Interim Report 2

Edge nodes Digital Decade Monitoring Methodology

Edge Observatory for Digital Decade, Edge Computing Nodes: Characterization, Deployment Monitoring and Trajectories – STUDY 2022/012

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This report was prepared for the Directorate-General for Communications Networks, Content and Technology, Future Networks (CNECT.E), by the Technopolis Group under the Framework Contract SMART 2019/0024, Lot 1: Edge Observatory for the Digital Decade, focusing on Edge Computing Nodes: Characterisation, Deployment Monitoring, and Trajectories, reference No. 2022/012. The views expressed in this document are solely those of the authors and should not, under any circumstances, be regarded as an official stance of the European Commission. The European Commission does not guarantee the accuracy of the information contained within this report and shall not be held responsible for any use thereof. References herein to any specific products, specifications, processes, or services by trade name, trademark, manufacturer, or otherwise, do not constitute or imply endorsement, recommendation, or preference by the European Commission. The author has taken all necessary precautions to ensure that he/she has secured, where required, permission to use any part of the manuscript, including illustrations, maps, and graphs, for which intellectual property rights already exist, from the rightful holder(s) of such rights or their legal representative.

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Executive Summary

On 9 March 2021, the Commission adopted the Communication "*The 2030 Digital Compass: the European way for the Digital Decade" ('Digital Compass Communication')*[1]. The Communication presented a vision, targets, and avenues for a successful digital transformation of the European Union by 2030. This transformation is also critical to achieve the transition towards a climate neutral, circular, and resilient economy. The EU's ambition is to be digitally sovereign in an open and interconnected world, and to pursue digital policies that empower people and businesses to seize a human centred, sustainable, and more prosperous digital future. This includes addressing vulnerabilities and dependencies as well as accelerating investment. The Communication responded to the European Council's call for a '*Digital Compass'* and built on the Commission's digital strategy of February 2020.

The Communication[2] proposed to agree on a set of digital principles, to launch rapidly important multi-country projects, and to prepare a legislative proposal setting out a robust governance through a monitoring and cooperation mechanism with Member States, to ensure progress – the Policy Programme *"Path to the Digital Decade ('Policy Programme')".*

In its conclusions of 25 March 2021, the European Council stressed the importance of the digital transformation for the Union recovery, prosperity, security, and competitiveness and for the well-being of our societies. It underlined the need to enhance EU's digital sovereignty in a self-determined and open manner, by building on its strengths and reducing its weaknesses and through smart and selective action, preserving open markets and global cooperation. It identified the *'Digital Compass Communication: the European way for the Digital Decade'* as a step towards charting the EU's digital development for the next decade. It invited a swift review with a view to the preparation of the envisaged Policy Programme "*Path to the Digital Decade*". In addition, it invited the Commission to widen the European Union's policy toolbox for digital transformation, both at the European Union and national level, and to use all available instruments from industrial, trade and competition policy, skills and education, research and innovation policy and long-term funding instruments to facilitate the digital transformation.

The "Path to the Digital Decade" aims to ensure that the European Union achieves its objectives and targets towards a digital transformation of our society and economy in line with the EU´s values, reinforcing our digital leadership and promoting human centred, inclusive, and sustainable digital policies empowering citizens and businesses. The objective is to deliver the EU's digital transformation in line with this vision by establishing a clear, structured, and collaborative process to achieve such result. To this end, the *"Path to the Digital Decade"* sets out the concrete digital targets which the Union is expected to achieve by the end of the decade, as first delineated in the Digital Compass Communication. It then sets out a novel form of governance with Member States, through a mechanism of annual cooperation between the Unions institutions and the Member States to ensure that the Union jointly achieves its ambition. The digital target for 20230 are based on four cardinal points: digital skills, digital infrastructure, digitalisation of businesses and public services. With the purpose to strengthen

[1] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions 2030 Digital Compass: the European way for the Digital Decade, COM/2021/118 final/2, 9. 3. 2021.

[2] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Shaping Europe's Digital Future, COM (2020)67 final, 19. 2. 2020.

European capacities for digital infrastructures that meet the needs of European Business and public administrations, the Digital Decade has set the ambition that by 2030 Europe will account with:

"*10,000 climate neutral highly secure edge nodes deployed in the EU, distributed in a way that will guarantee access to data services with low latency (few milliseconds) wherever businesses are located."*

The development of edge nodes will represent a paradigm change for data storage and processing, moving to a much more decentralized model (i.e., closer to users, on their mobile, computer, car-based, or local devices in cities), reducing the volume of data that needs to be transmitted over the network, along with improving cloud computing's overall performance. Global spending on edge computing is steadily on the rise: it has reached EUR 190 billion in 2023, an increase of 13.1% over 2022, and is expected to reach nearly EUR 289 billion in 2026[3]. By 2025, edge computing will complement cloud computing for nearly every enterprise.

The development of edge nodes in the EU is at a very early stage with only three total commercial deployments of edge computing in Europe in 2022, together with announcements of partnerships and pilots in 18 Member States, very far from the objective of 10,000 secure, sustainable edge nodes by 2030. Success on the achievement of this target will require a collective focus on setting up a whole ecosystem, based on a mix of skills, infrastructure, security, innovation, and public and private cooperation.

As a start, the EU has set up a comprehensive set of measures, with the support of the Important Project of Common European Interest for Next Generation Cloud Infrastructure and Services (IPCEI-CIS), to ensure rapid and balanced development with the objective of avoiding a divide. A divide would imply an unequal distribution of economic opportunities for companies and limit the cross-border usage of latency-critical applications like autonomous driving, which would have consequences for EU competitiveness.

[3] Report on the state of the Digital Decade 2023
file:///Users/madalenabranco/Downloads/Report20230929_Ai1lrJlev2WpY8hu8FDXtCIDfk_

Study needs and motivations

This study constitutes an integral support activity for the implementation act linked to the monitoring framework of the Digital Decade Targets. It concentrates particularly on the essential aspects of defining and measuring the deployment of Edge Nodes, which is a cornerstone Digital Decade Target.

The study began by developing a detailed classification system for the various types of Edge. This document presents the methodology crafted and the comprehensive data gathering executed across the 27 EU Member States, thereby enabling a structured monitoring of the Edge nodes deployment trajectory within the European Union.

Finally, yet importantly, the study will make publicly available this information by developing an Observatory for the deployment of Edge computing technologies in Europe that has the objective to act as a reference point for the collection of information of Edge computing deployment and technologic progress in Europe, as envisaged in the Path to Digital Decade Policy Programme implementation.

Relying in the previously introduced needs and motivations, the study has three main and complementary objectives:

1. To provide a taxonomy and define a characterization of the different types of Edge nodes and Edge computing environments available for deployment. This classification details the characteristics of Edge nodes, i.e., in terms of hardware, software and network features; in addition, and contemplates the identification of deployment scenarios and typical use cases for deployment of these nodes.

2. To define a methodology for the assessment of Edge nodes deployment identifying relevant data sources and including the definition of metrics (based on the node characterisation) baselines and trajectories.

3. To establish an observatory for Edge deployment progress that monitors progress and the relevant developments in Edge computing technologies across Europe. This observatory needs to provide data at the level of each Member state. In addition, it needs to provide more granular geographical data reporting, such as data reporting at region level (to monitor the need to have an Edge node always available within a maximum distance of 100km). These will need to result in edge nodes density identification by geography, including as much as possible information on nodes characterization, deployment industries, and comparison with international developments (including but not limited to US, China, Japan, South-Korea).

1. The role of technology observatories

1.1. Observatories as gateways to technological change

In the rapidly evolving digital landscape, the imperative to comprehend and track the emergence and adoption of innovative technologies has never been more crucial. This methodology focuses specifically on Edge Nodes, a pivotal component of Edge computing, with an aim to monitor their deployment across Europe. This task holds significant relevance as it promises valuable insights into the trajectory of digital transformation, aligning with the 'Path to the Digital Decade' targets. A comprehensive methodology, incorporating the function of technology observatories, the theoretical insights offered by the Technological Surge Cycle, and diverse research methods, is proposed to be employed. Although not directly tied to Edge Nodes, the role of technology observatories and theories like the Technological Surge Cycle provide a crucial context for understanding and monitoring technological evolution and adoption. These elements are anticipated to shape the proposed methodology, thereby ensuring a holistic and dynamic approach to this task.

Public and private organisations are increasingly facing continuous waves of innovation in digital technologies. These waves present opportunities, but also uncertainties. More often, these waves are gathered under the term of emerging digital technologies. Defining the term "emerging digital technology" is not a simple exercise. Rotolo, Hicks, and Martin explored this and identified some key characteristics of emerging digital technologies, including radical novelty, relatively fast growth, coherence, prominent impact, and uncertainty and ambiguity. They define emerging technology "as a radically novel and relatively fast-growing technology characterized by a certain degree of coherence persisting over time and with the potential to exert a considerable impact on socio-economic domains, which is observed in terms of the composition of actors, institutions, and patterns of interactions among those, along with the associated knowledge production processes. Its most prominent impact, however, lies in the future and, so in the emergence phase, is still somewhat uncertain and ambiguous."

This definition also provides indications of what the impact of emerging technology could be, "considerable socio-economic impact," and the factors that can drive that impact, "actors, institutions, and patterns of interactions." This leads to an assessment of the variables that will affect the adoption of emerging technology, the dynamics of adoption, and the actors involved. A great deal of technology adoption literature and tools have been developed. The Technological Surge Cycle, developed by Carlota Perez, is a powerful theory for exploring and assessing the adoption of emerging technology.

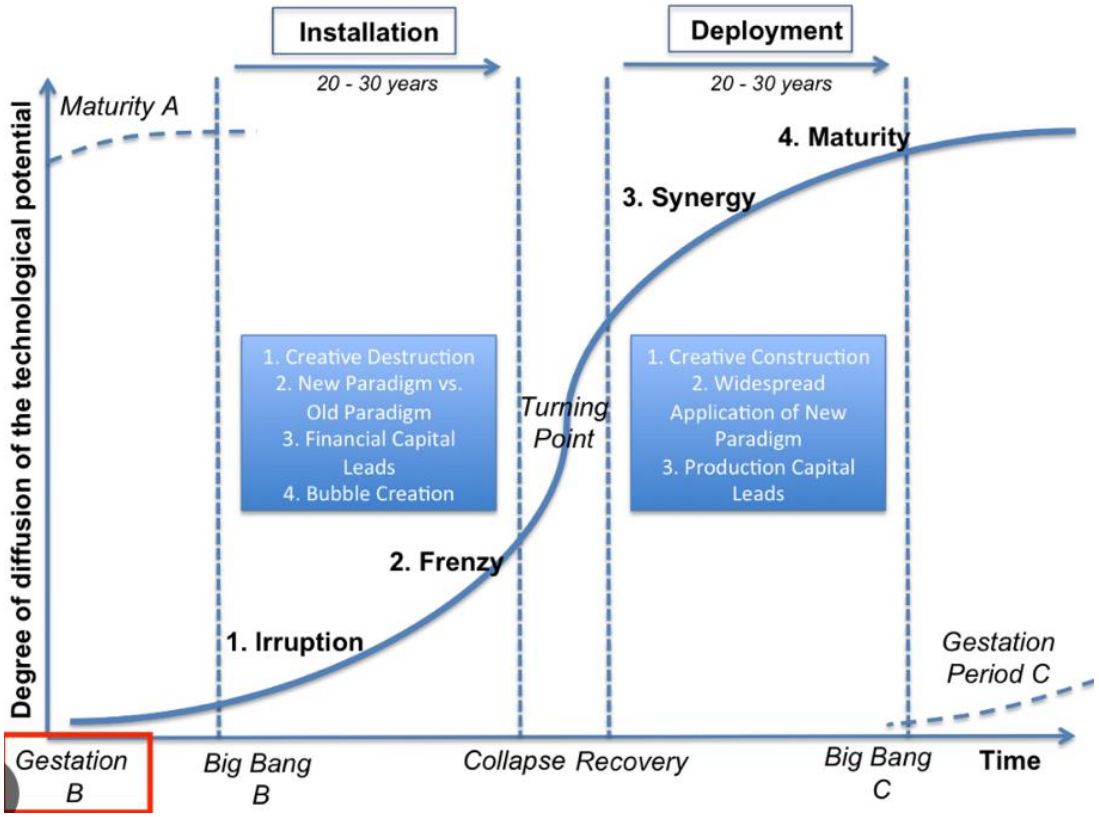
Observatories are becoming increasingly popular as a means of monitoring the development and adoption of new technologies. These observatories serve as gateways to understanding technological change by providing a comprehensive view of a particular technology, including its development, adoption, and impact on society.

The role of observatories is particularly important in the fast-paced world of technology, where new innovations emerge rapidly and can have significant implications for society. By closely

monitoring these developments, observatories can provide valuable insights into the future direction of a technology, as well as the opportunities and challenges that it presents.

Many observatories focus on specific technologies, such as the European 5G Observatory[4], the HPC Observatory[5], etc.

Figure 1: The technological surge cycle.



Source: Perez, C. (2004). Technological Revolutions, Paradigm Shifts, and Social Institutional Change.

The Technological Surge Cycle theory developed by Carlota Perez has been widely recognised as a valuable tool for understanding the evolution of technological innovation and its impact on the economy. In recent years, there has been growing interest in applying this theory to the emerging field of edge computing, which is seen as a potentially transformative technology that could reshape the way we process and analyse data.

Edge computing involves processing data close to the source of the data, rather than sending it to a centralized data centre or cloud. This allows for faster processing, reduced latency, and improved security and privacy, making it particularly well-suited to applications such as the Internet of Things (IoT), autonomous vehicles, and real-time data analytics.

To apply the Technological Surge Cycle to the edge computing context, it is crucial to first identify the specific technological innovations driving the surge in edge computing. Key innovations include the development of new hardware and software technologies, such as low-

4 European 5G Observatory. Available at: https://5gobservatory.eu (Accessed: Tuesday 10 April 2023).
5 RISC2 Project. HPC Observatory. Available at: https://www.risc2-project.eu/hpc-observatory (Accessed: Tuesday 10 April 2023).

power processors, specialized accelerators, and advanced AI algorithms. Additionally, the emergence of new communication protocols and network architectures, such as 5G and software-defined networking (SDN), have enabled edge computing to flourish.

Edge computing has primarily been used to enhance consumer quality of experience (QoE) by reducing network latency and potential congestion points, speeding up content delivery, and lowering operator costs by reducing peering traffic since its invention a decade ago. With the rollout of 5G, edge computing is more crucial than ever before due to the surge in data volume that will come from the massive number of devices.

In addition to improving user experience in areas such as video, augmented reality, virtual reality, mixed reality, and gaming, edge computing plays a vital role in enabling ultra-reliable low-latency communication use cases in industrial manufacturing. It also helps operators meet strict legal requirements on data security and privacy, making it increasingly problematic to store data in a global cloud.

Edge-computing applications will have varying requirements, depending on the driver that motivated them. They will be built around different ecosystems that utilize platforms, which may be ecosystem specific. For example, the platforms and application programming interfaces (APIs) for smart manufacturing are different from those required for gaming and other consumer-segment-related use cases, which can be based on web-scale platforms and APIs.

Phase 1: Innovation and entrepreneurial activity

During the first phase of the Technological Surge Cycle framework, we can expect to see a surge in the development and implementation of new edge computing applications and use cases, driven by the introduction of innovative technologies. It is certain that more compute capacity closer to where the data is created and/or used will be needed. It can be expected that there will be a need for significant growth in the edge computing industry in the next 5-10 years (2027-2030), with the sector potentially needing to grow by a factor of 10 during this period.

This growth is likely to be driven by the emergence of new applications and use cases, as well as the adoption of emerging technologies and the deployment of new edge computing infrastructure. It is anticipated that this growth will be facilitated by increased investment in research and development, as well as collaboration between industry players, academia, and other stakeholders.

Furthermore, this growth is expected to result in significant opportunities for companies operating in the edge computing industry. As the industry continues to mature, it is likely that we will see increased standardization and interoperability between edge computing platforms and technologies, further driving adoption and growth.

Great opportunities are on the horizon for technology developers (e.g., Intel, Microsoft, AWS), system integrators (e.g., Accenture, IBM), solution providers (e.g., Siemens, Schlumberger), IT providers (i.e., distributors, local integrators, experts), hyperscalers (e.g., Microsoft, Amazon, Google, Oracle), telecom operators, and likely many others. All these players are assessing which part of the value chain to focus on: hardware, orchestration solutions, system integration, ecosystem, or system operation.

Phase 2: Consolidation and standardisation

During the second phase of the cycle, we might expect to see consolidation in the industry, with larger companies acquiring smaller ones and the emergence of dominant players in the market. This phase is typically associated with a focus on efficiency and standardization, as companies seek to scale their operations and optimize their business models. For example, we are already starting to see major cloud providers such as Amazon Web Services, Microsoft Azure, and Google Cloud Platform develop their own edge computing offerings, which could potentially dominate the market as the industry matures.

For instance, there have been recent partnerships between telecom network operators and IT companies. Some examples can be found below:

Figure 2: Major telco-hyperscalers edge partnerships.

Operator	Platforms	Infrastructure	Region	Use cases
AT&T	Google Cloud Microsoft Azure	No announced plans	US, Americas	AI/ML, video analytics, Enterprise AR
Etisalat	Microsoft Azure	No announced plans	UAE, Middle East	Smart cities, IoT, public safety, vRAN
KDDI	AWS	No announced plans	Japan	Gaming & entertainment AR/VR, video optimisation
Proximus	Microsoft Azure	No announced plans	Belgium	Manufacturing, AR/VR, gaming, healthcare, logistics
Rogers	Microsoft Azure	No announced plans	Canada	Smart campus, gaming, AR/VR
SK Telecom	AWS Microsoft Azure Internal (MEC Open Platform) MobiledgeX	Planned 12 data centres	South Korea	Video optimisation, AR/VR, gaming, smart factory, autonomous vehicle
Telecom Italia	Google Cloud	No announced plans	Italy	
Telefonica	Google Cloud Microsoft Azure	No announced plans	Spain	Automotive (assisted driving), entertainment & media, financial services
Telkomsel	Microsoft Azure	No announced plans	Indonesia	Manufacturing, IoT, AI, AR/VR
Telstra	Microsoft Azure	Identified 500 potential locations	Australia	Financial services, gaming
Verizon	AWS	12 edge locations in 2020	US	AI-powered facial recognition software, AR/VR
Vodafone	AWS Microsoft Azure	24 sites planned for Europe	UK, Europe	Video analytics, real-time asset inspection, AR, drones, AI-powered media editing

Source: STL Partners.

Telecommunications companies and large-scale cloud service providers are principal players in the edge computing landscape. Each party is currently at a crossroads, with telecommunications companies possessing the infrastructure but lacking the advanced cloud platforms, and cloud providers holding the technology but requiring physical network proximity. Initially perceived as rivals, they were strategizing independently to capture market share.

Nonetheless, it has become clear to telecommunications companies that despite owning the necessary infrastructure, the sophistication of cloud services offered by the major cloud providers is indispensable for the development of a distributed computing environment that many modern applications demand. In pursuit of energizing the edge computing market, it is anticipated that telecommunications companies will predominantly collaborate with these cloud service providers. Such collaborations are emerging and will significantly influence both the immediate and future market dynamics, not only for telecommunications companies and cloud providers but also for other stakeholders in the field.

Overall, these developments demonstrate the growing importance of edge computing in enabling organizations to achieve their digital transformation goals. By providing low latency infrastructure, improved efficiency, and performance in data-intensive applications, edge computing is becoming a critical component in the digital strategies of many global enterprises.

To handle this data explosion, new locations for computing are needed, which must be physically closer to where the data is generated and consumed, and edge computing is best suited to meet these requirements. Edge computing provides low latency, ability to store, process substantial amounts of data, protection of data, and an ecosystem of software applications and data pools.

In the industry, there is a battle for the winning IT platforms on the edge, fought on two fronts: the location of computing and whether to operate a service, self-built infrastructure or a hyperscale edge infrastructure. During the second phase of the Technological Surge Cycle, the industry is expected to consolidate, with larger companies acquiring smaller ones and dominant players emerging.

To drive edge demand, telecom operators should motivate their clients to shift workloads from central data centres to near-premises distributed hosting or on-premises dedicated edge. Security and latency concerns drive the former, while market forces support the latter.

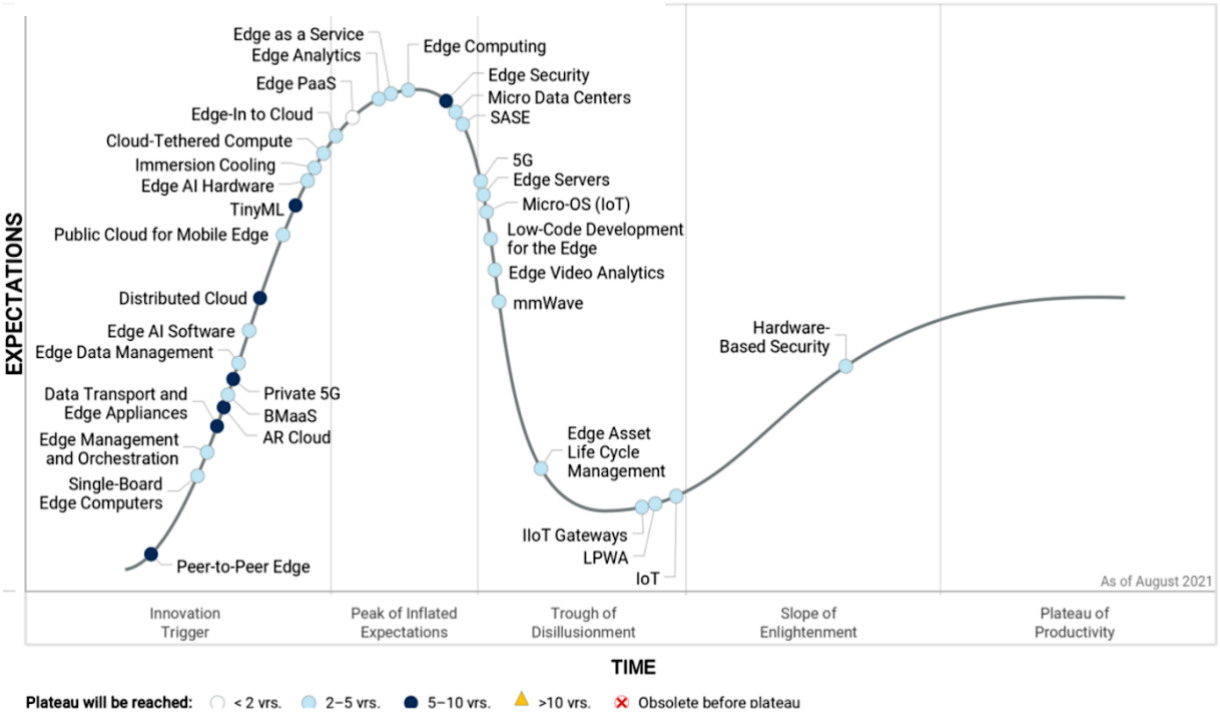
In the realm of economic policy, it is imperative for policymakers to foster a conducive environment for innovation and capital infusion in edge computing technologies in the initial phase of the deployment cycle. This entails enacting policies that bolster the growth and maturation of edge technologies, underpinning research, and development, and shaping industry standards and protocols. Within this context, the Digital Decade Policy plays a crucial role, as it aims precisely to achieve these objectives. The policy is designed to streamline and expedite the adoption of edge computing by setting clear targets, encouraging industry collaboration, and establishing a regulatory framework that promotes long-term sustainability and interoperability within the digital ecosystem.

Phase 3: Renewed innovation and disruption

During the third phase of the cycle, it is expected to see renewed innovation and disruption in the industry as new technologies emerge, new players enter the market, and existing players seek to maintain their competitive advantage. This phase is characterized by a focus on differentiation and innovation, as companies seek to create new value propositions and drive the adoption of edge computing in new industries and use cases.

According to this theory, the growth of edge computing is likely to follow an S-shaped curve over time, consisting of four phases: installation, deployment, maturity, and decline. In the installation phase, new technologies are developed, and new companies and business models emerge, leading to experimentation and high levels of investment. In the deployment phase, operations are scaled, and efficiency is optimized, leading to the emergence of dominant players in the market. In the maturity phase, the technology becomes deeply integrated into the broader economy and society and may become a foundational technology that underpins many other industries and applications. Finally, in the decline phase, the technology is gradually replaced by newer and more advanced technologies.

Figure 3: Gartner's Hype Cycle for Edge Computing.



Source: Gartner, 2021.

Phase 4: Saturation and commodity

In the final phase of the technological surge cycle, the edge computing industry is expected to become a commodity, with a limited number of dominant players and a focus on cost and efficiency. This phase is characterized by standardization and interoperability, as companies seek to streamline their operations and reduce costs.

As edge computing becomes a more established technology, the focus shifts from innovation and differentiation to scale and optimization.

During this phase, a consolidation of the market will take place, with smaller players being acquired by larger ones. This consolidation may lead to the emergence of dominant players who have the resources to scale their operations and optimize their business models.

One example of this trend can be seen in the cloud computing market, where a few dominant players, such as Amazon Web Services, Microsoft Azure, and Google Cloud Platform, control a significant share of the market. These companies have invested heavily in infrastructure and have the resources to drive down costs, making edge a commodity.

The Gartner Hype Cycle[6] serves as an objective framework for assessing the risks and opportunities associated with adopting innovative technologies, preventing early or late adoption, or lingering on an outdated technology. The cycle encompasses five phases, including the innovation trigger, peak of inflated expectations, trough of disillusionment, slope of enlightenment, and plateau of productivity.

Edge computing, a technology that has gained significant hype, is mapped on the Hype Cycle to determine its progress towards niche status, abandonment, or mainstream adoption. While some technologies and processes associated with edge computing are established and proven in other contexts, others reflect newer capabilities that can stand independent of edge computing but can be applied in new ways with edge deployment. The fact remains that edge computing is currently implemented in many client environments, generating revenue, saving money, improving safety and customer experience, and enabling entirely new applications and data models.

Since last year's Hype Cycle, the state of edge computing has evolved significantly due to aggressive adopters using edge computing to respond to the pandemic with agile business designs. However, the hype associated with the technology has also grown, leading to a static position on the Hype Cycle curve.

Providers are focusing on specific technologies and implementations in specific verticals to jump-start the market, while general impediments to edge computing deployments such as security and data management are moving through the hype cycle more quickly than in previous years. The paths to edge computing implementation range from "build your own stack" to business-outcome-based edge-computing-as-a-service solutions, reducing complexity, risk, and time to deployment.

Overall, data aggregation and analytics at the edge, combined with cloud access for scale-up capabilities, will create a new economy built on digitally enabled edge interactions.

[6] Gartner. (2020). The Hype Cycle for Cloud Security, 2020. [online] Gartner.com. Available at: https://www.gartner.com/en/documents/4004359

2. Tracking Technology Trends: Observatories

This section aims to provide a benchmark analysis of some topically adjacent technology observatories, examining their role in tracking and analysing the development of digital technologies. Specifically, the following observatories: European 5G Observatory, Blockchain Observatory & Forum, European Open Science Cloud (EOSC) and the HPC Observatory will be explored to gain insights into the information and analysis they provide and the roles they play within their respective ecosystems.

European 5G Observatory

Figure 4: European 5G Observatory.

Source: European 5G Observatory.

The 5G observatory and scoreboard is described as monitoring the progress towards the EU's 5G policy goals. It is funded by the European Commission and, since August 2021, has been produced by a consortium of three companies: VVA, PolicyTracker, and LS Telcom.

The website's objectives are to track and report on key policy changes in the 5G landscape in Europe and to monitor 5G rollout both within the EU and internationally via two separate scoreboards. The observatory aims to serve as an ecosystem support and go-to resource by covering news, EU initiatives, regular reporting, thematic sections, and event announcements. However, some sub-pages are no longer being updated as policy and technology development have already moved into 6G.

The website's content is organized into several categories, including an About section with a brief description of the site, its partners, and observatory aims, a Reporting section featuring the scoreboard and regular reporting, an EU Initiatives section highlighting program initiatives and existing toolboxes, and a Themes section with sub-themes that offer in-depth information about 5G. Additionally, there is a 5G Policy section that lists national strategies and funding

options and a 5G Spectrum section that provides an overview of the frequency spectrums assigned to 5G. An Archive section is also available.

The website aims to both track- and report about key policy changes in the 5G landscape in Europe, as well as keeping track of 5G rollout both the EU and internationally, via 2 separates 'scoreboards.
(see https://5gobservatory.eu/observatory-overview/interactive-5g-scoreboard/).

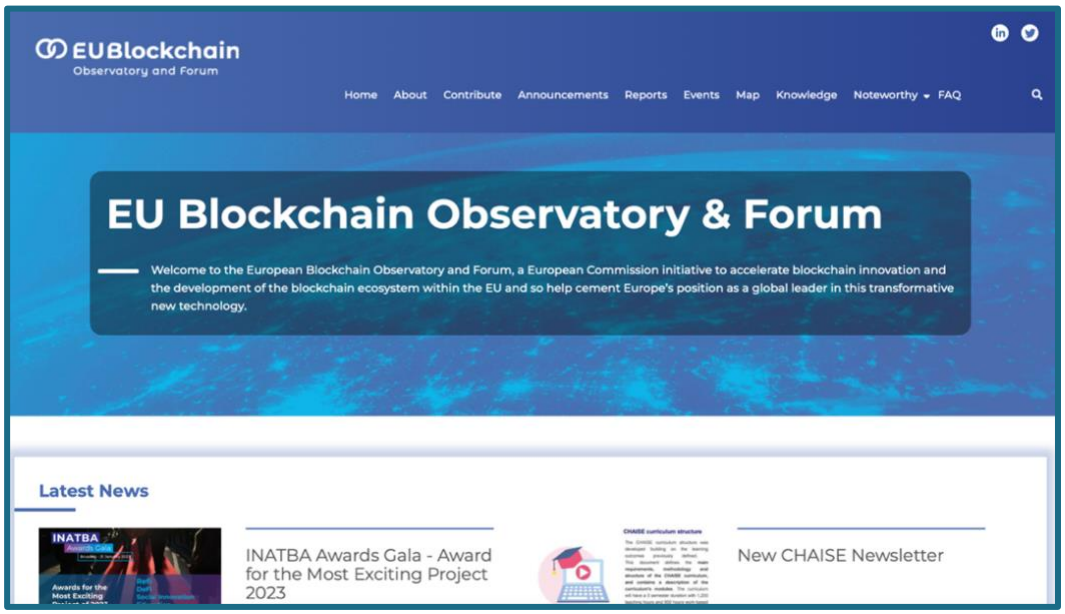
Besides these scoreboards, the observatory also aims to play a role as an ecosystem support and 'go to' place, by also covering news, novel EU initiatives, regular reporting, thematic sections and the announcement of events and conferences, among others. Some of the sub-pages are no longer being updated, as the policy-and forefront technology development has already moved into 6g.

Main content offered

- About: a brief description of the site, its partners, and observatory aims.
- Reporting: includes the scoreboard and regular reporting categories.
- EU initiatives: showcases program initiatives and existing toolboxes.
- Themes: features sub-themes falling under 5G with in-depth information.
- 5G policy lists national strategies and funding options.
- 5G spectrum provides an overview of the frequency spectrums assigned to 5G.
- Archive: an archive of previous content.

EU Blockchain Observatory and Forum

Figure 5: EU Blockchain Observatory and Forum.



Source: EU Blockchain Observatory and Forum.

The EU Blockchain Observatory and Forum aims to accelerate blockchain innovation and the development of the blockchain ecosystem within the EU, and to help cement Europe's position as a global leader in this transformative new technology. It is being run by the European Commission's Directorate General for Communications Networks, Content and Technology (DG CONNECT) and led by a consortium consisting of Netcompany Intrasoft (general

contractor), the University of Nicosia, the Institute of Information Technology/CERTH, White Research, Bitfury, OpenForum Europe, and PLANET S.A.

The Observatory's focus is on being a forum for policy influencing, although it also offers a map on which different initiatives are plotted. The website covers events and news related to blockchain and offers regular reporting, a repository of papers and educational material, and a call to contribute to the interactive map as a blockchain initiative.

Main content offered:

- About: a description of the observatory's mission, activities, and partners.
- Contribute: a call to contribute to the interactive map as a blockchain initiative.
- Announcements: news about blockchain.
- Reports: observatory reports on blockchain development, divided into thematic reports and workshop reports, and videos.
- Events: an agenda of blockchain-related events.
- Map: an interactive map showing blockchain initiatives in Europe.
- Knowledge: research papers developed in the consortium and educational videos on blockchain.
- Noteworthy: a selection of papers, events, and news within the blockchain observatory community.
- FAQ: frequently asked questions about both blockchain and the observatory.

European Open Science Cloud (EOSC) Observatory

Figure 6: European Open Science Cloud (EOSC) Observatory.

Source: European Open Science Cloud (EOSC) Observatory.

The European Open Science Cloud (EOSC) Observatory differs from the previous observatories as it focuses on a network and a concept rather than a specific technology. The Observatory describes itself as a policy intelligence tool developed by the EOSC Future project to monitor policies, practices, and impacts related to the EOSC.

Its objective is to assist the EOSC community in monitoring the implementation of EOSC and aiding policy makers in creating actionable policies.

The monitor tracks four things on different levels (regional, national, EU):
EOSC-readiness, 2) EOSC partnerships, 3) financial and in-kind contributions to partnerships, and 4) policies relevant to the EOSC ecosystem. The observatory monitoring has a different look and feel from the other two as it does not use a classical website-menu structure. Instead, users are prompted to go directly to the actual monitor. The observatory has been developed as a policy progress monitor, showing whether certain developments are in place without delving into what these developments are. The EOSC Observatory is funded by the European Union's Horizon 2020 Research and Innovation program under EOSC Future (No. 101017536).

Main functionalities offered:
Once on the actual monitor, users can view the different elements of the monitor in graph or table form and toggle through indicators to change views. The monitor looks at EOSC policies and EOSC practices and offers different views and indicator combinations to show different levels of readiness or progress. In addition to the landing page, the monitor also offers a log-in for members and an EU readiness link.

Comparing the Observatories
When comparing the observatories, it is evident that the EOSC monitor has a unique focus on policy intelligence, making it a bit more tailored to a specific audience. Unlike the other two observatories, it lacks links to news, events, and educational materials, as the monitor itself serves as the main feature. On the other hand, the 5G and Blockchain observatories have a strong community focus regarding a specific digital technology, combined with an outward-looking element for an interested audience. Overall, a digital technology observatory aims to provide fact-finding and progress representation, such as funding, new initiatives or companies, and new connections between entities. Additionally, it includes a strong community-organizing element that involves sharing news, events, drawing up collective policy recommendations, and sharing knowledge.

The table below summarizes the key elements of each observatory:

Table 1: Comparing features/sections of the different observatories.

Features	5G	Blockchain	EOSC	HPC
News	x	X		x
Events agenda	x	X		x
Scoreboard	x		x	
Education	x	X		
Reports	x	X		x
Map	x	X	x	x
Educational material		X		
Calls/ Funding opportunities	x			
Policy papers/ opinions	x	X		x
Policy monitoring			x	
Community portal	x	X	x	

Source: Own elaboration.

3. Overview of methodology

3.1. Conceptual framework

The approach to monitoring the deployment of edge nodes across the EU, employs a multifaceted methodology for gathering data, enhancing the comprehensiveness and reliability of the findings. This includes targeted surveys aimed at industry stakeholders, semi-structured interviews for more nuanced perspectives, country-specific reports to capture regional variations, case studies for in-depth analysis, and a review of existing literature to establish the overall context. This diverse toolkit allows for a robust evaluation of trends in the deployment of edge nodes and how they align with the goals and targets set forth by the European Digital Decade. In view of providing up-to-date evidence, the conceptual framework proposed here underpins the main elements of the study, notably the:

- mapping and monitoring EU countries deployment of edge nodes *(countries performance, strategies, initiatives, funding related to edge computing).*
- country-specific assessment of deployment *(evaluate the unique challenges, enablers, and barriers that each country faces)*.
- the progress within the EU wider context in view of the Digital Compass targets.
- monitor key international trends in edge computing.

Figure 7: Conceptual framework for the Edge Observatory for the Digital Decade.

Source: Own elaboration.

3.2. Quantitative research

The edge computing landscape is becoming increasingly diverse, attracting a range of participants such as telecommunications companies (telcos), hyperscale cloud providers, data centre operators, and enterprise connectivity services. Given the varied needs spanning multiple verticals, business scales, and application scenarios, the market presents opportunities for all these different actors.

In the investigation of prevailing trends and behaviours in the European market, quantitative methods have been extensively employed. Surveys tailored to capture insights from a multifaceted community—including IT service providers, cloud vendors, telecommunications companies, and other service providers—have been administered, thereby generating valuable data for rigorous statistical analysis. This foundational data will be augmented through scrutiny of nation-specific reports, adding a macro-level dimension to our understanding of the market. Such reports serve as a crucial underpinning, adding both breadth and depth to the study by providing a systematic basis for interpreting national trends. Packed with insightful statistical data, these reports are presented in an intelligently aggregated and easily consumable format, making them invaluable tools for interpreting national trends and shaping policy decisions.

Methodologies of foresight have been engaged to create trajectory curve analyses as well. These curves are instrumental in forecasting future trends based on existing data. Not only do they offer a glimpse into the present landscape, but they also serve as predictive tools for future market dynamics. As a result, the analytical depth of this investigation has been substantially elevated, enabling the derivation of more accurate and actionable insights.

The initial S-curve projection was formulated based on IDC's assumptions and expert knowledge concerning the likely number of both public and private edge facilities across Europe. A second curve is anticipated, following the release of the first European Data Resource Report (EDRR), and will be further refined upon the issuance of the third EDRR.

3.2.1. Scenario development and foresight analysis

Starting baseline

The starting point involves a comprehensive assessment of the current state of edge nodes deployment across the EU. This baseline data will provide an understanding of the prevalence and distribution. Existing measures for monitoring this deployment, which may include reports from regulatory bodies, industry surveys, and academic studies, should be reviewed to gain a complete understanding of the status quo. The target is to materialise the vision set out in the data strategy that is to have 80% of data processing done at the edge by 2025.

According to IDC's projections, which are founded on anticipated trends in budget allocation and spending for Edge IT infrastructure, the rollout of climate-neutral, highly secure edge nodes is expected to follow a standardized S-curve pattern in terms of technology and innovation adoption. Importantly, these projections are based on investment values rather than unit numbers, serving as a reliable point of reference for estimating the deployment of edge nodes in future years.

The graph below follows an estimated adoption starting in 2022, assuming there are already ~500 edge nodes deployed across Europe and presents the estimated evolution of this adoption to reach the target of 10.000 by 2030. This evolution is highly dependent on the assumptions presented below.

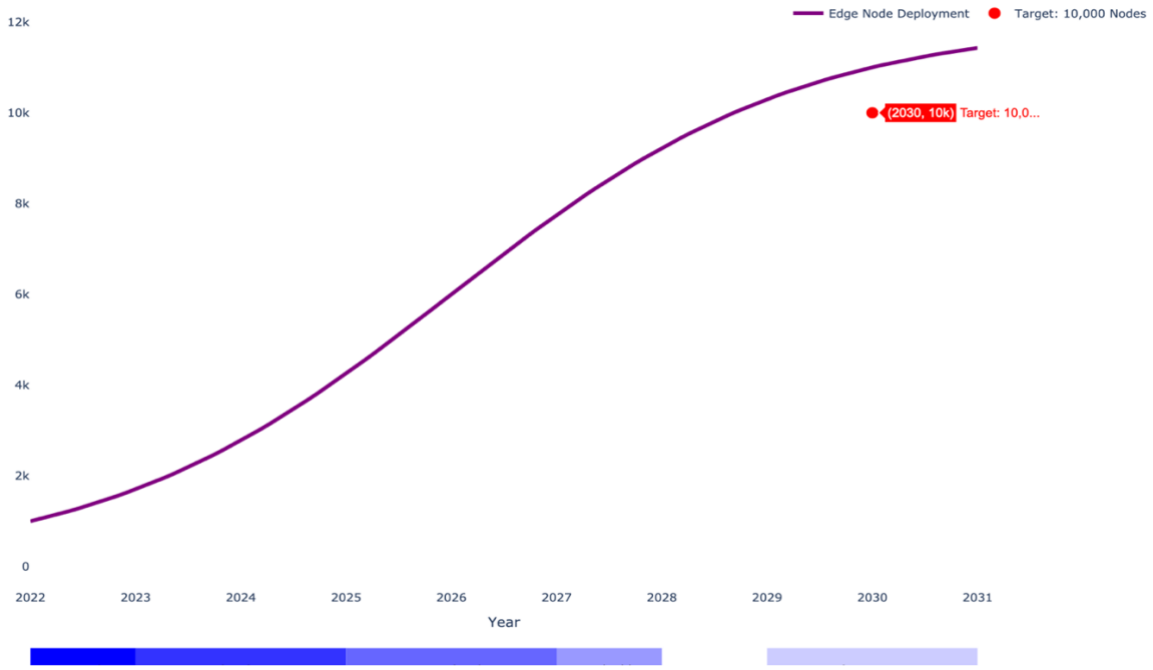
It is vital to acknowledge a deviation in this assumption from the forecast presented in the European Commission's 2023 Digital Decade Report. The Commission's report proceeds from a baseline assumption of zero, citing the absence of robust data for an accurate current count of edge nodes within Europe. The discrepancy is attributed to the Commission's commitment to data reliability and the anticipation that forthcoming phases of this study will yield the necessary empirical data to inform future projections accurately.

The initial number of nodes at the beginning of the curve represents IDC best estimation of nodes existing in Europe, based on assumptions and best of knowledge regarding the potential number of public and private edge facilities in Europe, including existing edge infrastructure/devices/edge nodes providing local computing and storage resources closer to where the data is generated.

Please note that these numbers are not linked to any of IDC's existing surveys. Any existing survey used as a reference was only intended to provide additional insights into the market trends. These surveys are meant to represent a statistically meaningful sample (typically a few hundred to a few thousand respondents) of views across the entire market (hundreds of thousands to millions of organizations) of the sampled countries, rather than implying that the universe of customers or organisations is limited exclusively to the number of companies that are included as respondents to a survey. Usually, surveys are used as an additional secondary research valuable tool for data collection, allowing us to get the necessary answers about certain markets/technologies and they are intended to be used together with other relevant research tools/reports*, such as interviews, primary research, macroeconomic data and so on.

IDC Publications corroborating the projections:
*IDC – Market Analysis Perspectives: European Edge Strategies, 2023;
*IDC – European Edge Market Forecast, 2022–2026;
*IDC - Worldwide Edge Spending Guide;

Figure 7: S-curve trajectory of climate-neutral and secure edge node deployment in the EU.



Source: Own elaboration.

Factors driving the edge nodes buildout in Europe

Assumptions accelerating demand

- Demand will result in 10,000 nodes deployed in 2030[7].
- Increasing edge workloads and relevance.
- More AI and Data Analytics.
- Increasing standardization of edge platforms for volume deployments.
- Design experience of climate-neutral and secure edge nodes - template approach.
- Increasing capabilities and reduction in costs for bandwidth and ground TX/RX hardware[8] costs for 5G and successors, emerging global LEO communications[9] networks such as Starlink, and continued rollout of ground-based physical network transports.
- Need for low latency processing driving edge infrastructure to a closer physical proximity to data generating facilities.

Constraints factoring a more linear build cycle than for S-curve

- Linear supply of construction personnel.
- Limitations on credit and financing.
- Limitations on network buildout.
- Long lead time and complexity of site selection and approval processes.
- Supply and provisioning of infrastructure support equipment.
- Qualification and production process.

[7] Europe's Digital Decade: Digital Targets 2030. Available at: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030_en (Accessed: Tuesday 10 April 2023).
[8] TX/RX hardware refers to the equipment or components responsible for transmitting (TX) and receiving (RX) signals. This terminology is common in electronics and communications, encompassing domains such as wireless communication, network hardware, and radio communications.
[9] Low-Earth-orbit (LEO) satellites typically communicate through intersatellite links, but some may operate independently. LEO satellites operate closer to Earth compared to traditional geostationary satellites, offering reduced latency and potential for higher data rates.

- The advancement of compute, storage, and networking inherent in Moore's law means that ever more capable infrastructure that can run multiple times the workloads can fit into existing edge node footprints over time, reducing the need to keep building out more physical capacity in edge node facilities.

Business goals driving edge adoption

- Performance.
- Innovation.
- Cost & efficiency
- Growth.
- Cybersecurity.
- Reorganisation.
- Regulation.

Main challenges holding back or slowing Edge computing projects

- Security concerns.
- High costs and unclear ROI.
- Lack of skills/qualified workforce.
- Lack of adequate IT infrastructure.
- Incompatible components.

3.3. Qualitative research

In the qualitative research section, the study delves into the nuanced aspects of edge node deployment that are not easily captured through quantitative metrics. Interviews, focus groups, and case studies are employed to gain deeper insights into the motivations, challenges, and strategies associated with implementing edge nodes. This approach allows for a more comprehensive understanding of the ecosystem, capturing the complexities and intricacies that quantitative data might overlook. The qualitative findings also serve to contextualize and enrich the quantitative data, providing a well-rounded view of the current landscape.

3.3.1. Literature review

The initial phase of collecting documents and research papers started with the keywords passed to the searching services. To perform such operations, the Boolean operators including AND and OR are used. The sentence is formed in such a way to get the finest practicable inferences to support the answers to the questions listed in the table below. Hence the sentences used to feed search queries were:

- (“Edge Computing” OR “Edge-Computing”) AND “Security”
- (“Edge Computing” OR “Edge-Computing” OR “Network Edge” OR “Fog Computing”)
- AND (“Security” OR “Cyber-Security” OR “Cyber Security” OR “Cybersecurity”)
- AND (“Climate-neutrality” OR “Environment” OR “Footprint measurement methodology”)
- AND (‘Sustainability” OR “Carbon-neutrality” OR “Green”)

The following platforms were used for conducting the search:

- The IEEE Xplore Digital Library
- Google Scholar
- SpringerLink

- ScienceDirect
- ACM Digital Library
- Research Gate

Different search engines/databases/portal were query, extracting strings from the title, as well as keywords as mentioned earlier, or even from the abstract. Over the course of one month, all pertinent documents and academic papers available up to that point were searched, analysed, and reviewed. To refine the resulting records, inclusion and exclusion criteria were applied to ensure a better fit for purpose.

Table 2: Research questions guiding the literature review.

Research questions (RQs)
RQ (1) Who are the dominant market players in the edge computing sector, and what are their primary strategies?
RQ (2) What are the current market growth trends associated with edge computing?
RQ (3) What are the latest applications focused on edge computing security?
RQ (4) What are the most common types of attacks and what associated mitigating solutions targeting edge computing networks?
RQ (5) Which are common parameters and optimisation focus of Energy efficiency in Edge computing?
RQ (6) Which are main criteria used for Edge placement strategies?
RQ (7) Which are common criteria and methods to define Edge deployment density?
RQ (8) Which are common capacity and latency thresholds used in Edge computing works and per Edge types?

Source: Own elaboration.

The literature review will not only be presented as a separate, standalone document but will also be incorporated into the first EDRR. The table that follows offers template for a summary of the key findings from the literature review.

3.3.2. Interviews

In-depth, semi-structured interviews with IT executives and IT decision makers.

The study encompasses providers of both heavy and light edge equipment infrastructure, networking infrastructure within the Near Edge and Far Edge ecosystems, services provisioned at the Edge and Far Edge, and professional services within these ecosystems across Europe. For each category of providers identified, at least one interview is conducted.

In-depth, semi-structured interviews with industry associations

To ensure a thorough collection of the requisite data, the interview script has been meticulously developed. This comprehensive framework is designed to guide the discussion in a manner that addresses all pertinent topics and questions.

Collecting information from companies, especially commercially sensitive information, can reveal itself to be challenging as companies will be reluctant to share, especially if it is uncertain for them who will have access to these data. Hence, this is a large potential risk for the study. This is likely to be particularly pertinent in relation to companies for whom Edge is a core business. To ensure compliance with the EU mandate underpinning the study and to handle sensitive data or information appropriately, all (potential) participants will be made aware of the process. Sensitive data will be anonymized and presented only in aggregate form.

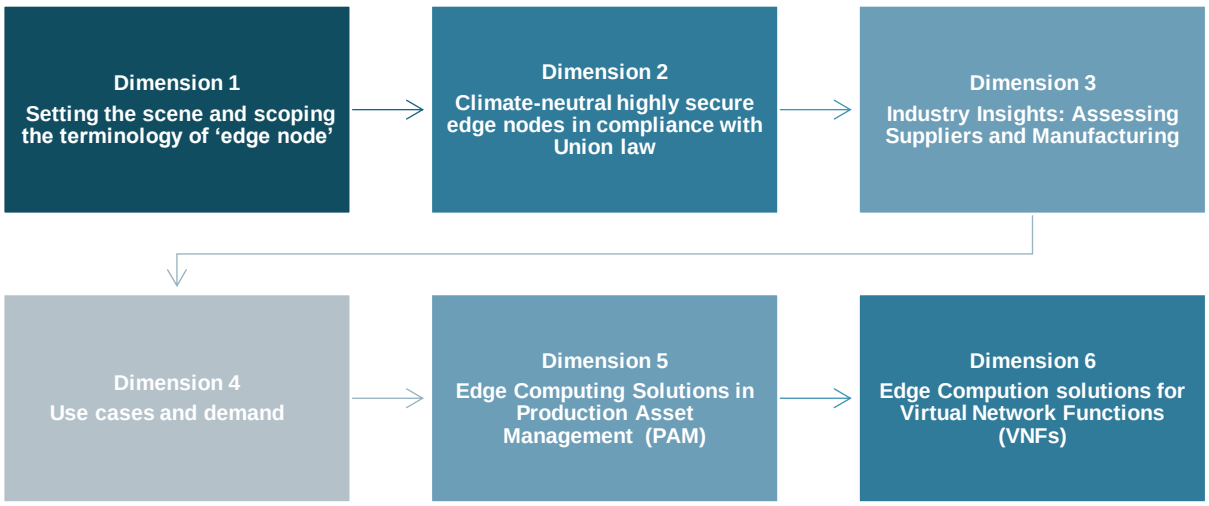
The above methods will be used in combination and will constitute the basis for quantitative analytical methods contributing to an initial quantification of the indicators. The initial quantification of the indicators will cover both the supply-side as well the demand-side of the edge market.

For the demand-side, additional primary research in the form of in-depth semi-structured interviews with Chief Information Officers and/or IT executives of user companies in different industries, vertical markets and sectors will complement the supply-side picture stemming from the above market analysis methods.

The starting point for the identification of the relevant interviewees will be the use-case analysis included in IDC Worldwide Edge Spending Guide which defines a set of specific usage of edge technologies for a specific function within a specific sector/vertical market and associates a market value for each use-case in each geography or region. The study team will identify the 10 most significant use-cases in Europe overall based on their market share per spending.
As of the time this document was written, the IDC Worldwide Edge Spending Guide indicates the top 10 use-cases in Europe based on spending value. These use-cases arise from either enterprises or service providers and are detailed later in this document.

This approach maximizes the reliability and completeness of the data gathered, thereby enriching the overall quality of the study. The dimensions incorporated into the script are outlined below. Dimensions 5 and 6 are specifically tailored to align with the use cases under examination in the various data reports.

Figure 8: Dimensions guiding the interview script with IT leaders and providers.



Source: Own elaboration.

3.3.3. Case studies

A minimum of 10 case studies will be developed, contingent on the assessment of the study's requirements. These case studies will be based on the top 10 use-cases as identified in the IDC Worldwide Edge Spending Guide. To ensure a comprehensive understanding of these use-cases, dedicated interviews will be conducted. This methodological approach aims to provide an exhaustive exploration of the most significant use-cases in terms of spending value.

Table 3: Top 10 use cases based on spending value.

#	Use Case	Description
1	Content Delivery Network	A content delivery network (CDN) facilitates the secure and timely delivery of content to end users within well-established performance and quality-of-service metrics. A CDN is typically architected with a geographically dispersed network of cache or proxy servers, deployed centrally and in edge servers.
2	Virtual Network Functions	Virtual network functions (VNF) are used to abstract network operations software from the network hardware.
3	Multiaccess Edge Computing	Multiaccess Edge Computing (MEC) is a term that refers to IT infrastructure (e.g., servers, storage) located at the Telecommunication service providers' network edge that enables cloud services delivery.
4	Omni-Channel Operations	IoT based Omni-channel Operations supports the evolving multi-channel retail strategy to provide a seamless consumer experience through any shopping channel, i.e., mobile internet devices, computers, brick-and-mortar, television, radio, direct mail, and catalogue.
5	Production Asset Management	IoT scenario that helps a company to remotely track, monitor and maintain industrial manufacturing devices that are part of the production value chain.
6	Freight Monitoring	IoT for freight management (air, railroad, land, or sea) that is based on the technology of radio frequency identification (RFID), global positioning system (GPS), GPRS, and GIS, and creates an intelligent, Internet connected transportation system.
7	Autonomic Operations	Real-time assessment of current demand and capacity availability continuously and intelligently re-sequences work on the factory shop floor.
8	Distribution Automation	Non-smart meter field devices owned by the electric utility used to control and optimize power flow to assure efficient, safe, and reliable service.
9	Insurance Telematics	IoT technology for usage-based insurance offerings for vehicles/autos for both consumer and business clients.
10	Remote Health Monitoring	Home or remote healthcare that uses the IoT technology platform to improve quality of life and care through accurate and focused medical home or remote monitoring for chronic diseases (e.g., asthma, diabetes).

Source: Own elaboration.

Table 4: Structure of the case studies.

Guidance
Objectives
Timing
Case study
Executive Summary
Introduction
Context and problem statement
Approach and implementation
Results and impact
Expert opinions
Key takeaways and prospects
Conclusion
Annexes
Bibliography
Data analysis/methodology

Source: Own elaboration.

3.3.4. Surveys

To address potential information gaps in specific parts of the market, two distinct quantitative surveys will be designed and implemented. These surveys will complement the demand-side indicators that have already been identified. The second survey will be conducted at least one year after the first survey to capture trends and monitor changes in the main indicators, providing a significant update to the initial baseline. The results of the first survey will be used to create Edge Deployment Data Report 1, while the results of the second survey will be used to create Edge Deployment Data Report 3. By conducting these surveys and analysing the results, a more comprehensive and up-to-date understanding of the Edge and Far Edge market can be achieved.

The first survey will provide a key input for the definition of the starting baseline both as to the preferred methodology mix to choose (Task 1.2), as well as in terms of actual data providing a starting point as to the deployment and uptake of Edge nodes in Europe. The second survey will include potential improvements and minor changes with respect to the previous one so to overcome potential methodological drawbacks and consider possible requests of improvements by the European Commission.

Both surveys will have a sample size of 300 respondents to be representative and statistically significant. Each survey will cover a distinct set of 10 Member States to ensure the largest possible number of surveyed countries

The distribution of the sample size, country coverage, number of completed interviews (n=) and Margin of Error (MoE) for each survey is displayed in the tables below:

Table 5: Sample size and MOE (EDDR1).

Region	Country	n=	MOE +/-%
Western Europe	France	30	17.9%
Western Europe	Germany	30	17.9%
Western Europe	Italy	30	17.9%
Western Europe	Netherlands	30	17.9%
Western Europe	Spain	30	17.9%

Region	Country	n=	MOE +/-%
Western Europe	Sweden	30	17.9%
Central and Eastern Europe	Czech Rep	30	17.9%
Central and Eastern Europe	Poland	30	17.9%
Central and Eastern Europe	Romania	30	17.9%
Baltics	Estonia	30	17.9%
TOTAL		300	5.7%

Source: Own elaboration.

Table 6: Survey with IT executives and IT decision makers (EDDR3).

Region	Country	n=	MoE
Western Europe	Austria	30	17.9%
Western Europe	Belgium	30	17.9%
Western Europe	Denmark	30	17.9%
Western Europe	Finland	30	17.9%
Western Europe	Greece	30	17.9%
Western Europe	Ireland	30	17.9%
Western Europe	Portugal	30	17.9%
Central and Eastern Europe	Croatia	30	17.9%
Baltics	Latvia	30	17.9%
Baltics	Lithuania	30	17.9%
TOTAL		300	5.7%

Source: Own elaboration.

Results and indicators for the non-surveyed Member States will be extrapolated through statistical analysis and additional desk research. The results of the non-surveyed Member States will be extrapolated to the rest of the EU by using a clustering methodology, associating the Member States based on their similarities in terms of socio-economic parameters, intensity of IT use and other indicators correlated with the actual and potential use of digital transformation. From here the results will be extrapolated from the surveyed countries to the other countries in the same cluster, considering corrections due to population size, GDP size and number of companies economic structure in terms of number of companies and SMEs[10]. This will lead to the calculation of indicators for each of the EU27 Member States. The use of the same sector, technology and company size definitions applied by IDC in its ongoing research will allow to leverage the other company databases and data assets. The international comparison will be carried out by leveraging IDC's databases which are global and cover 54 countries worldwide.

The sample size has been calculated to provide a representative sample of the population of European enterprises with more than 50 employees, with a very low margin of error (see table below). The indicative list of countries to be surveyed has been selected based on the following criteria:

Geographical balance (representing all main geographical areas in the EU).

- Country size (mix of large, medium, and small Member States).

[10] EUROSTAT statistics form the NACE Rev. 2 Statistical classification of economic activities in the European Community with reference to sections J – Information and Communication Technologies and Section M – Professional, scientific and technical activities will be used to identify the number of relevant companies and SMEs to be used in the extrapolation exercise.

- IT maturity balance (mix of MS with high, medium, and low intensity IT spending and sophistication of connectivity infrastructure).
- Share of Data Market value (the MS selected represent 75% of the European data market value in 2021 and 2022 according to IDC).
- Share of Edge Computing market size (the MS selected represent 81% of Europe's spending value according to IDC).
- Adequate coverage of the EU economy (the Member States surveyed together represent more than 73% of the EU GDP in 2021).

A hybrid data collection approach will be used for this study, utilizing both CATI (telephone) and CAWI (online) data collection methods. The sample will be split between CATI and CAWI at 50-50%. This approach will enable lower data collection costs, increased speed of delivery, a wide geographical coverage, and the ability to manage company size and industry quotas while maintaining the accuracy and representativeness of the sample. By utilizing both CATI and CAWI methods, a more comprehensive and diverse sample can be obtained, providing a more accurate and reliable analysis of the Edge and Far Edge market in Europe.

Table 7: Model criteria for the surveys.

Criteria	Europe
Milestones	Design and methodology report and 2 surveys: • M5: design phase and methodology • M7-9: first survey • M15-17: second survey
Sample size	• Survey 1: 300 completed interviews covering 10 countries: France, Germany, Italy, Spain, Sweden, Netherlands, Poland, Czech Republic, Romania, Estonia • Survey 2: 300 completed interviews covering 10 countries: Austria, Belgium, Denmark, Finland, Greece, Ireland, Portugal, Croatia, Latvia, Lithuania.
Method	20-25 min telephone (CATI) and (CAWI) survey. English language in most countries but using local language when needed.
Company size	50+ full time employees.
Target respondents	IT infrastructure decision-makers and influencers, manager-level+. Able to discuss company's usage / plans / evaluation of Edge Computing.
Company size quotas	Soft equal quotas in each country by employee size bands 10-249, 250-499,500-999,1000+, to allow for analysis by company size. Soft quotas by industry verticals at overall sample level.
Screener	Companies must be using/piloting/planning to use or evaluation Edge Computing
Industry coverage	14 industry ecosystems covered: tourism; creative & cultural industries; aerospace & defence; textiles; electronics; mobility-automotive; low-carbon energy-intensive industries; renewable energy; agri-food; health; digital; construction; retail; proximity & social economy. These industry ecosystems will be mapped to standard NACE and IDC vertical taxonomy.
Technology coverage	The survey will indicatively monitor the rate of adoption and distribution of Edge nodes in the EU
Margin of error	Sample size levels and margin of error (MOE) at standard 95% confidence level: n=300 Margin of Error is +/- 5.7 %

Source: Own elaboration.

The survey is designed as a quantitative instrument with closed-ended responses, available in English or the local language if needed. After finalizing the definition of indicators for the scorecard, the team has developed a comprehensive questionnaire. This questionnaire has been carefully designed to encompass all the main outputs discussed earlier, as well as the necessary

data for calculating the indicators. The survey includes specific policy research questions that address the deployment and adoption of Edge nodes, as well as the achievement of the Digital Decade targets.

To better understand the trajectory definition per country, an analysis of the specificities of each Member State's needs will be conducted. This will include factors such as connectivity, the telco landscape, investment capacity, and the situation regarding scenarios that can act as "edge-drivers," such as manufacturing, entertainment/media/events, or surveillance areas. To present market trajectories that could inform the evolution of Edge node deployment in the coming years, the IDC Worldwide Edge Spending Guide will be utilized. The Guide presents spending data on an annual basis plus five-year forecasts by technology, industry, geography, and domain (delivered twice a year). The wide scope of the Guide (17 technology markets, 19 industries, 400+ use cases, 6 different domains, and 9 geographic regions) makes it a suitable starting point for the foresight exercise. By utilizing these resources, a better understanding of the Edge and Far Edge market in Europe can be gained, and market trajectories can be developed to inform future deployment decisions.

Table 8: Market sectors for foresight.

Dimensions	Content
Technology markets	a. Hardware — compute, gateways, network equipment, and storage b. Software — AI and analytics, security, systems infrastructure, and other software c. Services — engineering, managed, project oriented, support and deployment, colocation, connectivity, IaaS, PaaS, and SaaS
Industries	b. Banking, c. Insurance, securities, and investment services, d. Discrete manufacturing, process manufacturing, construction, resource industries, e. Retail, f. Professional services, personal and consumer services, g. Transportation, h. Healthcare provider, i. Federal/central government, j. State/local government, k. Education, l. Telecommunications, media, m. Utilities, and wholesale
Use cases	o Production asset management, o Public safety and emergency response, o Omni-channel operations, o Freight monitoring, o Intelligent transportation systems, o Smart grid, o Automated preventative maintenance, and more
Domains	a. AI, b. AR/VR, c. Drones, d. IoT, e. Robotics, and the rest of the domains
Buyers	o Enterprise and service provider
Regions	1. The United States, 2. Canada, 3. Japan,

Dimensions	Content
	4. Western Europe, 5. Central and Eastern Europe, 6. the Middle East and Africa, 7. Latin America, 8. PRC 9. Asia/Pacific

Source: Own elaboration.

Data for the UK, US, Japan, Canada, and China will be added, although limited to the specific perimeter of the IDC Edge Spending Guide. Additional IDC sources that include forecasting market estimates on the Edge market in Europe will be leveraged, such as the following studies:

- TECH SUPPLIER April 2021 - Market Forecast - Doc # EUR147186321 European Enterprise Edge Market Forecast, 2020-2024 By: Gabriele Roberti, Alexandra Rotaru[41]
- TECH SUPPLIER March 2022 - Market Analysis Perspective - Doc # EUR147186421Market Analysis Perspective: European Edge Strategies, 2022 By: Andrew Buss, Alexandra Rotaru, Gabriele Roberti[42]
- TECH SUPPLIER September 2021 - IDC Survey Spotlight - Doc # EUR147186121 How Mature Are European Organizations in Terms of Edge and Emerging Technologies Adoption? By: Gabriele Roberti, Alexandra Rotaru[43]

3.4. Quantitative model

A quantitative model will be prepared based on the sources mentioned above. This model will apprehend the principal categories of the final Edge taxonomy, as agreed upon according to the outputs of Task 1.1 and based on the final design and results of the first survey. The final dimensions of the quantitative model will be based on the deliverable "Edge Computing Taxonomy and Classification."

The final definition of the vertical markets segmentation of the quantitative model will also be based on the report "Edge Computing Taxonomy and Classification." Results will be presented by sector and primary vertical markets defined by NACE Rev.2 codes.

Table 9: Sector and industry definitions.

Sector	Primary Vertical Market	NACE Codes
Finance	Banking	64
	Insurance	65
	Securities and investment services	66
Manufacturing and Resources	Discrete Manufacturing	14, 15, 16, 25, 26, 27, 28, 29, 30, 31, 32
	Process Manufacturing	10, 11, 12, 13, 17, 19, 20, 21, 22, 23, 24
	Construction	41, 42, 43
	Resource Industries	1, 2, 3, 5, 6, 7, 8, 9
Distribution and Services	Retail	45, 47, 56
	Wholesale	46
	Professional Services	33, 58.2, 62, 63, 68, 69, 70, 71, 72, 73, 74, 75, 77, 78, 80, 81, 82
	Personal and Consumer Services	55, 59.13, 59.14, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99

Sector	Primary Vertical Market	NACE Codes
	Transportation	49, 50, 51, 52, 79, 53
	Media	18, 58.1, 59.11, 59.12, 59.2, 60
Infrastructure	Telecommunications	61
	Utilities	35, 36, 37, 38, 39
Public Sector	Healthcare provider	86, 87, 88
	Federal/central government	part of 84
	State/local government	part of 84
	Education	85
n/a	Service Provider (is a non-standard IDC industry)	Multiple industries and primarily: Professional Services, Telecommunications, Retail, Discrete Manufacturing

Source: Own elaboration.

Table 10: Complete survey script.

Question number	Section	Question text	Response notes
S1	Screener	COUNTRY: In which country is the organisation you work for located? Please choose one.	10 countries: France, Germany, Italy, Spain, Sweden, Netherlands, Poland, Czech Republic, Romania, Denmark
S2		EMPLOYEES: How many people are employed by your organisation? Please choose one.	Balanced sample for SMB (50–499), midmarket (500–999), and enterprise (1,000+)
S3		INDUSTRY: Which one of the following industry classifications best represents the principal business activity of the company/organisation you work for? Please choose one.	14 industry ecosystems covered: tourism; creative & cultural industries; aerospace & defence; textiles; electronics; mobility-automotive; low-carbon energy-intensive industries; renewable energy; agri-food; health; digital; construction; retail; proximity & social economy. These industry ecosystems will be mapped to standard NACE and IDC vertical taxonomy.
S4		JOB ROLE: Which one of the following titles most closely describes your current title within your organisation? Please choose one.	Technology-related roles: CIO, CTO, VP of IT, IT director, IT manager, IT project manager, IT sourcing/procurement/governance, Technology/Integration consultant, Enterprise architect, IT admin/Tech support, Datacentre architect, Other (Please specify)
S5		DECISION/INFLUENCE OVER EDGE PROJECTS: Do you have responsibility or influence over your organisation's needs and plans regarding IT infrastructure,	1. I am the primary decision maker. 2. I am part of a team that makes such decisions. 3. I influence such decisions, and I am knowledgeable about this area. 4. I do not have any involvement.

Question number	Section	Question text	Response notes
		including edge infrastructure and related projects?	
1	Overall IT Approach	To what extent does your organisation use, or plan to use within the next 12 months, each of the following for your IT environment? Please choose one for each. 1. Not using and no plans to use 2. Not using but planning to use within 12 months 3. Limited use 4. Extensive use	a. Use of automation and orchestration b. API-centric development / API gateways c. DevOps and/or modern agile application development approaches d. Dynamic workload management e. AIOps — intelligent monitoring, optimisation, and remediation of IT infrastructure f. Service level agreement (SLA) monitoring and management g. Intelligent security and/or digital trust h. Formal risk management/governance processes i. Programmable infrastructure (SDS, SDN, serverless, containers, Kubernetes, etc.) j. Adoption of multicloud services (ability to deploy and manage IT services across two or more cloud locations or providers) k. AI/ML in actual business use cases (business processes, monetization, decision support) l. Access to integrated real-time data (less than 1 hour old)
2		IT Infrastructure BUDGET CHANGE: How will your company's overall IT infrastructure budget change in 2023 compared with 2022?	Increase > 10%/Increase up to 10%/Stay the same/Decrease less than 10%/Decrease more than 10%/I don't know
3		Approximately how much of your organisation’s total infrastructure spending was split between the following environments in 2022?	Approximately how much of your organisation’s total infrastructure spending was split between the following environments in 2022?
4	Edge Budget	What was your total edge infrastructure (hardware, software, services) spending in 2022?	Less than EUR 100.000 €100,000 to €1 million €1 million up to €5 million €5 million up to €10 million €10 million to €25 million €25 million up to €50 million EUR 50 million or more I'd rather not say I don't know
5		What proportion of your total Edge infrastructure spending went to: 1. Edge hardware 2. Edge Software 3. Edge Services	To nearest 5%, must total 100%
6		How will your company's edge infrastructure budget change in 2023 compared with 2022?	Increase > 10%/Increase up to 10%/Stay the same/Decrease less than 10%/Decrease more than 10%/I don't know

Question number	Section	Question text	Response notes
7	Edge Use Cases	Which of these edge-solution types are most important to your organisation? Please choose up to 3.	1. Business process automation and optimization 2. Manufacturing process automation and optimization 3. Customer experience 4. Employee experience 5. Video surveillance and analysis 6. Edge AI platforms 7. Asset/Equipment monitoring, tracking, or performance optimization 8. Automated threat-intelligence monitoring and prevention 9. Visual inspection for quality/integrity 10. Content distribution (CDN) 11. Fraud/Loss analysis and investigation 12. None of these [exclusive choice]
8		What proportion of your Edge use case initiatives are in the following stages (to nearest 5%, to total 100%)	1. Investigation 2. Design and planning 3. Proof of concept 4. Limited production deployment 5. Extensive production
9	Edge nodes deployment	Which of the following environments do you consider to be the most relevant for running your organisation's edge workloads or solutions A) today and B) in 5 years' time? Please choose up to 3. [RANDOMIZE]	Private edge optimized facilities Private on-premises datacentres Shared or community provided local edge facilities Colocation or third party general datacentres Colocation or third party edge-optimized facilities Telecommunications provider facility/service datacentres Telecommunications provider edge optimized facility Public cloud standard services (not edge specific) Public-cloud edge-cloud service directly with a public-cloud provider Public-cloud edge-cloud service via a third-party service provider
10	Edge Use Cases	Which are the Top 3 business drivers behind your organisations' edge solutions deployment?	Select three from: Open-standards compliant, low cost, integrated management, Security capabilities, RAS (reliability, availability, serviceability), automation capabilities, Climate Neutrality, designed for recyclability
11		How important are each of the following elements in your edge solutions architecture? 1. Not important at all > 5. Very important	Low networking latency, bandwidth optimisation, bandwidth cost control, data sovereignty, data security, process automation and optimization, power consumption reporting and management
12	Edge nodes deployment	At how many physically distinct locations have you currently deployed Edge solutions? How many will this be in 2 years' time?	Fewer than 10, 10 to 99, 99 to 499, 500 to 999, 1,000 to 4,999, 5,000 to 9,999, 10,000 to 49,999, 50,000 to 99,999, 100,000 or more

Question number	Section	Question text	Response notes
13		For your Edge workloads, what proportion would be suitable to run in the following deployment categories? (to nearest 5%, must total 100%)	On device edge, on-premises edge (1ms latency), Far edge (2-5ms latency), Near edge (10-20ms latency), Cloud edge (>20ms latency)
14		Which of the following do you consider the most important to your organisation's Edge strategy over the next two years? Select your top three	Hardware Vendors, Software Vendors, Global Public Cloud providers, European cloud providers, Global Telcos, European Telcos, Global System Integrators, European System Integrators, VARs, Internal skills or resources, external contractors, Other
15		Which information sources do you consider the most important when it comes to gathering information or insight into your Edge needs?	General IT infrastructure vendors, Edge specialist vendors, IT Analyst Firms, General IT press, Trade Press, Edge specialist press, Peers in other companies, Colleagues, Online forums, or exchanges, Other
16		How important are each of the following factors (1 - Not important at all, 5 - Very important) when it comes to evaluating or selecting edge facilities or edge hardware units for deploying your edge solution?	Physical distance or proximity Network connectivity Is very power efficient (low PUE or cooling overhead) Physical security Network security Platform or application security Uses little to no water Has low or no carbon energy supply Has a low subscription or rental cost Has sufficient headroom for our workloads to grow for the foreseeable future Is operated by a provider that we trust
17		How many climate neutral and highly secure edge nodes are currently deployed/will be deployed in the next 24 months/will be deployed by 2030 in your company – climate neutral and highly secure edge nodes are self-contained edge solutions with tolerance to failure (eventually redundancy) in a single location.	a. Up to 4 b. 5-9 c. 10-19 d. 20-49 e. 50-99 f. Over 100
18	Edge nodes spending	What proportion of your total Edge hardware spending is allocated to the following categories? (to total 100%)	Edge devices Edge networking Edge gateways Edge optimized servers or storage Repurposed Datacentre-optimised servers or storage
19		What proportion of your total Edge hardware spending is allocated to the following deployment categories? (to nearest 5%, must total 100%)	On device edge, on-premises edge (1ms latency), Far edge (2-5ms latency), Near edge (10-20ms latency), Cloud edge (>20ms latency)

Question number	Section	Question text	Response notes
20		For each edge category in Q18 above, how do you expect this investment to change over the coming year?	Increase > 10%, Increase up to 10%, Stay the same, Decrease less than 10%, Decrease more than 10%, I don't know
21		Which of the following connectivity types are most important to your Edge solutions currently? What will this be in 2 years' time (choose top 3)	Wired LAN, Wi-Fi, 3/4G, Private 5G, Public 5G, SD-WAN, Managed WAN connections (MPLS etc), Unmanaged broadband, Other
22		On a scale of 1-5, where 5 is most important, please rate how important are each of the following for your Edge investments over the next two years?	Speed/agile response to changing business needs, support growth in business, cost control, security, governance/compliance, innovation, performance of systems/applications etc (to be completed)
23	Edge nodes spending	What are the top three factors your organisation would most need to increase investment in edge solutions?	1. Staff expertise or a partner that can simplify the edge journey 2. Proof that edge overall will make my company more profitable 3. Proof that edge will make our company or IT infrastructure more environmentally sustainable 4. Better understanding on the overall edge benefits 5. Proof that my company will achieve return of investment 6. Proof that my company's privacy and security will not be affected 7. Other (please specify)
24	Edge Node Lifecycle	At procurement time for Edge infrastructure, how important are the following elements? (1. Not important at all, 2. Somewhat important, 3. Very important)	1. Purchase cost 2. Brand and reputation of the vendor 3. Product based circular economy credentials (embedded carbon, design for recyclability etc) 4. Service and support capabilities 5. Channel partner selection 6. Asset lifecycle services including end-of-life disposition 7. Security 8. Open standards and interoperability 9. Other
25	Main barriers and policy recommendations	Which are your organisations' main concerns/challenges associated to the deployment of edge solutions?	Purchase cost, connectivity, power cost, power availability, data privacy and security, physical security/theft/tampering, manageability and automation, physical reliability and servicing, incompatible edge platforms, Lack or skills, Lack of clear business case/RoI, Other
26	Preferred policy measures	Which policy measures (at EU/national level) would be the most effective to overcome the identified challenges? Rank in order from Most Effective to Least Effective	1. Infrastructure: direct funding and / or fiscal benefits for companies deploying a distributed network of edge solutions; 2. Connectivity: Government-led adoption of 5G enabling Gb/s connectivity for everyone (companies and individuals); 3. Chips production: state-aid and

Question number	Section	Question text	Response notes
			other incentive to increase the production of semiconductors in Europe to support the evolution of sophisticated computing devices; 4. Companies and Business: establishment of large and secure computing hubs in the EU through large and specialised computing companies.

Source: Own elaboration.

3.4.1. Country fiches

In this section, the template for the country-specific fiches is presented. These fiches are designed to capture the distinctive characteristics, challenges, and opportunities in each country, thereby contributing to a more comprehensive understanding that complements the overarching global analysis.

Table 11: Country fiches template.

General profile
Market dynamics
Total infrastructure spending split between following environments in 2022
Main business drivers for deployment
Edge infrastructure spending in 2022
Top 3 technical reasons for edge nodes selection and deployment
Investment in the next 2 years
Edge Nodes Deployment and Architecture
Edge workloads and suitable deployment categories
Edge workloads and suitable deployment categories
Challenges associated to the deployment of Edge Nodes (ENs)
Edge nodes deployment in Country vs. EU-27 average.
Top 3 IT Use Cases
Proportion of organisations edge use cases initiatives per stage

Source: Own elaboration.

3.4.2. Country reports or annexes

The country reports offer an exhaustive analysis of the deployment dynamics and the influencing factors, such as the challenges of ensuring security and climate neutrality that ICT companies encounter. Moreover, based on the estimated number of edge nodes deployed nationally, the annual growth rate is determined. Subsequently, an S-curve is plotted to visualize growth trajectories, and a comprehensive growth comparison is conducted. This includes an analysis based on annual growth estimates, the calculation of edge node density (the number of square kilometres per edge node), and the ratio of edge nodes per capita.

For clarity and precision in the reports, the following formulas are applied:

Annual Growth Rate = [(Number of Edge Nodes in Year X / Number of Edge Nodes in Year X-1) - 1] x 100

S-Curve Plot = 1 / (1 + e^(-k*(t - t0))) where 'e' is the base of the natural logarithm, 'k' is the growth rate constant, 't' is the current time, and 't0' is the inflection point time

Edge Node Density (S1) = Total Area / Number of Edge Nodes

Edge Node Ratio Per Population = Number of Edge Nodes / Total Population
These formulas serve to provide quantitative insights into the proliferation and dispersion of edge nodes within the given countries.

3.4.3. Datasets

The gathered data will be organized as structured, machine-readable files, such as spreadsheets or RDF files, in accordance with Commission Decision (2011/833/EU). These datasets are intended for internal use by the Commission and will also be published on the Open Data Portal. Alongside the final study report, the definitive dataset and any resultant indicators will be submitted to the Commission's services.

3.4.4. Visual mapping of edge nodes deployment

The fundamental role of the observatory, supported by data and insights gathered during the research collection phase, is to actively monitor and track the deployment of climate-neutral and secure edge nodes throughout Europe, including their distribution across member states and regions. This data should be displayed on the observatory's website through an interactive map, offering users a dynamic visual overview of the information.

Examples of such mapping applications already exist in the marketplace, as exemplified in the table provided below.

Table 12: Mapping exercises by industry.

Industry Name	Website URL	Description
Lumen	Lumen	Hybrid IT & Cloud Data Centers
Linux Foundation	LF Edge Landscape	Edge Computing Landscape
DartPoints	DartPoints	Regional Data Centers
AtlasEdge's	AtlasEdge	Edge Data Center Locations
Microsoft	Microsoft Azure	Global Network Infrastructure
Amazon Web Services	AWS	Global Infrastructure
EdgeConneX	EdgeConneX	EMEA Edge Data Centers

Source: Own elaboration.

The planned graphical representation for the observatory's website is designed to provide an all-encompassing map of Europe, showcasing deployments, data, and key metrics related to edge nodes. This would be done while respecting the necessary granularity at both national and regional levels. Due to relevant security and legal considerations, sensitive data will be protected in the display, which will identify the general locations of these nodes. In this study, special attention is given to the physical security of edge nodes, emphasizing its critical importance. However, it's important to note that for security reasons, the precise geographical locations of these edge nodes will not be disclosed in full detail. This precautionary measure is aimed at safeguarding the integrity and security of these crucial infrastructure elements.

The interface aims to be user-friendly, featuring a search bar to facilitate quick and effective data retrieval. However, it's important to note that there could be limitations related to data granularity and real-time updates, considering the regulations and technological constraints on europa.eu.

Additionally, the europa.eu may have bandwidth limitations and design constraints that could affect the responsiveness and real-time updates of the interactive map. It may also necessitate

a simpler design to ensure accessibility and compatibility across various devices and web browsers. The conceptual map visualization is outlined below. Please note that adjustments may be necessary due to technical limitations and insights gathered in collaboration with the Europa.eu IT team.

3.4.5. Validation workshop

The study team will present the preliminary findings based on EDDR1 at a Validation Workshop. This event serves as a forum for consulting external stakeholders and gathering expert feedback, which will be incorporated into the Final Report.

Scheduled to occur by the 3rd week of November, the workshop involves several key steps:

- Identifying relevant stakeholders for approval by the Commission at least two months prior to the event.
- Distributing workshop invitations and essential documents, including Interim Reports and a Discussion Paper, to stakeholders at least two weeks in advance.
- Managing logistics for the hybrid event at the European Commission's Brussels premises.

The study team will also generate a thorough and comprehensive report summarizing the discussions held during the workshop, which will be made publicly available.

4. Setting the reports-cycle

The four Edge Deployment Data Reports (EDDRs) will compile and summarize both quantitative and qualitative information about recent advancements in Edge Computing node deployments, focusing on their geographical distribution and deployment in various industries. These reports will identify and analyse key trends in the European Edge market, evaluating its progress in meeting the Edge Node Digital Decade target. They will also explore the implementation of the Path to the Digital Decade ambitions to assess overall progress across the EU. A dedicated section will discuss the anticipated growth and deployment of Edge markets and nodes, presenting a quantitative analysis forecast until the year 2030. This dedicated section will produce two distinct deliverables:

- incorporating findings into the main report.
- and creating individual country reports for each country, limited to a maximum of two pages as agreed upon with the client.

In EDDR1, the data from the first survey, which consists of 10 Member States (MS), will be included, and the findings for the remaining 7 non-surveyed MS will be extrapolated. In EDDR3, after the validation workshop, the data from the second survey, encompassing the other 10 MS, will be included, and the extrapolation of the findings for the 7 non-surveyed MS will potentially be updated and enhanced. Each report will be concluded with a section of recommendations and suggested actions, providing valuable insights and guidance to policymakers.