organisations are substantial, the cumulative impact of such projects promises to bring substantial benefits to European economies and societies as a whole. IoT will play a key part in ensuring that the European industry remains competitive globally. It will increase productivity in such areas as manufacturing, logistics, healthcare and public services. It will improve safety on the roads and in public transportation. It will enable monitoring and improvement of environmental conditions. And it will enable new connected services to proliferate throughout the economy.

5.3.2 Challenges Inhibiting IoT Usage

IoT remains a relatively new technology space, with an emerging ecosystem that is working to develop and simplify the technology, integrate components, develop best practices, and standardise solutions for key use cases. While this maturation process is underway, there remain multiple challenges and implementation barriers. To obtain concrete benefits, organisations must be aware of these challenges and the steps they can take to overcome them.

According to a recent survey, the most common challenges cited by European organisations were costs, deployment complexity and security (see figure).



Question: What do you think are the top challenges holding back or slowing progress on IoT project(s) within your organisation?
N=949 (all organisations except those with no plans or interest in IoT)

Figure 17 Challenges Inhibiting Faster IoT Deployment (Source: IDC's European 5G and IoT Survey, June 2022)

These challenges are discussed in more detail below.

- **Cost**: IoT costs include the technology components, application development, deployment, maintenance and lifecycle management. Where new solutions must be heavily customised, solution development often requires much greater amounts of time and costs.
- **Security**: IoT presents new security challenges for an organisation. In addition to utilising new technologies and solutions, each with their own risk profiles, the nature of connected devices presents new "physical consequences in addition to affecting other aspects such as an organisation's finance and reputation." When an IoT device is hacked, injury or death can ensue. Over the years, security researchers have identified vulnerabilities in connected automobiles, smart home appliances, energy grids, medical devices, and many others. Deploying IoT projects raises new security challenges that organisations may not have the expertise to mitigate.
- **Complexity**: Complexity is a common challenge, because most IoT use cases still require extensive customisation. Furthermore, IoT solutions incorporate a wide range of hardware and software technologies and protocols, requiring diverse skillsets. Organisations often must make a wide range of technology choices; develop applications; determine how to manage IoT-specific devices, connectivity, analytics models and applications; provision provide new kinds of connectivity to new kinds of devices that are often located off-site or are mobile; and resolve many other complex challenges.
- **Privacy**: IoT raises some important privacy challenges that must be considered by consumer users, enterprise users, IoT device and solution providers, and policymakers. Privacy implications vary between use cases, but in some cases, these concerns can be significant. Some use cases record data of a private nature, such as cameras and microphones in the home. Reports of baby monitors allowing hackers to view inside the home and even threaten residents present a clear example. In another case, the Electronic Frontier Foundation raised privacy concerns about Amazon's Ring doorbells, which record video that can be accessed with the owner's permission by police departments in the US.

One problem for managing privacy is that there is little regulation of this emerging space. Since 2018, the European Union's GDPR policy provides legal guidance that addresses some but not all of the risks. PWC advises companies not just to comply with the letter of the law but also to think more broadly about data ethics and evaluate the issue at a high level in the organisation.

- **Limitations of current infrastructure**: Many IoT projects generate large amounts of new data that must be transferred, stored and analysed. Existing data centres and enterprise networks may be insufficient, requiring much wider upgrades and greater costs than anticipated. Similarly, many IoT use cases include devices in new locations, such as in parking garages, on pipelines, and on portable freight. These devices may require new network coverage and connectivity solutions.
- **Unclear return on investment (ROI)**: Though In some use cases, return on investment may be easy to identify and calculate. For example, smart utility meters require measurable costs for deployment, and they then save specific operating costs once in use. However, some use cases bring benefits that are more difficult to measure obvious in some use cases, that is not always the case. For example, the benefits of a retail use case that is intended to improve customer experience may be hard to measure. They may indirectly increase sales, increase customer loyalty, or impact the brand, but measuring these changes and to what extent an IoT use case was the cause can be difficult. Organisations need to identify how to measure success of their projects, whether that be lower cost, increased revenues, improved net promoter score, reduced down-time, reduced injuries, or other measures.
- **Management buy-in**: Many IoT projects bridge multiple departments, such as IT, operations and lines of business, or they require significant changes to established business processes. Having executive management support is often critical to ensure the project can overcome pockets of resistance and progress efficiently.
- **Skills availability**: Companies rarely have all the skills needed to develop, deploy and manage a complex custom IoT project. They may not have internal experience with the types of IoT devices that they need, or the connectivity solutions, software platforms, edge computing, application development, security, analytics or other skills. In such cases, they must acquire those skills through training, recruitment, or consultants.
- **Lack of holistic offers**: Comprehensive packaged offers greatly reduce cost and time to deployment, but with the massive fragmentation of the IoT market into thousands of use cases it is difficult to create fully packaged solutions that can be resold to a wide audience. Instead, with so many niche requirements, it is still necessary to customise most solutions. Nonetheless, the industry is progressing in simplifying many of the most common use cases, standardizing some of the most common components of the value chain and improving the APIs and integration across components.

The various challenges facing IoT development are key factors slowing adoption and achievement of the full value that can be gained from IoT. However, there is no simple fix. Because IoT spans hundreds of use cases with unique solutions and a wide range of technology components, the entire IoT ecosystem must continue investing, innovating and collaborating to steadily overcome challenges.

6. Final Remarks

The research above has demonstrated that cloud, edge and IoT are interlinked technology domains that are jointly enabling a wide range of new use cases that will enable the digital transformation of European organisations and economies. These technologies are in a phase of accelerated adoption. The markets remain dynamic and competitive. Though there are some major players already carving out significant market positions, these markets remain open to new entrants, shifting leadership roles, and innovative new players.

While the CEI market presents opportunities for European companies, it is also a sector that has broader strategic significance for Europe. Europe will be in a far stronger position if it plays a major role in leading and defining the CEI market space, rather than being dependent solely on players from other regions. As is being observed with the microchip shortage, Europe will benefit from playing a significant role in defining advanced, strategic technology sectors and supporting robust local technology leadership.

In order to provide more insights for European policy makers and CEI value chain stakeholders regarding the key areas to tackle, the next steps in the UNLOCK-CEI project aim to enrich the demand landscape analysis further by running a custom survey. The survey will help to identify the most promising CEI use-cases, the updated status of CEI adoption across five verticals, and the updated list of drivers and barriers.

In addition, we will conduct in-depth interviews with industrial stakeholders to analyse the potential business opportunities driven by the paradigm change towards CEI and how it may reshape industry value chains. The focus will be to understand the distribution of potential benefits and innovation drivers for the main industry value chains with specific attention to the emergence of trusted and interoperable data-driven services within and across the five industrial sectors. The results will be included in the next report (D1.2) due in May 2023.

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ANNEX 1: Definition of CEI Technologies and Related Terminology

Cloud

This section discusses first the key attributes of public cloud services, followed by the key attributes of private cloud services.

Six Key Attributes of Cloud Services

IDC defines cloud services more formally through a checklist of key attributes that an offering must manifest to end users of the service (see Table 1). Cloud services, as defined by IDC, require support of all of these six attributes.

The following table summarises IDC's six key public cloud services attributes — those that define a "public cloud service." For the most part, these attributes also apply to private (dedicated) cloud service deployment models, although the specifics of how each attribute applies may vary slightly from public cloud.

Cloud Services Attribute	Details
Shared standard service	Built for multi-tenancy among or within enterprises
Solution packaged	A turnkey offering, pre-integrates required resources
Self-service	Provisioning and management, typically via a web portal
Elastic resource scaling	Dynamic, rapid, and fine scaling
Elastic, use-based pricing	Supported by services metering
Published service interface/API*	Web services and other common Internet APIs

Table 1 Key Public Cloud Services Attributes (Source: IDC)

***Shared*, Standard Service**

Cloud services are shared, standardised services. This is the most fundamental attribute of a cloud service, that is shared with a wide variety of previous-generation online services and the one that differentiates cloud services from many traditional customer-unique outsourced or hosted offerings.

"Shared" resources are servers, storage, software platforms, applications and related resources that are physically shared among multiple enterprises (for public clouds) or constituent groups (e.g., departments and divisions in private clouds). When the shared resources are infrastructure like servers and storage, they are commonly called Infrastructure-as-a-Service, or IaaS. Software sold as a shared service is often called software-as-a-service, or SaaS. and platforms sold as a service to multiple user groups are called platform-as-a-service, or PaaS. "Standard" does not mean that services do not offer customers the ability to create a "personalised" version of the service. Cloud services typically offer a wide range of built-in configuration options that allow customers to personalise the service; the key difference from traditional systems is that cloud services personalisation is based on choosing among commonly available, "engineered in" options, rather than making customer-specific customisations to the code.

The cloud's shared, standard service model offers customers and suppliers both enormous operating efficiencies and upgrade/enhancement velocity. In a private cloud deployment, the IT department can be viewed as the cloud service "vendor," offering a standard service within a single enterprise with multiple user groups or across an extended enterprise.

***Solution* Packaged**

One of the most obvious user benefits of the cloud service model is that it is presented as an all-in, "turnkey" solution: all solution resources are integrated, and the customer can access the offering without the need to own, manage, or understand any underlying resources required to support the offering. The cloud service provider bears that burden, offloading it from the customer, making it much simpler and faster to adopt for customers.

One important implication of cloud services being technologically less complex is that many line-of-business (LOB) organisations with lower IT skills have been able to purchase and leverage cloud services directly, although this applies to SaaS offering rather than IaaS or PaaS.

***Self*-Service**

Cloud services allow customers' self-service capabilities for service provisioning and administration. In the IT cloud services world, the range of self-service capability may vary up and down the stack: in the IaaS area (e.g., cloud storage and cloud servers), "click to buy" provisioning is widely available today, whereas some of the SaaS and PaaS community may lag behind here.

Most SaaS and PaaS vendors provide a lot of self-service administration and click-to-buy provisioning simplicity. Some onboarding and more complex customisation functions may require up-front human intervention from the provider's staff. Cloud service offerings must have at least some customer-accessible provisioning and management controls.

Increasingly, suppliers are taking advantage of APIs to allow other systems to gain "self-serve" access to cloud services (see the Published Service Interface/API section).

Elastic *Resource* Scaling

Rapid and flexible expansion (and contraction) of service usage is among the major benefits of cloud services for users. Because the cloud services model allows users to quickly access and utilise required services, they can greatly speed up systems' implementation/deployment.

Cloud services' dynamic provisioning (and deprovisioning) capability — including the ability to access resources in finer-grained increments — also reduces the need for costly overprovisioning. In addition, this characteristic substantially reduces user burden to come up with demand plans for resources (e.g., CPU, storage, network bandwidth, and support staff), which is a major challenge for organisations and typically drives companies to greatly overprovision IT.

Like self-service, the way elastic scaling is manifested varies by the type of cloud service offering. As for infrastructure-related services, such as server instances (virtual machines) and storage, service expansion/reduction is possible on a very detailed level such as the number of server instances, storage capacity, and data transfer volume. On the other hand, contracts in the application field are often based on the number of users (subscribers), but — optionally — contracts may not necessarily be defined for individual subscribers but for an entire user group.

Elastic, Use-Based Pricing

Customers want services not only scaled to need but also priced to reflect actual consumption, whether in proportion to resource usage, the number of users, transactions, screen views, or some other consumption metric. As a convenience to some customers, providers may mask this pricing granularity with long-term, fixed-price agreements, but — to meet the cloud service definition — suppliers must design their offering so they have the capability to do fine-grained metering and pricing for customers that wish that. In a private cloud setting, some IT vendors may take advantage of the fine-grained metering to support more detailed, usage-based chargebacks.

Published Service Interface/API

The ability to combine services with each other, and to integrate them with traditional, on-premises systems, is the foundation for being able to rapidly create — and, importantly, allow others to create — new solutions and value, and is therefore a core element of modern cloud services.

Published cloud service APIs transform online services from "islands" to high-leverage building blocks within large innovation communities and marketplaces. It is already clear that CSPs that do not offer open/published, programmatic interfaces — and thus fail to develop large ecosystems of solution developers around their services — will simply not be competitive.

These APIs, and the ecosystems around them, form the foundation for expanding suppliers' market power. In our view, this is the brightest "red line" that separates true cloud services from first-generation online Internet offerings. It's no surprise that the first-generation Internet businesses that have become cloud leaders — Amazon, Google, and eBay — were among the first of the first-generation online/ecommerce providers to open up their services with APIs and recruit huge developer communities.

In the IT industry, many SaaS/PaaS providers — and a fast-growing number of IaaS providers — have published service APIs that allow customers and other vendors to access functionality within their offering; some providers expose a minimal number of controls, while others publish many. But it is hard to imagine any successful cloud services vendor not providing a way for its offerings to be leveraged for greater value by customers and by its own ecosystems. These APIs and the ecosystems around them will be the foundation for expanding suppliers' market power. The successful CSPs will have APIs in some form as the market matures, while "walled gardens" will have a hard time being competitive in the cloud services space — think "AOL versus the Internet."

Dedicated (Private) Cloud

In addition to public cloud, IDC defined also **dedicated (private cloud)**. A dedicated cloud represents a pool of resources that are shared within a single enterprise or an extended enterprise, with restrictions on access and level of resource dedication. These restrictions are defined or controlled by the enterprise. Table 2 lists the inclusion criteria for any cloud to be considered as a dedicated cloud, self-built, and operated or delivered as a service.

It is important to note that these attributes are capabilities of the dedicated cloud deployments. Organisations choose whether to use them or not and this end-user decision would not impact categorisation of dedicated cloud IT services.

Cloud Services Attribute	Details
Dedicated infrastructure resources	Infrastructure resources (hardware and software) dedicated to a single organisation (These resources can be deployed either at an organisation's data centres, in a colocation facility, or at a service provider data centre.)
Defined internal enterprise services	Pre-integrated defined templates and workflows defined for end users accessible via catalogues or service requests
Elastic scaling	Dynamic, rapid, and fine-grained
Consumption metering	Enterprise tracking resource usage and consumption for internal chargeback/showback and, in some cases, for service contract management
Self service	Self-service provisioning and administration options
API/published service interface	Programmable access via open/published API
IT services	All life-cycle and management services for the systems and software done by the provider of the assets
Control plane	The manner by which the cloud is operated

Table 2 Key Dedicated Cloud Services Attributes (Source: IDC)

Edge

This section discusses key topics in the edge market, including edge technologies, components and terminology.

Core — The "Central Data Centre"

Core could be located on the firm's own physical premises, off premises in a colocation facility, or off premises at a virtual location such as a public cloud. From an infrastructure perspective, the core is an epicentre for storage and compute or an information aggregation and dissemination facility. Core computing therefore describes computing processes that occur inside the firm's "data centre."

A core is usually distributed (i.e., it has a multilocation footprint, including some of it in one or more public clouds).

Endpoints

An endpoint is a remote device that communicates back and forth with a network to which it is connected. It can connect either to an edge device or directly with the core depending on the network architecture.

Edge Technology Landscape

The edge spending market sizing and forecasts can include spending from services providers as well as from enterprises building their own infrastructure. The edge technology scenario includes various sub-markets, such as hardware, software, and services spending, making the distinction between multiple edge platforms, such as light edge, and heavy edge, combined with other hardware capabilities (networking), provisioned and professional services and software technologies.

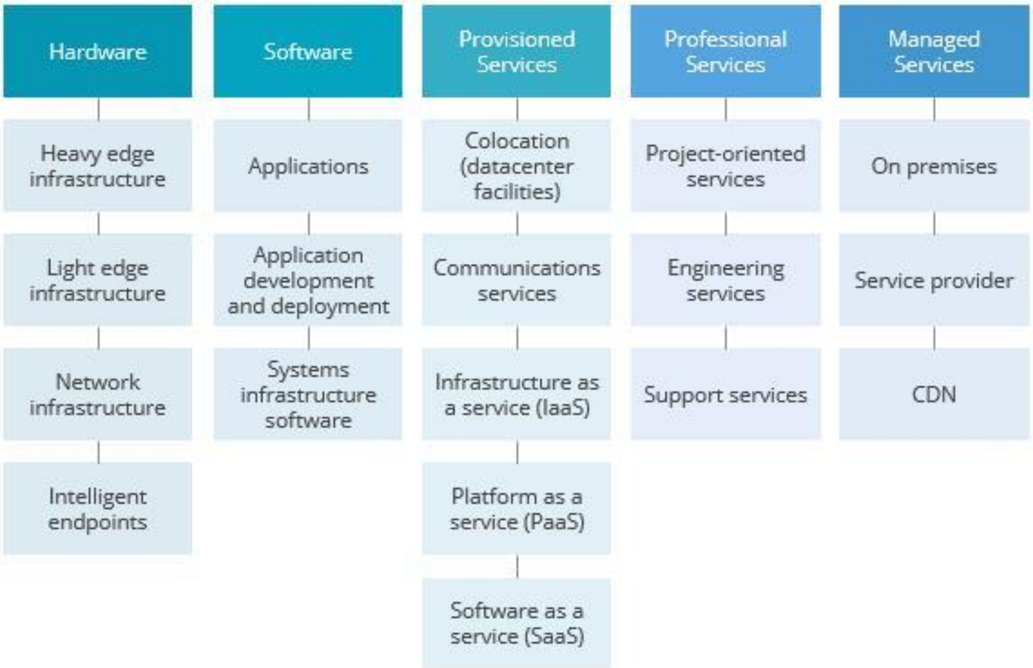

Figure 18 Edge Primary Segments (Source: IDC European Edge Practice Research, 2022)

Edge Hardware

Edge hardware includes the physical equipment that serves as the foundational infrastructure for edge.

- **Heavy edge computing platforms** are meant to perform complex computing tasks that are adapted for the edge location or deployment. They are usually a variant of core general-purpose computing platforms (servers) that are built with data centre-grade industry-standard components, feature ruggedised packaging and onboard control and data acquisition hardware designed to control devices such as robotic arms, autonomous cars, conveyer belts, and wind turbines. This enables them to function as “converged systems” that concurrently run multiple IT, operational technology (OT), and communications technology (CT) functions.
- **Light edge platforms (aka edge gateways)** are designed with low-power components (such as fanless processors, low-power memory, and flash). Most of these devices are designed for running limited or single functions in environments wherein power and cooling availability is limited. Such platforms are also heavily customised in terms of form factors, and, like heavy edge platforms, these platforms can feature onboard control and data acquisition hardware; local, wireless, and wide area network connectivity; and specialised low-power accelerators (FPGAs or ASICs) for performing limited add-on AI functions like inferencing.

  In general, most light edge platforms are designed to perform functions such as data aggregation, condensation and optimisation, local data storage (in flat files or databases), real-time clock synchronisation, IPv6 to Ipv4 translation, local caching for firmware updates, proxy services, and core connectivity, to name a few.

  A newer breed of gateways can be used for software-defined functions. These gateways can carry out network functions such as managing and collating endpoint-to-core traffic and/or aggregating data from distributed devices and sensors in a local environment. Edge gateways can run applications that analyse, transform, or aggerate/summarise data from endpoints or monitor data. As the capabilities of these systems increase, they will be able to host any application that makes decisions, creates new data, or alerts or informs end users or other systems.

  IDC includes the following market segments in light edge:

  - General-purpose multifunction gateways
  - General-purpose fixed-function gateways
  - Purpose-build fixed-function gateways
- **Intelligent Endpoints**: These are endpoints with configurable onboard compute capabilities and support the remote provisioning and management of programmable application logic. These devices typically have system on chip (SoC) solutions or highly integrated microcontrollers if they are a wearable or disposable product. The intelligent features including AI inferencing and connectivity are already integrated into the SoC, except for the radio frequency (RF) and filters.

  Examples of intelligent endpoints include smart meters, video cameras with built-in analytics, drones, robotics, automotive systems, and retail kiosks. In general, these are devices built for a specific task.

  Note: For this taxonomy, laptops, desktops, tablets, and mobile phones are excluded, as they are considered personal computing devices.

- **Network Infrastructure**: This consists of network infrastructure (hardware and software) deployed to provide connectivity within, to, and from edge environments to core sites and clouds.

  Such network infrastructure can include the following:

  - Switching
  - Routing and SD-WAN
  - WLAN (with the edge)
  - Application delivery (including local and global load balancing)
  - Ingress controllers and service meshes (to support cloud-native environments)
  - Software-defined networking (SDN) and network automation

- Network management, including analytics and monitoring/observability

Edge Software

Software includes three major segments: applications, application development and deployment (AD&D), and systems infrastructure software.

- **Applications**: Application software includes commercial, industrial, and technical programs and code sets designed to automate specific sets of business processes in an industry or a business function, to make groups or individuals in organisations more productive, or to support education or support data processing in personal activity. Packaged applications designed for the edge typically have a control plane and other software modules that run in the core. Some software functions can run in both locations.
  The categories of applications with edge components include:
  - Content management
  - Enterprise resource management
  - Supply chain management
  - Production and operations
  - Engineering
- **Application Development and Deployment**: Application development and deployment software represents tools and platforms used primarily by developers to build, test, and deploy software as well as process, integrate, govern, and analyse data.
  The categories of AD&D software with edge components include:
  - Analytics and artificial intelligence
  - Data management
  - Integration and orchestration
  - Application development
  - Software quality and life cycle
  - Application platforms
- **Systems Infrastructure Software**: Systems infrastructure software includes software solutions that provide the basic foundational layers of software that enable bare metal infrastructure hardware resources to host higher-level AD&D software and application software and provide the virtualisation and management software used to configure, control, automate, and share the use of those resources across heterogeneous applications and user groups.
  The categories of systems infrastructure software with edge components include:
  - System and service management
  - Network
  - Security
  - Storage
  - Endpoint management
  - Physical and virtual computing

Provisioned Services for Edge

Provisioned services include leased facilities and technology that is sold and deployed in an as-a-service model.

- **Colocation (Data Centre Facilities):** Colocation services are defined as a customer's use of a third party's data centre facilities (i.e., physical floor/cage/rack space, network capacity, and HVAC/power infrastructure) in which the customer operates its own servers/storage systems, network equipment, and other types of infrastructure.
  IDC includes colocation as an edge deployment location when it is not considered the epicentre of computing resources for an enterprise. Colocation facilities can be used to deploy resources closer to users or other points of data generation to reduce latency.

- **Communications Services**: This includes communications services by a network operator to connect edge and endpoints to core infrastructure. Depending on the edge deployment scenario, a mix of fixed data services (Ethernet, MPLS, digital leased lines) and mobile services (LoRa, LTE, 5G) may be used.
- **Infrastructure as a Service**: The IaaS compute market consists of all compute services delivered to customers as a public cloud service. The IaaS compute market is segmented into four functional markets based on the type of compute functionality delivered by the instance:
  - Virtualised x86 compute
  - Accelerated compute (including GPUs)
  - Bare metal compute
  - Other (includes ARM and other CPU architectures)
- **Platform as a Service**: PaaS is application development, deployment, and execution capability delivered as a service. The PaaS market includes all the revenue of an IT capability in the application development and deployment primary software market when it is composed and delivered as a cloud service. PaaS provides integrated (i.e., made up of multiple discrete software functions) services organised around the tasks of application development and life-cycle management; application deployment; code testing, quality, and application life cycle; data management; and integration when they are provided as a service delivered through public cloud or specifically designed to be included in a private cloud implementation.
- **Software as a Service**: Software-as-a-service (SaaS) applications are based on a service composition and delivery model made up of a utility computing environment in which unrelated customers share a common application and infrastructure that is managed by an independent software vendor (ISV) or a third-party service provider. The code or intellectual property of the service is typically owned by the SaaS ISV. There are many emerging models for providers of this software code (ISVs) to leverage third-party infrastructure, business services, and other providers as hosting, selling, fulfilment, or support partners, and many new models are forming far beyond the comparatively well-understood direct versus tiered distribution models of packaged software.

Professional Services for Edge

Professional services are delivered by consultants, engineers, and other technology professionals.

- **Project-Oriented Services**: These include services that have a predefined scope and are not long term or ongoing.
- **Strategy and Technology Consulting**: Strategy and technology consulting is a professional services activity. It is the delivery of advice aimed at helping customers manage their current or planned edge infrastructure with the goal of improving the organisation's edge infrastructure performance, latency, security, and other considerations. Examples include:
- **Systems Integration Services**: This category includes edge services such as the planning, design, implementation, and project management of a technical solution that addresses an organisation's specific technical or business needs. When systems integration (SI) deals involve edge services partnerships for deploying microservices to connect products/sensors with edge infrastructure, then those activities are included in the definition of SI.
- **Engineering Services**: Edge engineering services refer to the design and building of edge products.
- **Support Services**: Support services are often long-term contracts related to deployment, ongoing support and maintenance, and decommissioning for IT hardware and software. The support services segment is comprised of hardware deployment and support, software deployment and support, and IT education and training. These services are conducted via telephone support, remote diagnostics, electronic support, onsite support, extended warranty, predictive/preventive maintenance, parts repair, and inventory/asset management services. Hardware support services are provided by the hardware vendor or a third party and are either attached to the hardware contracted or included in a site agreement.

Managed Services for Edge

These services represent the monthly recurring revenue (MRRs) that service providers accrue from managing all or part of a client's edge process, infrastructure including network, applications, security, analytics, and any other operations elements. They usually entail long-term contractual arrangements with typical terms of 24 to 36 months. Managed edge services represent three primary deployment models:

- **On-Premises Deployment**: This represents managed edge use cases where the edge compute infrastructure is deployed at the enterprise's premises, generally referred to as private deployment. A case in point is the evolving private mobile network market. This deployment model is intended to address the need for extra low latency, generally below 10ms. It is applicable to industrial use cases, healthcare, and AR/VR applications. We are witnessing strong interest in this category with a growing number of proofs of concept (POCs).
- **Service Provider Edge Deployment**: This represents managed edge services provided by edge compute deployed at the provider edge, both fixed and mobile. This is intended to support use cases with latencies in the range of 10–25ms. We expect this deployment model to spur the development of a wide range of vertical use cases.
- **CDN Edge Deployment**: This represents managed edge services provided by edge compute deployed at the content delivery network points of presence (CDN POPs) or edge locations. CDN providers are intensifying their effort to provide edge applications, leveraging their global presence and the programmable edge. Typical latencies are in the range of 25–45ms and address mostly media and entertainment use cases. These use cases will enhance content delivery with personalised, high-fidelity, and interactive rich media customer experiences.

IoT

This section discusses technology components that are often utilised to assemble complete IoT solutions. IoT solutions combine many different types of technology, including a wide range of types of hardware, software, services and connectivity. This section reviews many of the major technology categories that make IoT solutions possible.

- **IoT Hardware**: This category includes a variety of technologies from sensors up to cloud infrastructure.
  - **Modules and sensors:** The module/sensor category includes communicating and computing device modules as well as communication hubs or controllers, sensors, or other such wired or wirelessly connected IoT devices.
  - **Security hardware:** Security hardware includes physical security appliances and other security hardware used in an IoT solution and network including IoT security domains in device and sensors, network and edge, analytics and enablement infrastructure, and physical safety and security.
  - **Servers:** Servers include systems used as a multiuser computing device that accesses and delivers services via a network. A typical server system entails one or more processors, a motherboard, memory, internal disk or flash storage, a bundled operating system, power supply units, and network interfaces.
  - **Storage:** Storage is the part of a computer system or connected system or peripheral device that stores information for subsequent use or retrieval in traditional enterprise infrastructure. It can take the form of storage, which is an integral component of functional computer systems, or additional systems and devices. This spending does not include spending on storage software (captured in the software category) or storage services (captured in the services category). To avoid double counting between servers and storage spending, the storage segment includes only external storage as spending on internal and ODM Direct storage is counted under the server segment.
  - **Other hardware:** "Other" hardware includes all hardware categories that fall outside the aforementioned hardware segments, including enterprise and consumer networking

hardware (e.g., switches, routers, repeaters and gateways), infrastructure as a service (IaaS), and industry-specific hardware such as RTUs, specialised computing devices (e.g., ruggedised field devices), antennas, LED screens, and batteries.

- **Software**: This category includes many types of software throughout an IoT solution, including platforms, analytics, applications, security, and others.
    - **Analytics software**: This category includes the software that analyse and use the data collected by the connection endpoints to turn it into actionable insights that business decision makers can use to affect change in business processes. This includes both cloud and on premises spending.
    - **Application software**: This category includes software used to organise and access a range of structured and unstructured information. It is used to either extrapolate information produced by the analytics software or serve as an input mechanism, and it is designed to deliver a specific functionality, either horizontal or industry specific, within the IoT solution.
    - **IoT platform**: Includes software middleware packages that provide the device management, connectivity management, data management, visualisation, and applications enablement for connecting IoT endpoints. Analytics can be bundled but is not a mandatory feature. These platforms may be horizontal (enabling multiple industries) or vertical (focused on the needs of a specific industry).
    - **Security software:** Security software includes software used in an IoT solution and network for including IoT security domains in device and sensors, network and edge, analytics and enablement infrastructure, and physical safety and security. This can be an extension or enhancement of pre-existing security software solutions.
    - **"Other" software:** "Other" software includes all those software categories that fall outside the aforementioned software segments used to implement and operate an IoT solution including, but not limited to, unbundled software associated with IoT platform, storage management, structured data management, and integration and orchestration middleware.
- **Services:**
    - **Industrial implementation:** Industrial implementation refers to services needed to evaluate, design, and deploy the physical devices (the "things"). Evaluation and design services involve site assessment by engineering fields including civil, industrial, mechanical, and power engineers. Deployment services involve site preparation to allow field installation of equipment. These services are typically carried out by skilled and semiskilled trades including electricians, plumbers, carpenters, site technicians, and other various laborers. Deployment services also include device-specific modifications such as field retro fits (e.g., sensors, actuators, and relays) but exclude all IT configuration or provisioning tasks.
    - **Ongoing IT services:** IT outsourcing and support includes the following hosted application management, application management, IT outsourcing, networking endpoints and operations, hosting infrastructure services, hardware deploy and support, and software deploy and support. (Training is excluded.)
    - **Other ongoing services:** "Other" ongoing services includes: Industrial maintenance services to support ongoing operations of the device hardware ("thing") and include maintenance, repair, and operation (MRO) processes in the field supported by (non-ICT) technicians, engineers, and laborers; Vertical business process outsourcing services to support industry/use case–specific processes (e.g., call centre services and concierge services); infrastructure as a service; and Data as a service
    - **Project-oriented services:** Project-oriented services include systems integration, business consulting, IT consulting, consulting, network consulting, and custom application development. (Training is excluded.)

  - **Strategy and system design:** Strategy and system design refers to design and building of IoT systems and custom components, for example: Co-development of solutions with clients and technology partners; IoT servers customised to support use case–specific AI and real-time analytics functionality; Customised hardware with embedded ARM processor computing capability; Customised software development of IoT applications and management platforms to monitor/manage analytics and other apps as well as manage workloads at the IoT environment such as edge locations; non-volatile memory products with low-power technology, security, and high-density memory operations
- **Connectivity**: IoT connectivity includes the connection of devices to each other or to central applications, monitoring and control systems.
  - **Cellular connectivity**: Cellular networks include the various cellular mobile networks, from 2G GSM networks initially deployed in the 1990s up to newer 5G networks that are now being deployed. Earlier generations provide low-bandwidth connectivity that is sufficient for many IoT connections, while newer generations can also support high-bandwidth use cases. Cellular connectivity is typically provided as a service by a cellular mobile network operator or virtual network operator. In recent years, cellular networks are also deployed as private networks for some organisations, such as ports, manufacturing facilities, hospitals and campuses.
  - **Low-Power Wide-Area Networks (LPWAN)**: LPWAN networks are designed for IoT endpoints that often operate on batteries for extended periods without maintenance (e.g., 10+ years) and premised on periodic communication intervals with limited data transmission requirements. Within this category, we account for two types of LPWA technologies: 3GPP LPWA standards (primarily NB-IoT and LTE-M) designed to operate in licensed spectrum, and proprietary radio technologies operating in unlicensed spectrum, such as LoRaWAN, 6LoWPAN, Ingenu, Weightless, and Sigfox.
  - **Wired connectivity**: The earliest forms of telemetry to network IoT devices use wired communication infrastructure, which is increasingly overshadowed by wireless technology adoption. In several early adopter industries, wired IoT devices are still supported in the field, which include healthcare, manufacturing, utilities, and transportation. The wired category covers all forms of wireline networked devices including those connected by legacy POTS/twisted pair, cable, DSL, powerline communications, and fibre-TTX.
  - **Short-range wireless**: IoT devices communicate over a myriad of networks wirelessly at short range (<1,000ft) using radio frequency bands typically found in unlicensed spectrum are aligned with this category. Unlicensed spectrum varies by country and region and can include several frequencies — for example, 450MHz, 902MHz, 928MHz, 2.4GHz, 4.9GHz, and 5.1GHz (inclusive of ISM bands). Open industry standards generally aligned with this category include Wi-Fi, Bluetooth, Zigbee, NFC, HaLow, and 6LoWPAN. Proprietary (non-industry standard-based) technologies operating in unlicensed spectrum also support IoT devices.
  - **Satellite:** Various satellite communications services are available for IoT connectivity. Larger geostationary satellites have long offered relatively expensive connections for such purposes as oil platforms and ships, while newer constellations of smaller low-earth orbit (satellites) are expected to lower costs and enable a new range of IoT use cases monitoring assets in remote locations.