Project Title	Artificial Intelligence in Secure PRIvacy-preserving computing coNTinuum
Project Acronym	AI-SPRINT
Project Number	101016577
Type of project	RIA - Research and Innovation action
Topics	ICT-40-2020 - Cloud Computing: towards a smart cloud computing continuum (RIA)
Starting date of Project	01 January 2021
Duration of the project	36 months
Website	www.ai-sprint-project.eu/

D6.2 – Market Outlook and Forecast Report

Work Package	WP6 | Dissemination & Impact
Task	T6.3 | Market Analysis & Forecasting
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Peer reviewers	Christophe Baron (GREG), Danilo Ardagna (POLIMI), Stephanie Parker (TRUST), Niccolò Zazzeri (TRUST)
Version	V2.0
Due Date	31/12/2021
Submission Date	28/12/2021

Dissemination Level

X	PU: Public
	CO: Confidential, only for members of the consortium (including the Commission)
	EU-RES. Classified Information: RESTREINT UE (Commission Decision 2005/444/EC)
	EU-CON. Classified Information: CONFIDENTIEL UE (Commission Decision 2005/444/EC)
	EU-SEC. Classified Information: SECRET UE (Commission Decision 2005/444/EC)

Versioning History

Revision	Date	Editors	Comments
0.1	07/10/2021	Golboo Pourabdollahian, Gabriele Roberti, Alexandra Rotaru, Alba Balla (IDC), Danilo Ardagna (POLIMI), Stephanie Parker, Rita Giuffrida (TRUST)	Deliverable structure and table of contents agreed
0.2	12/11/2021	Gabriele Roberti, Alexandra Rotaru, Lorenzo Veronesi, Gaurav Verma, Adriana Allocato (IDC)	First draft version of the deliverable generated
0.3	26/11/2021	Gabriele Roberti, Alexandra Rotaru, Lorenzo Veronesi, Gaurav Verma, Adriana Allocato, Golboo Pourabdollahian, Giorgio Micheletti, Nevena Raczko, Mike Glennon, Marianne Kolding, Martin Sundblad (IDC)	Updated version of document generated and submitted for preliminary Internal review
0.4	29/11/2021	Gabriele Roberti, Alexandra Rotaru, Golboo Pourabdollahian, Martin Sundblad (IDC), Daniele Lezzi (BSC), Matteo Matteucci, Federica Filippini (POLIMI), German Moltò (UPV), Patrick Thiem (C&H), Andrè Martin (TUD)	Input from other contributing partners collected and integrated
0.5	03/12/2021	Gabriele Roberti, Alexandra Rotaru, Luca Butiniello,	Updated version of the document by IDC

		Golboo Pourabdollahian (IDC)	
0.6	09/12/2021	Golboo Pourabdollahian (IDC), Federica Filippini (POLIMI), Grzegorz Timoszuk (7BULLS)	Remaining input from partners received and integrated
1.0	10/12/2021	Golboo Pourabdollahian (IDC)	Final draft consolidated and submitted for review
1.1	16/12/2021	Stephanie Parker (TRUST)	Internal review
1.2	20/12/2021	Danilo Ardagna (POLIMI)	Internal review
1.3	20/12/2021	Christophe Baron (GREG)	Internal review
1.4	21/12/2021	Niccolò Zazzeri (TRUST)	Internal review
2.0	23/12/2021	Gabriele Roberti, Alexandra Rotaru, Golboo Pourabdollahian (IDC)	Comments addressed and the document finalized for submission

Glossary of terms

Item	Description
AD&D	Application Development and Deployment
AI	Artificial Intelligence
APM	Asset Performance Management
ATM	Automated Teller Machine
AR	Augmented Reality
BDA	Big Data and Analytics
CAGR	Compound Annual Growth Rate
CEE	Central and Eastern Europe
EU	European Union

FTF	First Time Fix
IaaS	Infrastructure as a Service
ICT	Information and Communication Technology
IoT	Internet of Things
IPV	Internet Protocol Version
IT	Information Technology
LAN	Local Area Network
M&A	Mergers and Acquisitions
ML	Machine Learning
MTBF	Mean Time Between Failures
NLG	Neutral Language Generation
NLP	Neutral Language Processing
O&G	Oil and Gas
O&M	Operations and Maintenance
OT	Operations Technologies
PaaS	Platform as a Service
QoS	Quality as a Service
PdM	Predictive Maintenance
RoBo	Remote office/Branch Office
SaaS	Software as a Service
SCM	Supply Chain Management
SMB	Small Medium Businesses
VR	Virtual Reality
WAN	Wide Area Network
WE	Western Europe

Keywords

Artificial Intelligence; Edge Computing; Computing Continuum; Market Forecast; Farming 4.0, Predictive maintenance and Inspection; Personalised Healthcare; Technology landscape; Industrial Ecosystem.

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Executive Summary

This deliverable, which is the first release of the market analysis and forecast report for AI-SPRINT, provides a detailed assessment of the market status-quo and market forecast for edge computing with a specific focus on AI and other enabling technologies. It also gives a deep dive into the market forecast of the three main use-cases of the AI-SPRINT project.

The European enterprise edge market has grown 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 and other emerging technologies. The COVID-19 pandemic has reshuffled the investment plans of many organisations in the world, in some cases stimulating the need for edge to ensure business continuity, to improve the decision-making process and to support remote operations. European enterprise edge spending is expected to reach €39.6 billion by 2025, driven by the tremendous role of edge in enabling low latency use cases, deployments in locations that are either remote or without IT support staff, and supporting new vendor propositions and a supply chain that is being built up.

Major findings in this document include the following:

- European enterprise edge spending will grow from €18 billion in 2020 to €39.6 billion in 2025, with a five-year Compound Annual Growth Rate (CAGR) of 18%, outpacing the total ICT market average that is forecast to grow at single digits over the same period.
- 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 increase over the forecast period, especially within key verticals.
- Within the three main technology groups, services (including professional and provisioned services) will continue to make half of the total market spending. Hardware will outpace the market average, reaching a fourth of the market, as new hybrid edge infrastructures drive innovations at the edge.
- Edge supports a wide array of other emerging technology markets referred to as domains, that are driving the overall edge market and generating value outside core data centers. These are Internet of Things (IoT) as the largest domain within the European edge market, followed by artificial intelligence (AI) with tremendous capabilities on real-time data processing, augmented reality (AR)/virtual reality (VR), robotics and drones.
- The distribution and services sector along with manufacturing and resources have the largest share of European enterprise edge spending. Despite the pandemic heavily hitting some industries within those sectors, edge use cases linked to the Internet of Things (IoT) and AI domains will drive developments, especially in edge environments where edge bridges the gap between IT and operations technologies (OT).

The report double clicks into the market dimension for edge solutions by type of edge technology, and by industry, looking also at the AI domain in the context of AI-SPRINT. In particular, the report provides a detailed analysis on the three use cases in the AI-SPRINT context: maintenance and inspection, personalised healthcare and farming 4.0, looking also at the drivers and the barriers for the edge market overall and in the context of specific industry use cases.
In the market context chapter, the report presents the significant market developments for the edge market but also an analysis of how the ecosystem is a pivotal point for deploying edge solutions, particularly in the context of the three AI-SPRINT cases.

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1. Introduction

1.1 Scope of the report

This deliverable is the first report of AI-SPRINT task T6.3 on market analysis and forecasting. The next T6.3 deliverables are two webinars and one report which are expected on M23 (*D6.5 First market outlook and forecast webinar*) and on M30 (*D6.6 Second market outlook and forecast update webinar* and *D6.7 Market outlook and forecast report update*). The current deliverable provides a detailed analysis of the market status-quo and market forecast for the edge market. The analysis covers the market forecast from different dimensions, in particular from a technological perspective including AI which is the main focus of the AI-SPRINT project. In addition to this, the analysis covers market forecasting by geographical areas in Europe and industrial domains. In order to provide insights to the partners of AI-SPRINT regarding the technologies and use-cases that are being developed within the project, a specific analysis has been carried out focusing on the three main use-cases that are the core focus of AI-SPRINT namely maintenance and inspection, farming 4.0 and personalised healthcare. It should be mentioned that since the activities of use-case development started in M12 (December 2021), the analyses are based on the collected information from the use-case description as well as IDC specific analysis on each use-case updated in November 2021. This information provides insights to the project partners about the potential of the leading vertical markets of the use-cases. Due to the importance of ecosystem analysis for the use-cases, an analysis of the edge ecosystem players and market development in terms of domains of use-cases are conducted as well. Eventually the report is concluded by providing an analysis of European data market in terms of its size and aggregate value of the demand of digital data which could bring insights to the partners about the forecast of data market in Europe by 2030 and the growth of data market in different vertical domains including the ones AI-SPRINT is focusing on.

1.2 Methodology

For the purpose of this report, IDC has used diverse resources available as company knowledge around relevant topics like edge computing, internet of things (IoT) and artificial intelligence (AI). In particular, IDC has used different qualitative and quantitative available studies, enriching the available information with assumptions and considerations for the purpose of this study, especially around the three detailed use cases that AI-SPRINT focuses on.

The methodology for this study, as a consequence, derives directly from IDC's standard methodology. IDC employs several assets with the aim of understanding multiple technologies and industries. The global research model, which is IDC's study of both local and regional markets yields insights into the nuances of local national markets, ensuring forecast and analysis consistency across a wide range of geographies and coverage areas.

IDC has developed a set of standards consisting of the documentation of methodologies used and forecast assumptions, projections from only surveys that are statistically sound to ensure only objective and accurate data is used, validation and additional checks to help provide boundary conditions for major forecasts, implementation of standard definitions across geographies and coverage areas, and the use of common analytical tools to ensure consistency.

IDC uses a variety of primary and secondary sources for sizing and forecasting markets including, but not limited to, interviews with IT vendors, public financial records, historic market data, and user surveys. These sources around demand- and supply-side data source proprietary models of market segments to generate IDC market data and forecasts. Finally, preliminary values in the market models are validated using several different procedures. And lastly, the market models are adjusted accordingly.

Additionally, IDC acknowledges its duty to preserve objectivity, integrity, and independence in the creation and dissemination of research and analysis and is thus committed to avoiding bias and conflicts of interest. Data presented in this document is therefore fully consistent in terms of taxonomy and methodology (see also Figure 1.1) and is based on the following:

- Built bottom-up with regional/country, industry, and technology analyst participation.
- Standard methodology, taxonomy, and inputs across all countries and reconciled with existing IDC data.
- Leveraging supply- and demand-side pricing structure, vendor revenues, technology adoption rates, attach rates, and survey data.
- Building on third-party data — extensive list of demographics and economics.
- Standard forecasting tools based on comprehensive analysis of supply and buyer adoption developments.

Figure 1.1- IDC research methodology

The five-year forecast published in this study focuses on the European enterprise edge market as derived from IDC's Worldwide Edge Spending Guide, V1 2021 — Enterprise forecast [1].
The tables and figures in this study are generated from a proprietary IDC database and analytical tools. IDC's Continuous Intelligence Service and consulting services can provide additional insights beyond the scope of this study using the database supporting it. All the surveys leveraged in the present document are part of the IDC's proprietary research methodology and are not publicly published.
It is important to note that all numbers in this document may not be exact due to rounding.
Countries taken into consideration when estimating the European enterprise edge spending are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom as part of Western Europe and Czech Republic, Hungary, Poland, Romania, Russia and Rest of CEE countries for Central and Eastern Europe.

1.3 Market Definition

The current report focuses on Edge as a new possibility for deploying artificial intelligence capabilities within the use cases the AI-SPRINT project focuses on. The benefits of edge come from having computing resources

close to where the data is generated, significantly reducing time to bring value and the instant enablement of business processes, decisions, and intelligence outside the core IT environment.
IDC defines edge as the technology-related actions that are performed outside the centralised datacentre, or the cloud, where edge is the intermediary between the connected endpoints and the core IT environment supporting all key business decision support systems. An edge device is typically connected to multiple endpoints to aggregate or process data. The endpoints such as IoT devices, robots and drones, AR/VR headsets, mobile laptops, and mobile phones, even though positioned at the edge, **are usually excluded from** this definition of **edge**. Definition of edge, therefore, depends also on which type of resources are considered as core, meaning the epicentre of computing and storage capabilities, from a company, as shown in Figure 1.2 .

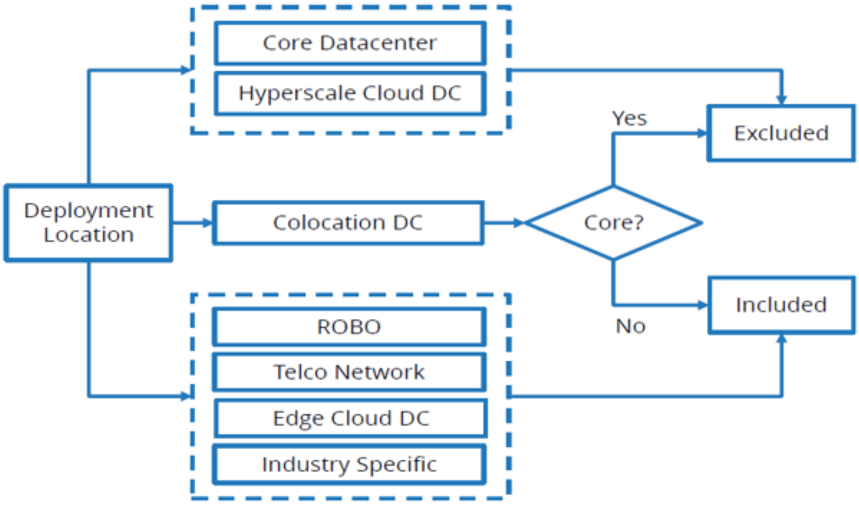


Figure 1.2 - Definition of edge computing simplified (Source: IDC European Edge Practice Research, 2021 [2])

Characteristically, edge is distributed, software defined, and flexible and is the foremost technology infrastructure that extends and innovates the capabilities found in core data centres, whether they are enterprise or service provider oriented.
IDC distinguishes addressable markets in the edge spending market forecast as spending from services providers as well as enterprises building their own infrastructure. This document refers to the latter, and considers **enterprise edge spending** as **investments from end-user organisations for deploying edge solutions**, **excluding** spending by **service providers** along the edge value chain to support and enable end-user solutions. **Consumer spending** on edge technologies is currently **excluded** from the edge forecast spending.

Edge enables a wide array of connected technology markets referred to as "domains." These domains span innovative IT markets such as mobile edge computing, operational technology (OT) markets such as robotics and drones, and "innovation accelerator" markets such as IoT, augmented reality (AR)/virtual reality (VR), and artificial intelligence (AI).

This analysis focuses on the edge in relation to the AI domain and broadly with the other domains. IDC defines artificial intelligence (AI) as systems that learn, reason, and self-correct. These systems hypothesise and formulate possible answers based on available evidence, can be trained through the ingestion of vast amounts of content, and automatically adapt and learn from their mistakes and failures.

1.4 Technology Landscape

As reported in Figure 1.3, IDC divides the edge technology scenario into various segments to capture details of sub-markets such as hardware, software, and services spending generated by end users' companies, excluding consumers.

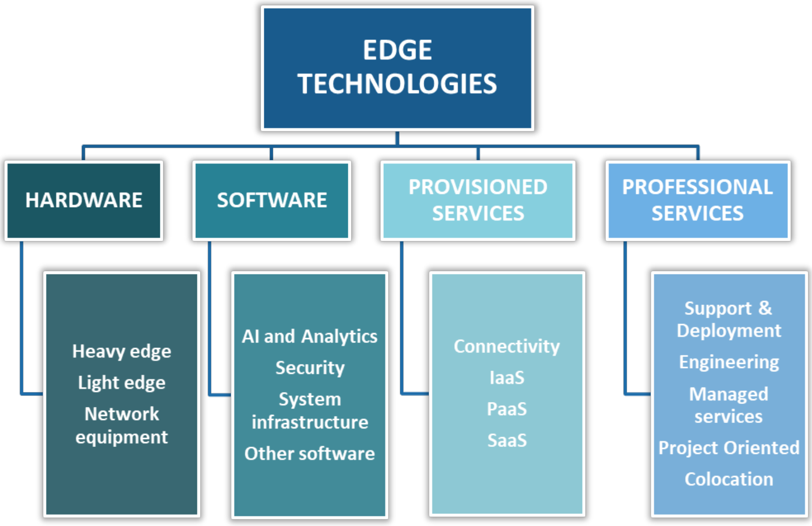


Figure 1.3 - Edge technologies (Source: IDC European Edge Practice Research, 2021 [2])

Computing and storage infrastructure enabling edge workloads is key in this context. IDC makes 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.

- **Heavy edge computing platforms** are meant to perform heavier computing tasks but are adapted for the edge location or deployment. They are usually a version of core general-purpose computing and storage platforms that are built with datacentre-grade, industry standard components and that feature ruggedised packaging and onboard control and data acquisition hardware designed to control devices such as robotic arms, autonomous cars, conveyor belts, and wind turbines. Heavy edge includes both datacentre-in-a-box type of infrastructure, down to single hyperconverged machines for standalone deployment. Heavy edge platform usually supports accelerators and components enabling artificial intelligence workloads.
- **Light edge platforms or 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, these platforms can feature onboard control and data acquisition hardware; LAN, wireless network, and WAN connectivity; and specialised low power accelerators for performing limited add-on AI functions such as 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.

The overall view of enterprise edge ecosystem embraces technologies and services that include computing infrastructure such as servers, storage, and networking equipment, as described above; diverse software such as system infrastructure, security, and application development and deployment (AD&D); and services

that span professional implementation and management and provisioned services delivering cloud-based technologies.
Different other technologies, like artificial intelligence, are processed directly on the edge devices. Basically, edge and AI processing encompasses the computation that enables machine learning or artificial intelligence neural networks at the edge. By moving AI capabilities to the edge, organisations can benefit from low latency, increased security and privacy as well as cost reduction for data transmission to the cloud.

Edge environments

Different edge environments are characterised by different features and peculiarities like computing/storage/networking capabilities, power consumption, latency or form factors. With each technology use case, it is necessary to keep all those variables into consideration to define which is the most suitable environment for running the use case in the optimal fashion.

These environments are working together in a continuum of resources, platforms, connections and architectures, from the sensors to the core or the cloud. Sensors gather and collect a variety of heterogeneous data, sometimes apply basic analytics and run simple applications, to transmit only the optimal amount of information. They are often in remote locations, harsh environments and with scarce computing, storage and connectivity. Sensors are useless if the information they gather is not used and acted upon. This requires some intelligence that can be placed over the hybrid continuum of Edge, up to the core or the cloud.

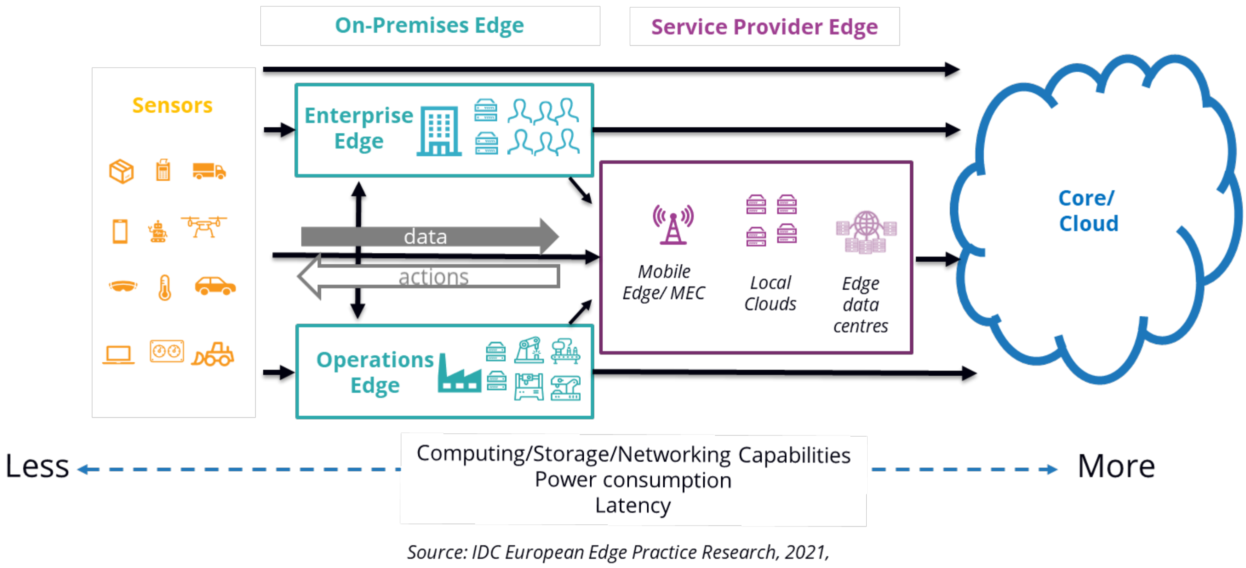


Figure 1.4 - Edge Environments (Source: IDC European Edge Practice Research, 2021 [2])

As shown in Figure 1.4, there can be different types of edge:

- **On premise edge**: this is the part of the edge that is run within the perimeter of an organisation. It refers to IT driven (enterprise) or OT driven (operations) geographically dispersed facilities, Remote Offices / Branch Offices (RoBo) with the need to support a wide range of workloads and use cases, remaining outside the organisation epicentre of computing capabilities.
- **Service provider edge:** with direct connection to central cloud services and provisioning high-performance computing, storage and networking services (e.g., distributed DC facilities, interconnection sites, telco network nodes, local cloud facilities). These environments enable edge services for end-users without the need of resources on their premises.

1.5 Structure of the document

This document is divided in five main chapters. While Chapter 1 provided an introduction of the report and described the methodology and technology landscape, the following chapters are structured as follows. In Chapter 2, an overview of the enterprise edge market is provided in relation with artificial intelligence. The chapter presents the status-quo of the edge market in Europe and then it does a deep dive into the edge market forecast taking into account different dimensions such as technology, geographical distribution, domain, industry and selected use-cases that are being investigated in AI-SPRINT. The chapter also provides an overview of drivers and barriers of the edge market.

In Chapter 3, the market context analysis will be presented. In particular, this chapter is focused on analysing the market ecosystem players and the technological developments in the market. Considering this analysis, the chapter also provides an overview of technological baseline and tools that are being used in the AI-SPRINT project to highlight what are the main added value of the tools and what specific pain points are addressed by these tools, considering that AI-SPRINT tools are not meant to compete with big market players but to allow to use cloud systems without lock in and, based on the core open source solutions to foster application evolution and portability.

In Chapter 4, the analysis of European data market (as of November 2021) is presented. The analysis has been done focusing of the value of the European data market from a geographic perspective in Europe and also from a sector perspective including the main sectors of interest for AI-SPRINT. Considering the accelerated implication of technologies such as edge, this analysis could be quite relevant to understand the impact of uptake of these technologies on growth of the data market in Europe.

The final chapter of the document is dedicated to the main conclusions of the analysis and the future outlook.

2. Edge Market Forecast

This chapter provides an overview of the enterprise edge market spending in relation with Artificial Intelligence in Europe between 2020 and 2025, looking at different dynamics such as the current situation in Europe, estimated spending by technology (hardware, software and services), by geography (both Western Europe and Central & Eastern Europe view), by domain (Internet of Things, Artificial Intelligence, Augmented and Virtual Reality, Drones and Robotics), by industry sectors (Distribution and Services, Manufacturing and Resources, Infrastructure, Public Sector and Financial) and by the selected use cases (Maintenance and Inspection, Personalized Healthcare and Farming 4.0). The end of the chapter emphasizes the Edge-AI market drivers and barriers, highlighting various trends that could influence the adoption of Edge-AI solutions in Europe.

2.1 Market status-quo

This sub-chapter provides an overview of the current situation in Europe regarding the adoption of edge computing, focusing on the adoption levels and the related business goals driving this adoption as well as the key enablers for edge market supporting the adoption of other emerging technologies.

2.1.1. Edge adoption in Europe

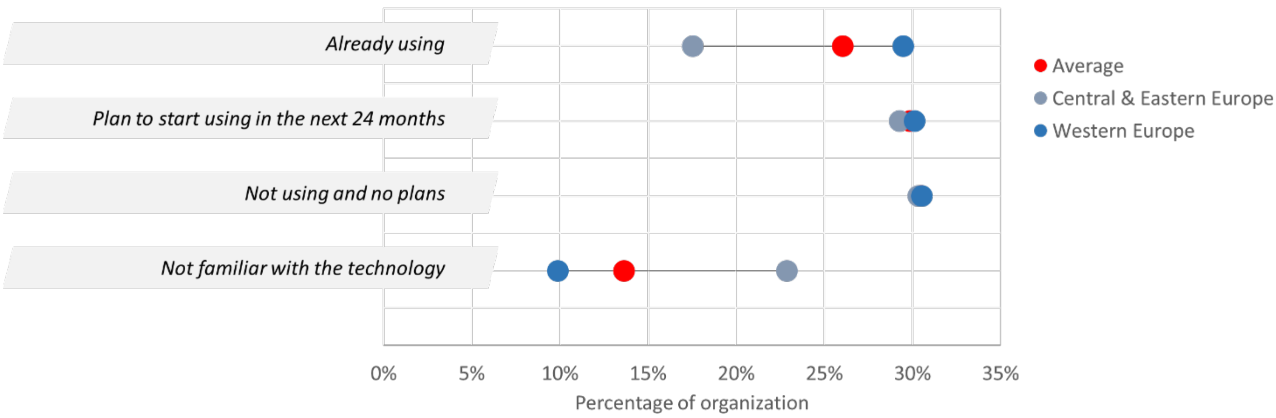


Figure 2.1 - Edge adoption in Europe (Source: IDC Europe Emerging Technologies Survey, July 2021 [3])

Despite the interesting level of adoption across Europe, maturity is still low. According to the IDC Europe Emerging Technologies Survey (July 2021, N=653, see Figure 2.1), only 26% of the European organisations are implementing edge computing solutions in their daily business, with this number expected to double over the next two years. At the same time, most of these organisations adopting edge solutions are implementing them in a pilot or educational phase (47% and 35% respectively), with only a small share of them adopting these solutions in a more structured way.

Indeed, this is not just an edge computing-related issue, but a much wider phenomenon: when it comes to emerging technology adoption, organisations have to face several barriers to safely implement the solution into their business. Among the many barriers, two can be identified as most significant for edge computing adoption: lack of skills/qualified workforce and privacy concerns. For the former, database expertise, system design and security are just some of the skills required to properly manage this innovation and leverage its benefits. On the other hand, since data is handled by many different devices, the surface exposed to cyber-attacks increases dramatically, thus raising concerns for data privacy and cyber threats.

However, the picture outlined is multifaceted, with changing trends according to the different dimensions considered. For example, when analysing edge maturity across different organisation sizes, it is interesting to highlight how enterprises outperform smaller organisations in adopting edge computing solutions in a more established phase. From a country perspective, France and Germany are European champions regarding higher maturity, with Italy still having a high number of organisations leveraging this technology in a pilot phase. Spain and the Nordic countries, on the other hand, lead on the educational phase. Overall, Western European countries are more advanced compared with Central and Eastern European peers where only 18% are already using edge computing and only 24% are planning to start using it in the next two years.

Other major differences can be observed when looking at the industry level: distribution, infrastructure, and manufacturing/resources sectors are the leading sectors, with more than one in five adopters already beyond the pilot phase. This is mainly linked to the several applications edge computing has in these sectors: from real-time supply-chains monitoring to inventory management, to asset remote monitoring and enhanced virtual experiences, all these different applications make edge computing a technology able to drive significant value to these sectors.

Overall, the edge landscape across Europe looks better than a few years ago, with European organisations now investing approximately 18% of their infrastructure spending on Edge workloads and solutions (*IDC's European Infrastructure Survey 2021, N=925, [4]*). Over the last two years this figure has increased dramatically compared to 2019, with both edge and public cloud significantly increasing 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.

2.1.2. Edge in relation with other Emerging technologies

Among all emerging technologies, edge is the platform closing the gap between emerging technologies (such as IoT, AI) and more traditional technology (such as cloud), supporting new architectures, enabling multiple connectivity standards (e.g., 3G/4G/5G, but also LAN, Wi-Fi, Bluetooth, etc.), real-time analytics and AI on data, reducing latency and ensuring privacy and trust with distributed solutions.

Comparison with other emerging technologies often used in conjunction with edge highlights similar maturity patterns. IoT saw higher adoption, but most users are still in the pilot rather than the advanced phase. Robotics, AI, and 5G are mostly in line with the edge, while AR/VR is still in the pilot phase.

Edge is often the architectural choice supporting and enabling other emerging technologies. It helps IoT and robotics deployments in managing large amounts of data, reducing time to action, and enabling processes to remain active even when disconnected. The critical role of low latency and high bandwidth in retrieving real-time data makes edge the perfect candidate for AR/VR deployments. 5G heavily relies on distributed computing and storage capabilities, with edge being a critical component in both public telecom networks and private network deployments.

Also, AI inferencing is increasingly performed at the edge, reducing latency, therefore Edge AI has tremendous capabilities to make predictions and recommendations or to process very complex and large data, enabling the possibility for edge devices to make real-time decisions.

Based on that, it is clear how edge computing is acting as a strong support and accelerator for other emerging technologies, from AI, to 5G, to AR/VR and IoT. Therefore, improving the edge computing technology will boost the adoption and implementation of related emerging technologies across European organisations.

2.1.3. Edge Business Goals driving the adoption in Europe

Business goals driving European organisations to adopt edge computing technology span enhanced productivity to higher efficiency, cost reduction, improved product and service quality, organisations with the aim of deriving more value from daily business activities. Moreover, edge is often considered for the innovative use cases where its implementation unlocks value, as well as for the synergy it creates with other emerging technologies, bringing previously established procedures and processes to the next level (e.g., through a combination of AI solutions to achieve higher automation of current processes). Moreover, organisations are adopting edge technology also to achieve other results, such as connecting IT and OT environments. Indeed, organisations consider edge computing as an enhancement for cloud computing capabilities (which in some case is characterized by higher latency) 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 (see Figure 2.2).

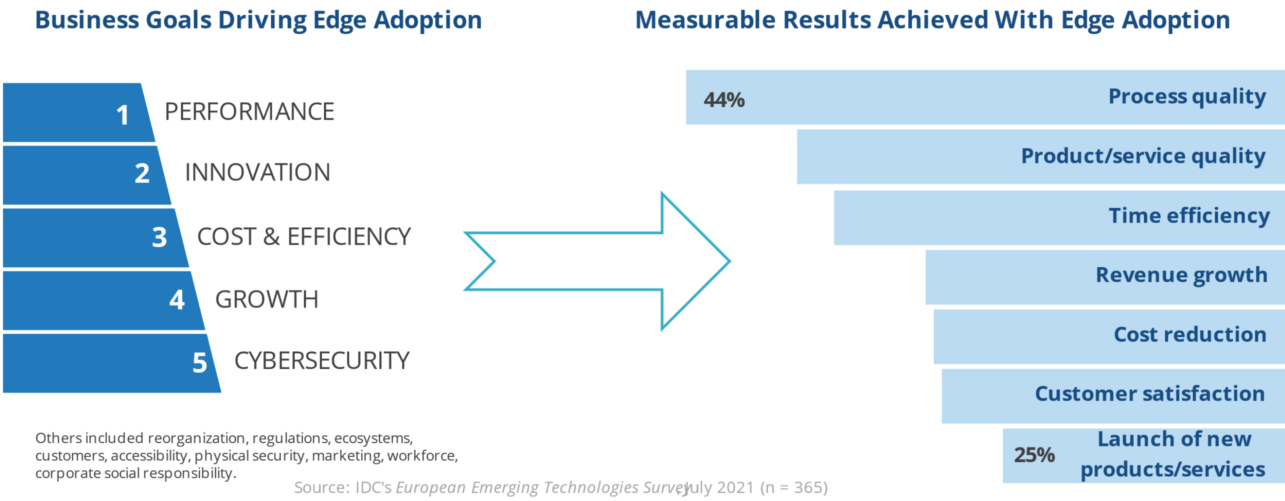


Figure 2.2 - Reasons Behind Edge adoption in Europe: Topline vs. Bottomline (Source: IDC European Edge Practice Research, 2021 [2])

Analysing how organisations are actually implementing edge computing solutions in daily business gives real and concrete examples of what has been said so far. For example, organisations in the financial sectors are leveraging edge computing to develop super-fast trading algorithms, thanks to the reduced latency, therefore leading to service improvement offered to investors. On the other hand, edge and IoT can lead to significant cost reduction by helping organisations across all sectors sending only pertinent information to the cloud, significantly minimising the need for data storage on the network.

In conclusion, edge is delivering more results as a tool for improving the bottom line of the organisations, even if it has continuously been looked at as an innovative force that may bring, maybe in new use cases and together with other emerging technologies, new revenue streams and growth opportunities.

2.2 Edge market forecast

This sub-chapter provides an overview of the edge spending five-year forecast in Europe, deep diving into details regarding edge hardware, software and services, edge domains (Internet of Things, Artificial Intelligence, Augmented and Virtual Reality, Drones and Robotics), industry sectors (Distribution and Services, Manufacturing and Resources, Infrastructure, Public Sector and Financial) and the selected use cases (Maintenance and Inspection, Personalized Healthcare and Farming 4.0) forecast.

The European enterprise edge market represents a tremendous opportunity as the market continues to develop and there are new solutions and features on the horizon addressing specific edge use cases. The COVID-19 pandemic has changed the plans of organisations across the world, in some cases stimulating the need for edge to ensure business continuity and improving remote working experience by shortening the distance data needs to travel and speeding up data processing activities. European enterprise edge spending is expected to reach €24 billion by 2022 and increase to €39 billion in 2025, driven by the role of edge in enabling low latency use cases, deployments in locations that are either remote or without IT support staff, and backed by many new vendor propositions and a supply chain that is being built up.

The growth of edge computing spending is expected to keep a steady trend over the next few years, with a compound annual growth rate (CAGR) between 2022-2025 of roughly 18%. This number clearly shows the importance of how this technology will gain momentum over the next few years, as well as in the short-to-medium term. This is in sharp contrast with just a few years ago when edge computing was still in its infancy, with major players in the ICT market unable to clearly identify how it could be implemented in the daily business and unable to grasp what benefits it could bring to adopters.

Now, the situation is different, both in terms of maturity of technology, as well as in terms of possibilities and application this technology has in businesses. This is also due to the latest trends organisations are experiencing: with the massive amounts of data produced, collected, and transmitted over the cloud by mobile devices, IoT devices, cars and other devices, there is a high pressure on networks to offer high availability, speed and efficiency. In this context, edge can indeed support organisations in saving core datacentres from overcrowding with data and pushing the bandwidth to the limit.

Therefore, organisations are now forced to adopt new solutions, new operating models, and channels for data governance and to ensure business continuity and to avoid possible disruptions now and in the future. Moreover, edge in collaboration with other emerging technologies like IoT, AI, AR/VR, robotics and drones, can support more advanced analytics and automation capabilities, improved security and privacy requirements and real-time data management benefits.

With applications and data expanding beyond core IT environments to the cloud and edge, the volume of data created and processed at the edge will grow exponentially and will change traditional approaches to how the data is managed and used to increase organizations' efficiency and performance. Therefore, deploying AI and machine learning capabilities at the edge will enable faster decision making and provide a real-time and even personalised response, leveraging the critical role of data and analytics processed at the edge.

This will have tremendous impact on various industries, starting from manufacturing, resources and utilities where automation and intelligence capabilities at the edge can enhance the monitoring and inspection systems by predicting possible bottlenecks and avoid possible failures on equipment and factories, or in healthcare, where edge AI can transform the industry by providing real-time patient data analysis and enabling instant response, critical for providing uninterrupted care.

2.2.1. Edge Forecast by technology

This section provides an overview of the edge spending by the main technology groups, hardware, software and services, analysing key dynamics and trends that are reshaping the edge market evolution across technologies.

Three technology groups characterise IDC's Enterprise Edge spending market forecast: hardware, services, including professional and provisioned services, and software (see Figure 2.3). This section, while providing a description of the technology details in each technology group, analyses key dynamics and trends that are reshaping the edge market evolution across technologies.

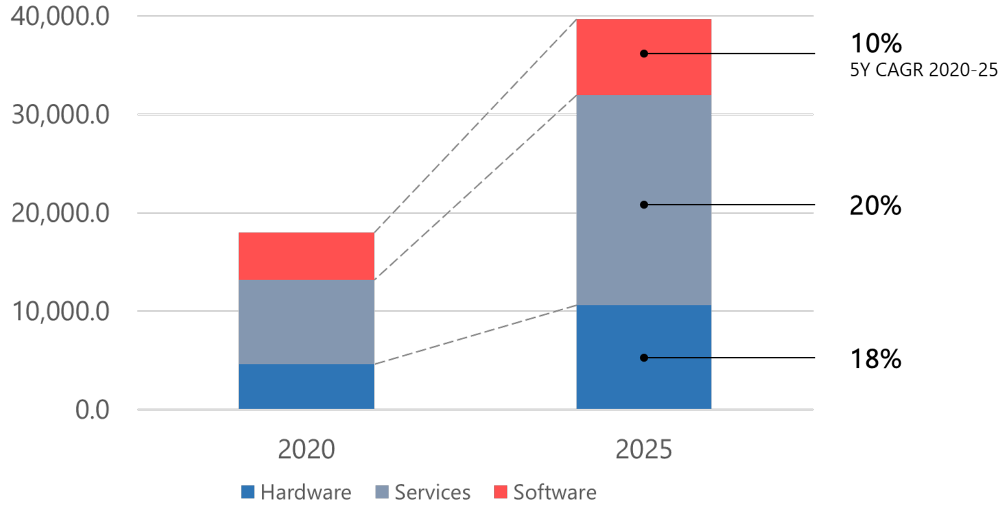


Figure 2.3 - European Enterprise Edge Spending by Technology Group (Source: IDC Worldwide Edge Spending Guide - Enterprise Forecast 2021 [1])

Hardware

According to IDC's European Enterprise Edge Spending Guide, in 2022 the hardware category will account for €6.7 billion within the European enterprise edge forecast, and 28% of the total market. Among the three technology groups, hardware is expected to grow at a 18% CAGR and reach almost €11 billion in 2025.

The great majority of the hardware market is on the heavy edge side, followed by light edge, with network equipment having a lower share. Among the three categories, light edge is expected to grow faster, at a 22% five-year CAGR.

Heavy-edge computing platforms (servers and storage) accounts for more than 45% of the hardware market and are meant to perform heavier computing tasks for the edge location or deployment, while light-edge platforms, often called edge gateways and accounting for 34% of the market, are designed with low-power components such as fanless processors and flash memory. Networking equipment, the smallest part of the market and forecasted growth at a slower pace over the forecast period, is used to connect communicating equipment such as servers, storage, and intelligent endpoints through a computer network. This category includes networking hardware (e.g., switches, routers/SD-WAN, bridges/repeaters, etc) as well as industry-specific network hardware.

Despite the constraints on underlying costs and increased power consumption, hardware is a critical part also for AI deployments at the edge, being the foundation on which AI can realise tremendous capabilities on training, inferencing and running advanced AI systems. AI training and inferencing are workloads that can better perform on compute hardware that benefits from high bandwidth memory connections. Edge is a better fit for AI inferencing as it is mostly carried out on a mobile device at the edge. Basically, the specific environment where the AI is deployed will have an impact on the type of platform an organisation might choose to use, as the edge device can have different power and form factor constraints than a datacentre or a public cloud platform. The environment where the AI algorithms such as training and inferencing are located is correlated with the nature of the intended use case, basically if there is a need for real-time response. The main advantage of locating AI training and inference at an edge device is that it enables the device to develop a personalised model of that device scenario in near real time. Organisations must consider some key factors when choosing where to locate the AI algorithms, such as the amount and complexity of data that will be transferred across a network, the computing required to perform the algorithm, compliance regulations relating to the data, and the required speed.

Services

According to IDC's European Enterprise Edge Spending Guide, the services market, including provisioned and professional services, is the largest category in the European enterprise edge market, and will account for €11.6 billion in 2022 and almost half of the entire European enterprise edge spending. The services market will reach more than €21 billion in 2025, with a 20% five-year CAGR and is expected to be a key component of the European edge scenario. Within the total services market, provisioned services accounts for the largest part, driven by the connectivity category, which helps connect edge devices and locations to the core datacentre and clouds through a commercial network. The remaining part of provisioned services is composed of colocation and cloud services delivered from edge locations, such as infrastructure as a service (IaaS), software as a service (SaaS), and platform as a service (PaaS). The cloud portion of edge services spending was a minor portion of the services component at the beginning of the forecast, in 2020. However, it will gain more importance over the years as it benefits from a value chain that is being built up and from partnerships that will bring cloud offerings from the main players nearer to customer locations.

The professional services category sees a five-year CAGR of 20% and is steered mostly by support and deployment services for hardware and software, followed by project-oriented services used for planning, design, implementation, and project management of various technical solutions that addresses an organisation's specific technical or business needs.

The third category within the professional services is managed services that include cases where the ownership and responsibility for managing all or part of an enterprise's edge processes, infrastructure, applications, security, analytics, and any other operations elements stays within services providers and technology vendors. It represents a huge market opportunity driven by the need for low-latency services that can enhance customer experience, performance, and efficiency and the complexity of managing such solutions.

The AI domain will account for more than 7% of the edge services market and is forecast to grow at a 34% five-year CAGR, driven by the spending on provisioned services, especially public cloud services and connectivity services required to connect edge intelligent endpoints to the core data centre. On the other hand, Professional Services are a critical part of Edge AI deployments as, for example, engineering services can help with the design and building of the overall Edge AI solution by customising the edge servers to include AI and real-time analytics functionalities or to customise the deployment of edge application software and management platforms to monitor and manage AI analytics.

Software

According to IDC's European Enterprise Edge Spending Guide, software is the third-largest technology group in the European enterprise edge market, accounting for €5.7 billion in 2021 and slightly more than 25% of the total market. The share of total software is expected to slightly decline over the forecast period.

Applications such as data management, integration and orchestration, application development, software quality and life cycle, and application platforms together make up the larger portion of the software market, with growth rates below the total market average of 9.6%. Other categories are instead sized separately: security software, system infrastructure software and analytics/AI software. The latter is expected to grow much faster than the overall software market, while the security software market, used to ensure integrity of data, end points, and infrastructure (server, network, and storage) and systems, is the second-largest category of enterprise edge software market, followed by system infrastructure software.

The AI domain will account for almost 9% of the edge software market and is forecasted to grow at a 23% five-year CAGR, driven by analytics and AI software that analyses and use the data collected by the intelligent endpoints to turn it into actionable insights that business decision makers can use to affect change in business processes, will strongly develop and expand over the forecast period.

Analytics are a key component for edge computing, enabling organizations to choose the kind of data to be sent to the cloud and to make real-time decisions. Despite the small dimension of this component at the beginning of the forecast period, it will grow three times faster than the total edge software market on average.

2.2.2. Edge forecast by European geography

This section provides an overview of the edge spending in Europe, deep diving into the differences across the two main regions estimated by IDC: Central and Eastern Europe and Western Europe. Countries considered in the IDC's spending forecast are described in the Methodology section.

Edge investments have different nuances of adoption across the two regions of Europe, Western Europe and Central & Eastern Europe, especially in terms of local initiatives driving the market, specific industry focus, and edge players' propositions. As happens in other technology areas, the Western European market is far more advanced in adoption at scale of new technologies, with consequences on the overall investments, see Figure 2.4.

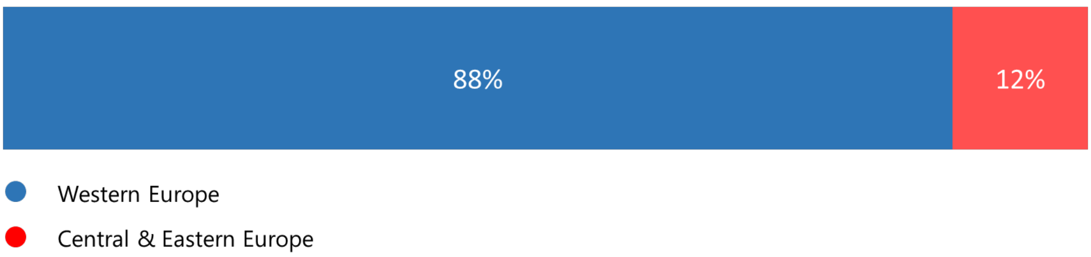


Figure 2.4 - European Enterprise Edge Spending by European Region, 2020 (Source: IDC Worldwide Edge Spending Guide – Enterprise Forecast 2021 | Jun (V1 2021))

Central and Eastern Europe

Enterprise edge spending in CEE is expected to go from €3 billion in 2021 to nearly €5 billion in 2025, with less than a half of CEE organisations using, or planning to use, edge computing solutions in the next two years *(IDC Europe Emerging Technologies Survey, 2021 [3]).* Geographically distributed datacentre facilities (directly linked to core datacentres and to cloud), integrated/converged computing platforms, and ROBO deployments outside the organisation's "central datacentre" are the most adopted edge computing solutions across CEE organisations.

Even if less mature than Western Europe, CEE is catching up in terms of edge computing adoption and is driven by connectivity services for IoT deployments, heavy-edge solutions for robotics, and light-edge platforms linked to IoT.

For that matter, most of the edge computing spending in CEE (with more than 35%) is driven by the combined application of this technology with IoT, followed by robotics and AI. Despite its light role in the edge computing landscape in 2020, augmented reality/virtual reality (AR/VR) will be the fastest-growing domain, followed by AI, which will gain nearly 7% of the market by 2025. This is also linked to the growth of analytics and AI software used to analyse data collected from intelligent endpoints. Together with light-edge solutions and networking equipment, AR/VR and AI will be the fastest-growing solutions in CEE in the next couple of years.

From an industry perspective, manufacturing, professional services, and telecommunications together have a more than 37% of the market in 2021. They have the biggest proportion of spending in the CEE region, driven mostly by manufacturing operations and smart buildings initiatives.

Despite growing at a slower pace than in Western Europe, the edge computing market in CEE will gain more importance in organisations' agenda for the next several years. According to the IDC European Emerging Technologies survey from July 2021, almost 30% of the Central & Eastern European organisations are planning to start using edge solutions in the next two years.

Western Europe

Spending for enterprise edge in Western Europe is expected to go from €21 billion in 2021 to nearly €35 billion in 2025. In the region, edge is driven by distributed and remote datacentre deployments, followed by light-edge platforms usually linked to IoT solutions. Both distribution of datacentre capabilities over geographical footprint (including colocation) and IoT are factors that are quickly evolving in Western Europe, driving edge spending.

Compared to CEE, edge adoption is higher in Western Europe, with one in three organisations already using edge computing and another 30% planning to start using in the next 24 months *(IDC Europe Emerging Technologies Survey, 2021[3]).*

From an industry perspective, manufacturing, retail, professional services and utilities account for almost a half of the market in 2021. The spending is driven by manufacturing operations, production asset management for remotely tracking, monitoring and maintaining industrial manufacturing devices that are part of the production value chain, and IoT-based omni-channel operations that supports the evolving multi-channel retail strategy to provide a seamless customer experience through any shopping channel.

From a domain perspective, most of the enterprise edge spending in Western Europe relates to the IoT domain, which drove nearly 60% of the region's spend in 2021. The contribution of the IoT domain will slightly decrease over the forecast period as other domains develop further.

The second largest named domain is the AI domain which will grow in importance, reaching over 10% of the total spend in 2025. All remaining domains combined will continue to drive just above 40% of the total spend, as this is connected mainly to ROBO deployments and the legacy aspects of edge technologies.

2.2.3. Edge forecast by domain

This section provides an overview of the main domains enabled by edge computing: Internet of Things, Artificial Intelligence, Augmented and Virtual Reality, Drones and Robotics.

Edge supports a wide array of other emerging technology markets and solution areas referred to as domains, that are driving the overall edge market and are generating value outside of core data centers. These domains are Internet of Things (IoT), augmented reality (AR)/virtual reality (VR), artificial intelligence (AI), robotics and drones (see Figure 2.5).

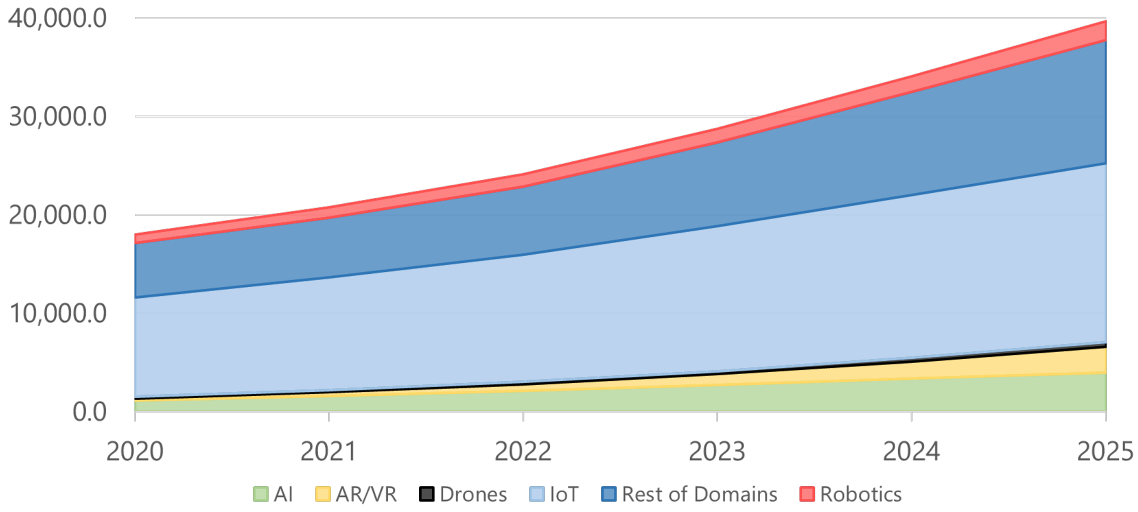


Figure 2.5 - European Edge Spending by Domain (Euro million) (Source: IDC Worldwide Edge Spending Guide – Enterprise Forecast 2021 | Jun (V1 2021) [1])

Internet of Things

IoT is the largest domain within the European edge spending, driving more than a half of the edge computing spending in 2021, driven by the accelerated increase of the overall number of IoT devices that reside at the edge, generating an enormous amount of data. By processing this data on the edge, organisations are able to reduce the underlying costs linked to transferring massive amounts of data and address the imperious need for reducing time to value.

Among different applications that the combined use of edge computing and IoT unlocks, the most widespread and adopted are manufacturing operations, production asset management and freight monitoring.

An example of these applications comes from the manufacturing industry, where edge and IoT combined allow organisations to make real-time assessment of current demand and capacity availability, while monitoring end-products quality level and controlling the production systems, ultimately detecting or predicting production deadlocks.

When coming to freight management (air, railroad, land, or sea), IoT systems carry out the intelligent recognition, location, tracking and monitoring of freight and cargo through exchanging information and real-time communications via wireless, satellite or other channels. Moreover, all these activities are automatised and made "smart" using IoT and edge computing. While before all complex shipments and movement processes were tracked through specific freight databases updated based on human-entered data, now freight management is present a high level of automations, frequency and accuracy thanks to smart sensors attached to boxes, items and many other different physical assets.

Artificial Intelligence

AI is the second largest domain and its spending within the European edge market is driven by the need to process data in real time, easily extract critical pieces of information, structure this information and finally connect the dots around it in order to transform the most valuable data into actionable insights. The AI component of the edge is expected to become increasingly important over the next few years, driving 10% of the market and doubling its market share by 2025.

Machine learning and artificial intelligence requires an extensive base of data, with higher computational and storage capabilities found not only in the core datacentre of a company or in the cloud but also at the edge.

In this context, federated learning will emerge as a new machine learning approach enabling a faster, cheaper and secure intelligence share with single or multiple organizations. With federated learning, organizations can share AI models instead of the underlying information, enabling insights in a "closed-loop system" to build common and powerful models without exchanging data, allowing them to address critical issues related to data privacy, data security, data access rights, and access to heterogeneous data. Federated learning is particularly meaningful in the context of Edge. It can exploit both decentralised data (i.e., not stored in one location, usually vulnerable data as a consequence) and decentralised, or edge, processing power. All of this leads to an improved cost model, with improved data privacy, capitalizing on the data minimization principle (which is mentioned in the European Union's General Data Protection Regulation, GDPR) and increased performance with lower latency and less power consumption.
Federated learning will open new opportunities for AI applications and platforms enhancing user experience in a way that was not possible before. Thus, model building and computation on the edge, based on federated learning and secured with encryption, will make a significant progress over the next few years.
With the advancements in the silicon industry and the ability to run increasingly efficient AI models on small footprint devices, edge is becoming the preferred environment where AI models will be applied, with benefits in terms of time-to-value, continuity and cost effectiveness of the use cases.

Automated threat intelligence and prevention systems, automated preventative maintenance and diagnosis and treatment systems are the top adopted use cases driven by the use of AI at the edge across different sectors (e.g., public sector, financial and manufacturing and resources sectors).

For what concerns the first application mentioned, automated threat intelligence and prevention system is indeed a type of application of edge computing and AI which is shared across different sectors, from financial services to public sector and telecommunications. This use case leverages systems that process the intelligence reports, extract the critical pieces of information, structure information in a fixed format, push the information into the pipeline, connect the dots between different pieces of information, and identify any threat to the database, systems, website, and so forth.

When it comes to automated preventative maintenance, machine learning algorithms build an accurate predictive model of potential failures. Higher levels of asset availability results in less factory downtime and lower capital appropriation spending, including lower maintenance costs. Similar to the previous use case, this is spread across different industries, from manufacturing to utilities to transportation.

Moving to other specific applications, AI and edge computing can be leveraged for diagnosis and treatment in the healthcare industry. In this case, AI systems extract insights from the intersection of diverse data sets — including medical records, lab tests, clinical studies, medical images, and other sources — to assist in the diagnosis and provide personalized treatment at the individual patient level.

Robotics

Robotics can be defined as technology that encompasses the design, building, implementation, and operation of robots. Robots are machines and systems that can operate autonomously (or semi-autonomously) to complete a particular task or process.

Depending on their variety of functions, some robots are capable of instant decision making and reasoning in complex environments, collaborating and interacting with customers. Therefore, edge computing can support these functions enabling real-time data processing, without connectivity interruptions. These kinds of robots can learn and make decisions to support optimal function and performance and can be designed to support commercial operations.

The spending of robots in the edge environment will be driven by the several advantages that organisations can experience when leveraging these two technologies together. In the manufacturing industry, for example, edge and robotics can be used to achieve the next level of automation in processes such as assembly, inspection, painting, welding, and much more. By providing more intelligence close to the process, there is less need to move data layers and traditional automation can be expanded with intelligent AI-based real time applications.

On the other hand, the transportation industry can get advantage of edge and robotics for autonomous trucks, also improving safety and decreasing traffic congestion.

Other applications of edge robotics can be found in the retail industry, where these solutions are used for picking and packing products in warehouses, as well as in the healthcare industry, with robots assisting surgeons in complex medical procedures.

Complemented by the use of drones and 5G connections, robots could be used by manufacturing organisations to build fully autonomous, zero-touch production facilities.

Augmented and Virtual reality

Augmented reality (AR) and virtual reality (VR) are two different but related technologies that represent a profound change in the way humans interact with computers, either to overlay digital information or objects with a person's real-world view of reality or to be fully immersive, placing users into a completely new reality, obscuring the view of their surrounding real-world environment.

Despite its light weight in the European edge computing landscape in 2021, augmented reality/virtual reality (AR/VR) will be the fastest-growing domain, with a 5-year CAGR of over 50%.

The critical role of technicalities such as low latency, high bandwidth, storage and security capabilities to retrieve real-time data can make the AR/VR the perfect candidate for edge deployments, combining the disruptive effect of both technologies.

Drones

Drones have tremendous capabilities especially in the manufacturing, construction and utilities industries, being able to collect real-time environmental data, 3D mapping, compliance, aerial photographs in order to provide information for tracking the progress of a large project, identifying potential safety hazards, or inspecting hard-to-reach places, for examples machinery or equipment in plain field (like wind or solar turbines). The role of edge is critical to take real-time decisions based on aggregated and localised information from multiple sources, in a secure and very fast way.

According to IDC's European Enterprise Edge Spending Guide, , the drone market is experiencing steady growth, with European edge spending on drones expected to reach a 20% CAGR by 2025.

2.2.4. Edge forecast by industry sectors

This section provides an overview of the edge spending trends and dynamics in Europe across different industry sectors: Distribution and Services, Manufacturing and Resources, Infrastructure, Public Sector and Financial.

Edge computing has been developing and maturing for European industries within the past 12 months, with some interesting adoption levels and successful case stories in various verticals. The current crisis has affected various industries at different paces. Some industries were more exposed to drastic measures and demand decline, such as transportation, manufacturing, or retail. Others were more resilient, such as the financial or healthcare industries, in which the impact was more contained.

Edge solutions will play a major role in organizations' recovery process after the crisis. Maintaining cost controls, customer experience, and employee health is among the main business priorities driving organisations' digital investments. On the other hand, in the road from recession to return to growth, organisations will focus more on investments that support business transformation to address new market requirements, especially in industries such as retail, transportation, and manufacturing.

Service providers and technology vendors have continued to support organisations' challenges, planning, investing in, and launching new solutions and capabilities regarding edge computing and targeting specific industry use cases.

The following section highlights the key drivers, trends, and use cases characterising the edge computing landscape across some of the main European industries as summarised in Figure 2.6.

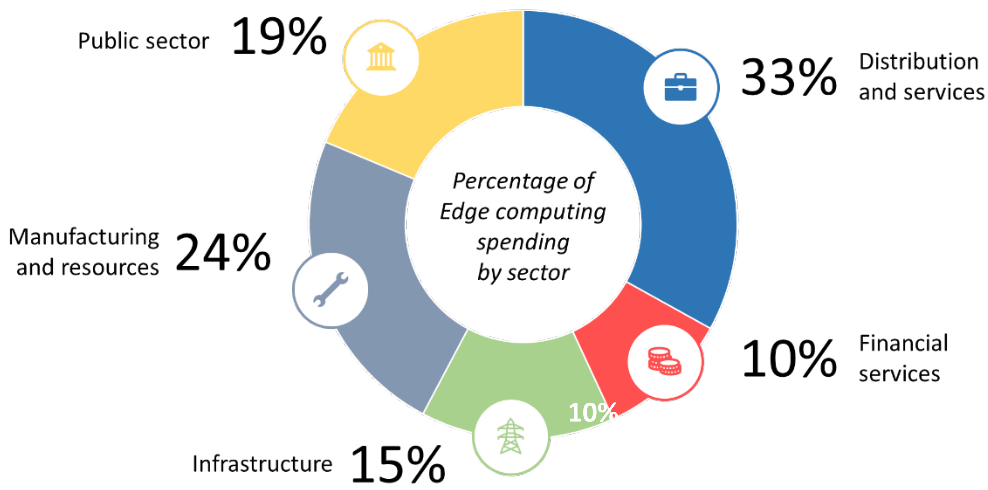


Figure 2.6 - European Edge Spending by Sector, 2020
(*Source: IDC Worldwide Edge Spending Guide - Enterprise Forecast 2021 | Jun (V1 2021) [1]*)

Distribution and Services

The distribution and services sector, composed of retail, wholesale, professional services, personal and consumer services, transportation and media industries, will be the largest sector in terms of European enterprise edge spending in 2022, driving a third of the total market share and will continue to lead the market over the next five years. Within the sector, the retail industry accounted for the largest part, followed by professional services and transportation.

The 2020 crisis strongly impacted edge development projects in the retail and transportation industries, which rerouted their budgets due to lockdown measures, supply chain challenges, and travel restrictions to support business continuity initiatives.

Spending from this sector will double over the forecast period, driven by use cases across the largest industries mentioned above: retail (e.g., in-store contextualized marketing for interactive shopping, enabled by continuous, real-time streams of data about customer behaviour and desires), transportation (e.g., fleet management for tracking trucks, railroad cars, and ships or determining/controlling optimal routes) and professional services (smart buildings and staff identification).

In terms of domain spending, IoT is the largest domain followed by AI, driven by use cases related to customer experience, such as AI computing engines that can work with CRM systems to understand customer context in real time and recommend actions to the sales agents that are most relevant to the specific interactions and recommend the "next best action" sales process to try and qualify or close a sale and by use cases related to IT automation, such as AI systems that orchestrate the linking of IT systems to become self-acting and self-regulating and automate tedious software maintenance activities. The automation engine can perform decision making and execution tasks of IT systems. New events are learned from IT human operators, not programmed by software programmers, with the aim to optimise, streamline, predict, and automate core IT processes and back-end IT operations. Examples may include automation of fixed price contracts from IT service companies or infrastructure monitoring (the prediction of infrastructure issues before they become bottlenecks).

Manufacturing and Resources

Manufacturing and resources, composed of discrete and process manufacturing, construction and resource industries, despite being one the most affected sectors by the COVID-19 crisis, is the second-largest sector in terms of European enterprise edge spending. It has nearly a fourth of market share over the forecast period, and five-year CAGR slightly above the overall enterprise edge market, *which is estimated at €20.7 billion in 2021 and a five-year CAGR of 17.1%*. Edge computing has proven to be essential for many manufacturers to thrive in such a challenging environment, driven by the rise of IoT use cases in this sector such as production asset management, manufacturing operations, and maintenance and field services. In this scenario, IoT helps organisations to remotely track, monitor, and maintain industrial manufacturing devices that are part of the production value chain.

AI and machine learning algorithms can help with automated preventive maintenance by building an accurate predictive model of potential failures. Higher levels of asset availability will result in less factory downtime and lower capital appropriation spending, including lower maintenance costs. The objectives are lower time and cost to repair, longer MTBF (Mean Time Between Failures) and higher FTF (First Time Fix) rates, and lower factory downtime.

For the manufacturing industry, these technologies can help transform field service operations by automating the measurement, recording, transferring, and formatting of service data remotely from the field. Real-time assessment of current demand and capacity availability, product quality monitoring, status tracking for production systems and machinery, and automatic detection/prediction of production deadlocks and failures are just a few examples of how edge computing services can help organisations to thrive even during disruptive situations. The sector provides the perfect example of how edge is bridging the gap between the IT and OT worlds, with solutions that need to integrate and often retrofit existing machinery and assets into digital systems.

For the oil & gas field, in the wake of pandemic, supply chain management (SCM) emerged as a key concern among many high impacted business areas and drove AI adoption in the oil firms, aiming to pivot to the resilient process. AI-powered SCM yields real-time insights, predictability and visibility on resources and vendors. According to IDC research, 9 out of 10 European O&G firms are either conducting pilots or already using AI in SCM processes to varying extents.

Furthermore, the pandemic-impacted operational disruptions triggered a flurry of adoption of remote-operations management solutions. AI-ML technologies are the key enabler of these solutions in terms of precise analysis of massive data streams, data analytics lifecycle automation, tools and algorithms for use cases development, and many other innovation opportunities. The recent IDC's Industry AI Path Survey, 2021, N=430 (European only) [5] indicates that over 70% of European oil players have adopted AI in asset monitoring and maintenance management space. Over half of such work is still under the pilot phase.

Edge computing investments particularly in oil upstream operations will likely be a particularly important area of focus as increased production and asset operations connectedness and automation continues to be a focus area. Some oil players considering edge computing capabilities to enable decision making at the point of data creation such as on the rig or in the plant and removing the latency issues (and cost) of transferring large amounts of data across the operation deliver a big step change in the quality of decision making and the ability for workers to be enabled by locally generated equipment and production data. The drive towards real-time operations is drawing some European energy and utility organisations' attention from cloud to edge, with around a quarter of European oil players having already pushed some applications to the edge of their network.

Other resource environments are also looking at the edge with interest. This is true not just for the use cases that are connected with the deployment of heavy assets, like machineries in mining or smart tractors, but increasingly in use cases leveraging edge to enable local computing capabilities without the need of continuously transferring data to a central location, like in smart agriculture and farming.

Public Sector

For the public sector, composed by healthcare providers, federal/central government, state/local government and education, which maintained IT spending in 2021, edge adoption will be key for maintaining public safety and emergency response, monitoring, and tracking to inform decisions about the long-lasting pandemic's impact and containment, as well as for addressing many healthcare-related use cases (e.g., hospital asset tracking, telemedicine, personalised healthcare, remote health monitoring).

The public sector, even if with a more traditional approach in CEE countries than in Western Europe, presents a huge opportunity for vendors to offer industry-specific solutions and address government recovery programs focusing on health and wellness, public safety and security, and intelligent transportation systems.

Healthcare providers, the fastest-growing industry in this category, accounts for the largest part of the public sector, followed by federal and central government and state and local governments. Education, retaining a smaller portion of public sector spending, will grow at a slower pace over the forecast period, underlining the use of AI and AR/VR technologies for intelligent advanced learning that require local, low-latency services to support the real time response.

For the healthcare sector, including the public portion, edge capabilities promise to make the care delivery cheaper and easier. COVID-19 awakened many providers, overnight, to virtual care and digital patient experiences. Today, the spending on remote health monitoring and diagnosis and treatment systems related technologies drives the overall healthcare industry spending, where a quarter is within the public sector. IDC predicts that by 2023, digitally enabled remote care will drive 70% growth in spending on connected health technologies by providers. In the pre-pandemic world, such initiatives were typically limited to rolling out a white-label application on the front end, such as for open access scheduling or a telehealth solution. Since March 2020, when most global social distancing went into effect, the provider case mix and care model largely shifted from "majority physical, minority digital" to "minority physical, majority digital."

To scale virtual patient services, manage medical devices, and support smart hospital applications, modern health systems must handle massive data sets closer to the data source—to reduce the delay in the transfer of data, called latency, and enable real-time decision-making. Edge computing allows data collected by sensors and other medical devices to be analysed where patients are, supporting advanced remote patient monitoring. As a result, care providers can diagnose and begin treating conditions faster, improving patient outcomes.

Infrastructure

The infrastructure sector is balanced between the telecommunications and utilities industries. Telecommunications is the fastest-growing industry, driven by increasing demand for continuous connectivity and collaboration as well as pressure to ensure high bandwidth and low latency. Edge computing is also a key component of the development of the telecom industry as the value chain of service providers (including telecom organisations) is closely linked to network evolutions and 5G developments. Telecom operators are going beyond connectivity-only offerings. Together with infrastructure and services providers, they have started building comprehensive and integrated solutions offerings for their existing large client base, including new applications and services based on edge capabilities.

Both industries will reach high levels of adoption across European countries where use cases related to automated threat intelligence and prevention systems, automated preventative maintenance, industrial maintenance, and smart grid will thrive through the years.

IDC also predicts that by 2025 over 50% of utilities will increase spend in automating operations with an emphasis on edge, AI, and ML technologies, thus doubling the penetration of predictive and prescriptive maintenance (*IDC FutureScape: Worldwide Utilities 2021 [6]*).

Currently IDC research shows that one of the top 3 investment priorities for utilities in the operational assets space is automating asset operations. The automation of operations will be enabled by edge computing, AI and ML technologies, which will be essential technologies that will enable not only preventive and predictive maintenance but will also enable prescriptive maintenance and recommendations on how to best optimise assets.

Particularly for field-asset intensive operations such as wind farms, utilisation of edge, AI, and ML will have profound implications for visualizing and predicting asset performance. It can provide asset operators and owners actionable intelligence that can lead to better informed and quicker decisions regarding asset operations, which in turn will create better business and financial outcomes. A strategic approach to automated asset operations will benefit asset owners and operators in reducing maintenance costs, improving reliability and uptime, and extending the life cycles of their operational assets.

Thus far utilities have been using cloud environments for data storage, processing and management. Deployment of edge into operations was relatively very small. However, in coming years many utilities are increasingly looking at edge solutions to complement their monitoring and control system infrastructure in a new way or build an entire edge to cloud operational infrastructure, replacing the traditional methods. Currently, according to an IDC survey, about a third of European utilities are using edge or moving into production within two years, with a quarter planning a pilot.

Financial

Financial sector, composed of the banking, insurance and securities and investment services industry, is the smallest sector in terms of edge spending in 2021. Even though the spending has a lower portion at the beginning of the forecast, according to IDC's Emerging technologies survey, 43% of the financial sector organisations are planning to start using edge computing in the next two years.

The spending within the sector is driven by the banking industry, where edge computing can enable financial institutions to guarantee secure remote collaboration by having data closer to the source, followed by insurance where IoT technology can help with insurance telematics offerings for vehicles for both consumer and business clients, where the driver's behaviour is monitored directly through a vehicle mounted device, which impacts insurance policies and rates.

In the financial sector, edge is mainly linked to AI and IoT technologies. AI has proved to be a powerful tool by providing automated threat intelligence and prevention capabilities, which is increasingly moving to the edge for contained latency and increased data control. IoT at the edge, instead, helps improve customer interaction between financial institutions by remotely tracking and monitoring any activity in automated teller machines (ATMs) in different locations. Finally, the ROBO and dislocated location aspect is playing a key role, as financial institutions are usually distributed across multiple locations. Edge solutions also support financial organisations in running the business efficiently, maintaining the continuum from the cloud and core locations to the most remote agencies.

2.2.5. Edge market forecast by selected use cases

This section provides an overview of the edge spending five-year forecast in Europe, deep diving into details regarding main trends and dynamics for the AI-SPRINT project selected use cases (Maintenance and Inspection, Personalized Healthcare and Farming 4.0).

2.2.5.1. Maintenance and Inspection

Predictive maintenance is a methodology that allows industrial organizations to collect and evaluate data from machinery to increase efficiency and optimise maintenance processes. Not only can the condition of the equipment be gauged in real-time, but manufacturers and maintainers can also more accurately predict when maintenance work is needed. This is important because the traditional asset management practice, which entails replacing asset components at a regular time according to the equipment manufacturers' specification, while it was a perfectly reasonable way to carry this process, it is today suboptimal when it comes to the opportunities current technology provides. For example, it risks increasing maintenance costs unnecessarily and resulting in premature changeovers and lost revenue due to unnecessary downtime.

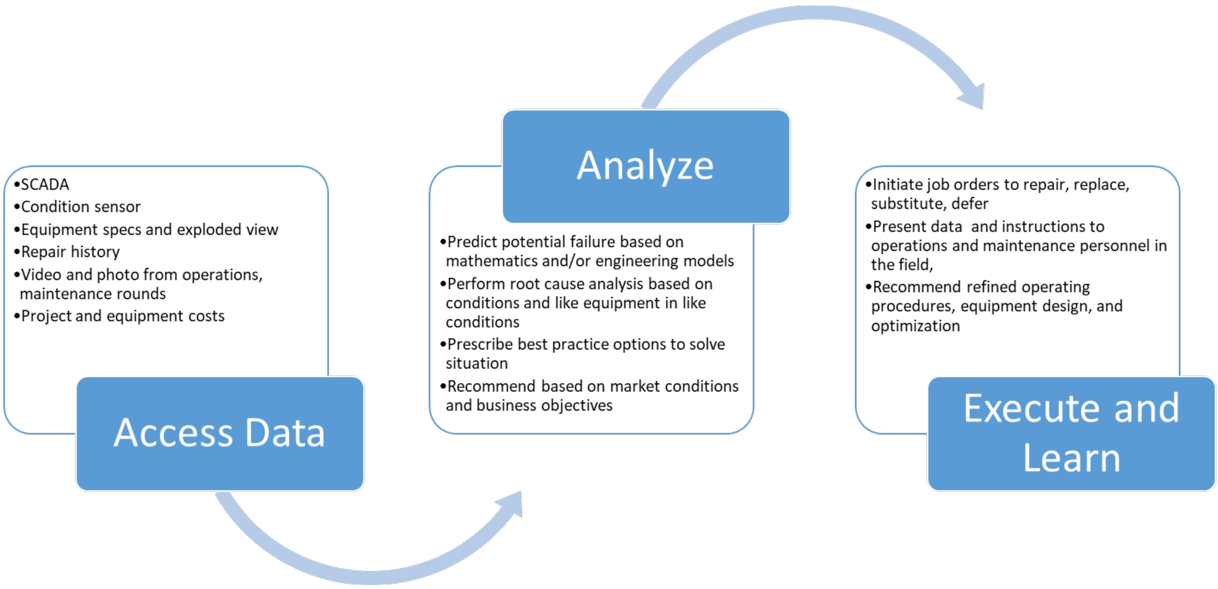


Figure 2.7 - Maintenance & Inspection framework (Source: IDC Manufacturing Insights, 2021 [7])

As depicted in Figure 2.7, instead, managing the process based on the actual machine performance data can optimise the costs of labour and parts, while ensuring that the assets that have a higher dependency on productivity are not affected. Moreover, by analysing the live stream of data produced by the machine, manufacturers can reduce the probability of facing " dangerous" situations, since the equipment under consideration is likely to be maintained before a possible failure or an all-out breakdown occurs. At the same time, it increases the chance of using the equipment longer and more effectively than under traditional maintenance mechanisms: the latter are based on average usage conditions pre-defined by the equipment vendors, whereas the actual usage conditions within a specific manufacturing process may be different. Predictive maintenance can therefore easily adapt to these "real-life" conditions, rather than rely on theoretical usage assumption.

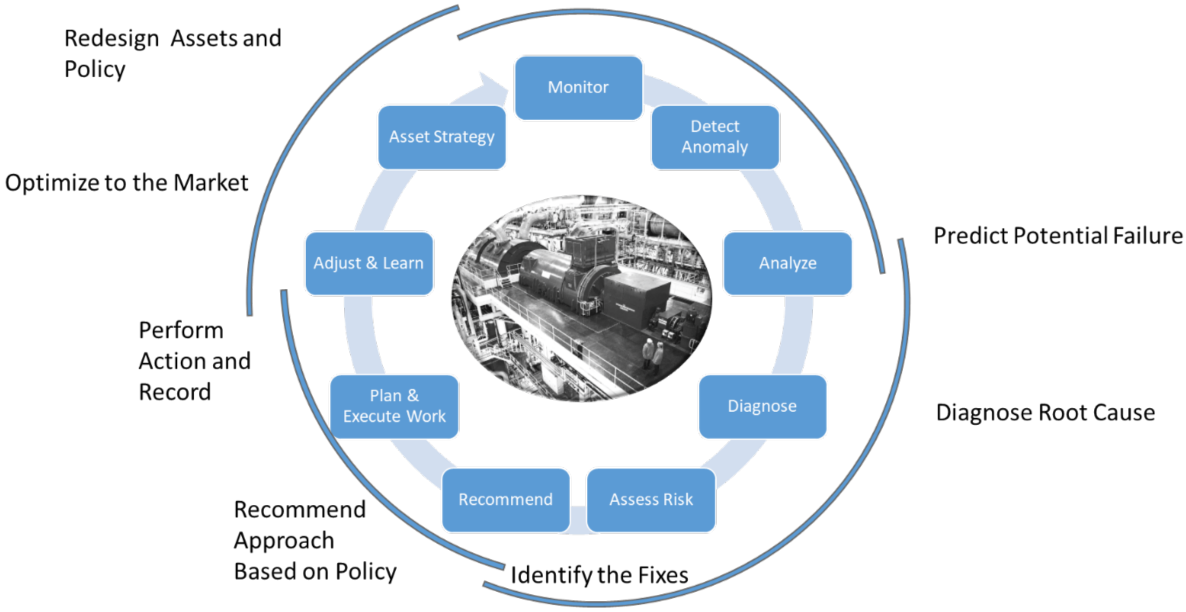


Figure 2.8 - Predictive maintenance process (Source: IDC Manufacturing Insights, 2021[7])

This practice of actively monitoring assets to keep them in the best operating conditions possible enables closed-loop improvement management practices, where work cycles such as monitoring, anomaly detection, analysis, diagnostics, strategy, plan and execution can be performed in synergy (see Figure 2.8).

Mechanism of predictive maintenance

As described in Figure 2.9, wireless sensing devices, IoT sensors, smart cameras, and condition monitoring systems such as SCADA acquire data from assets in the field. Data from certain complex assets can be stored as time-series in historian systems.

Data is transmitted to either onsite edge system or in a cloud environment or an on-premises data platform for real-time, quasi real-time, or batch processing, depending on the use case. Data is fed to predictive analytics software that uses algorithms and statistical data-driven, or physics-based/expert models (or a mix of the two). This is used to analyse current and past equipment condition data, asset history from work and asset management systems, and other structured and unstructured data sources to detect performance degradation patterns and predict possible equipment failures.

Machine learning technology (either supervised or unsupervised) is used to improve algorithms and related machine models to make predictions more accurate over time and part of the process can employ edge computing protocols leveraging memory and computing power onboard smart equipment.

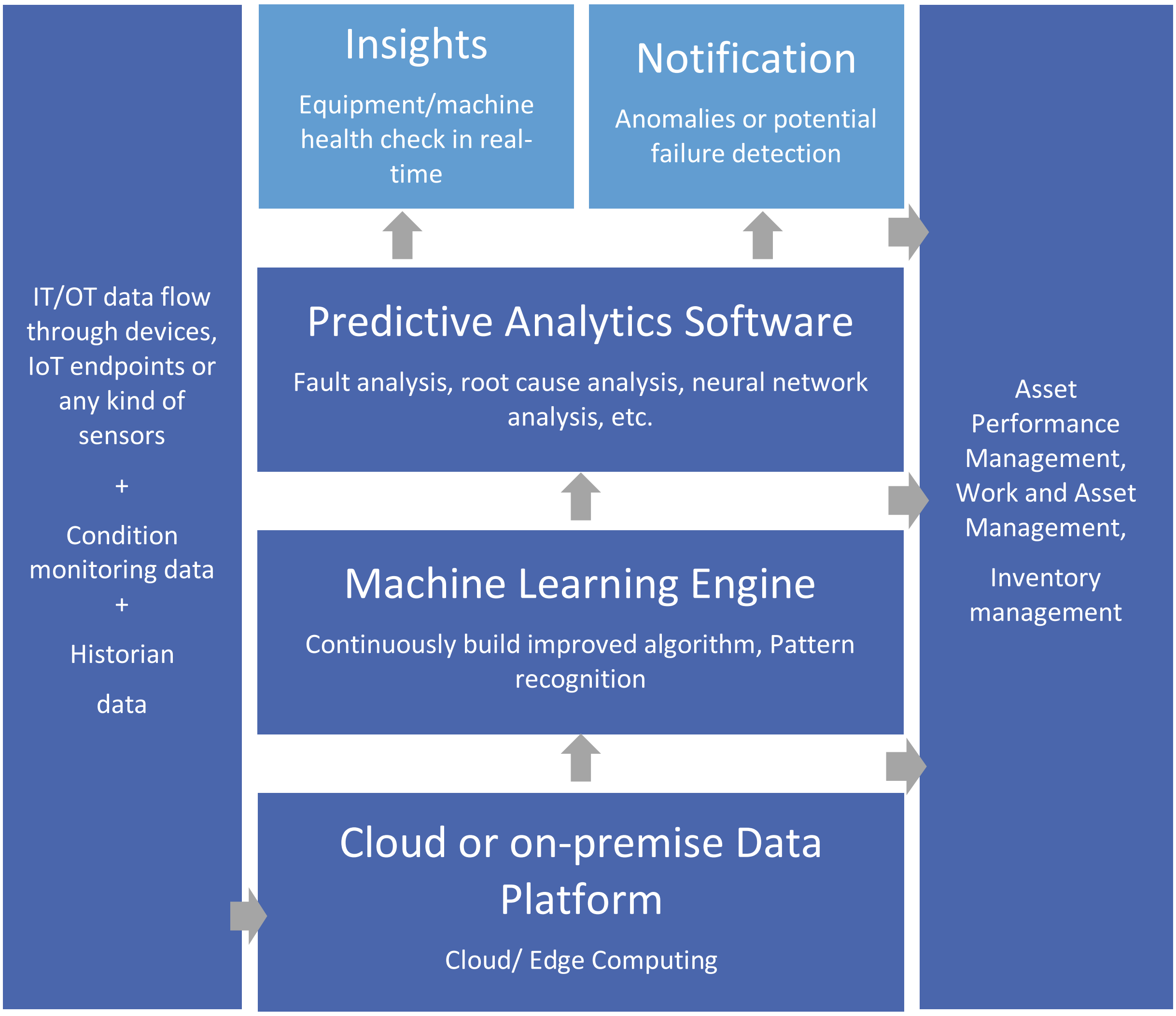


Figure 2.9 - Mechanism of predictive maintenance (Source: IDC Manufacturing Insights, 2021 [7])

In brief, the generic architecture of a predictive maintenance platform is diverse but mostly includes majority of the following layers:

- Smart device and connectivity management.
- Data integration, ingestion, processing, and management.
- Machine learning agent.
- Predictive asset analytics algorithm.
- Applications (e.g., visualisation tool, decision management).

European organisations' spending on Edge-AI solutions for maintenance and inspection will account for €313 million in 2022 and will reach €505 million by 2025, with a 18% five years CAGR (see Figure 2.10). This estimation includes elements of edge-deployed technologies pertaining to use cases like automated preventative maintenance, maintenance & field service and inspection in the manufacturing, resource and utilities industries.

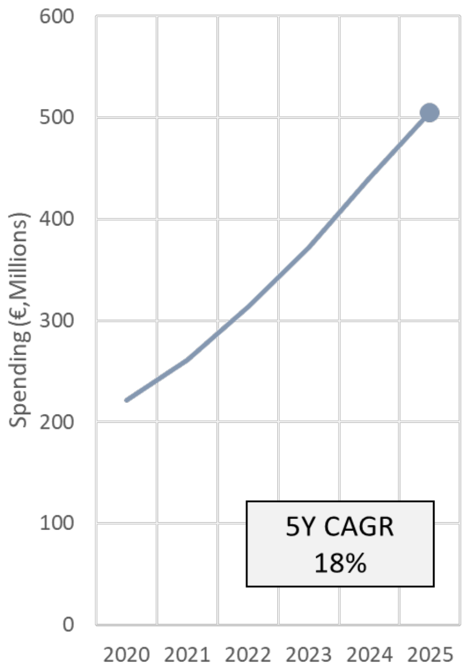


Figure 2.10 - Maintenance & Inspection five-year forecast
(*Source: IDC Worldwide Edge Spending Guide - Enterprise Forecast 2021 [1]*)

Predictive Maintenance for Wind Turbines

In the last few years, sustainability has increasingly been on the agenda of many European countries. Finding and maintaining permanent clean and sustainable sources of energy has become an imperative for countries pressured to lower the costs with energy without aggressively impacting the environment. Using renewable energy from natural resources such as sun, wind, rain and so on will be critical for a sustainable future. Countries need to pay increasing attention to equipment and devices that are producing this renewable energy.

Wind turbines are such devices that are using the power of wind to produce electricity. Maintenance and inspection for these devices is critical to avoid possible failures and delays in energy production. For wind turbines manufacturers, technology is a key enabler to prevent and predict possible damages and to minimise the costs with possible repairs.

Manufacturing organisations will deploy a technology stack including drones to continuously inspect the wind turbines equipment, AI and machine learning algorithms that build an accurate predictive model of potential failures and monitoring of assets availability and IoT technologies that are automating the measurement, recording, transferring, and formatting of data remotely from the field, giving technicians access to real-time and historical data. Processing all the data in real-time at the edge and sending the relevant information over cloud will result in decreased downtime and lower maintenance costs.

Wind turbines are rapidly expanding among renewable resources. Often located in remote areas, mainly the offshore wind farms, accessibility is hard for regular inspections and maintenance. The operations and maintenance (O&M) cost increases with the age of the turbine, which generally has 20-25 years of operating life. Compared to onshore the wind farm installed offshore has a higher cost of O&M. Wind farm owners' main challenge of operating the wind turbines has always been the O&M cost. Most wind farm owners rely on SCADA, which is often commissioned with wind turbines, as one of the preferred OT systems to monitor and control wind farm operations. Seeking to operate wind turbines efficiently with optimised maintenance process and minimum downtime, industry is evolving from manual maintenance to AI-ML based predictive maintenance.

AI based predictive models can be developed to operationalise data obtained from sensors, as well as from other sources such as service reports or historical performance trend reports to determine when and how each wind turbine should be serviced. Specifically, advanced predictive models can estimate the need for servicing months and even years in advance. The solution allows wind farm owners to carry out maintenance on an as-needed basis, reducing logistics and material costs, as well as potential downtime. Using AI-powered predictive maintenance, wind farm owners can get early warnings and performance monitoring of turbine's blade and electronic components, reliability prediction, energy production forecast, and outage monitoring.

Many utilities operating large scale field assets benefit from AI-assisted smart maintenance. US-based Duke Energy has a large fleet of nuclear, coal, gas-fired units as well as hydro, wind, and solar plants. It has evolved its asset maintenance and operations management and moved from simple reporting and analysis for combustion turbines to fleet-wide monitoring and predictive analytics of all operational assets. The programme, involving more than 33,000 new sensors and 11,000 failure models based on half a million data points, offers early warning of equipment failure. Another example is the French energy giant EDF, which also runs fleet-wide monitoring of solar, wind and energy storage assets combining historian data and predictive analytics to analyse equipment health and performance.

2.2.5.2. Personalized Healthcare

Driven by the combination of rapid development of technology, market demand and financial pressures, the evolution toward an integrated and patient-centred care is already underway. The market for this new care delivery model was moving very quickly pre-COVID-19 and has accelerated during the pandemic with the support of innovative digital technologies. According to the IDC EMEA, Future Enterprise Resilience survey (August 2021, N=430 [8]), over half of European healthcare providers are expected to increase their IT spending to primarily bring their business model innovation at scale, but also to optimise processes and reduce operational costs while enhancing their resilience capabilities (see Figure 2.11).

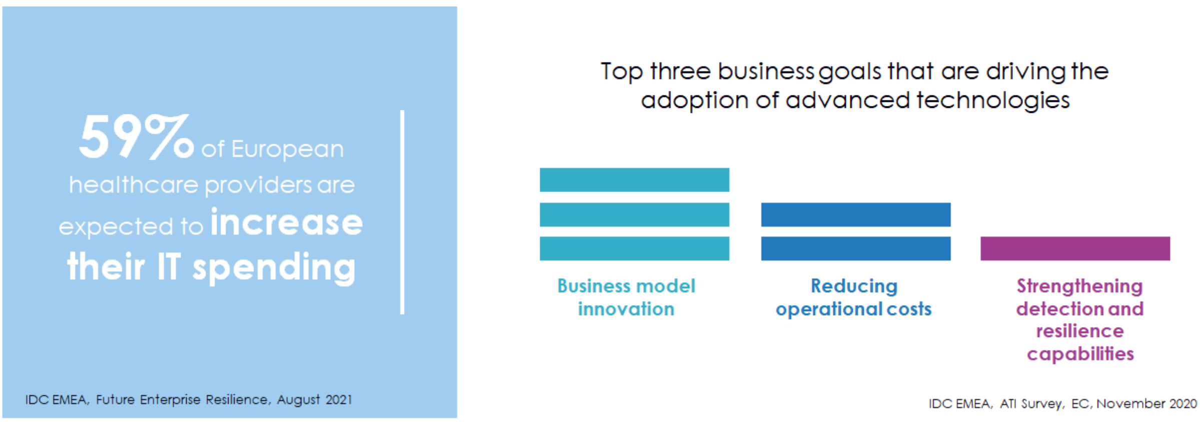
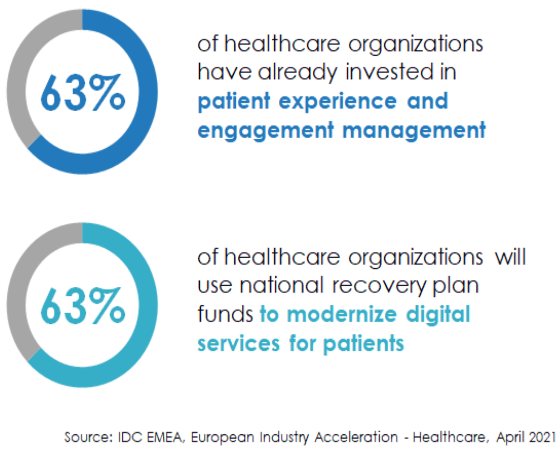


Figure 2.11 - Reimagining the delivery of care through digital technologies (*Source: IDC Healthcare Insights, 2021 [9]*)

Technology-driven innovation improves the understanding of patients, enabling the delivery of more convenient, personalised care. By adopting a patient-first mindset and leveraging the tools of patient-focused innovation, healthcare providers can implement high-quality, personalised end-to-end experiences that promise stronger provider-patient relationships, better health outcomes and long-term viability in an increasingly competitive market.

Conscious of this, 63% of European healthcare providers have already invested in patient experience initiatives, but more relevant is that they are using the recovery plan funds to make it happen.

Digitising patient experience began long before the outbreak of COVID-19, but the global pandemic has only served to underscore the benefits of this new era in patient care. COVID-19 has offered a new and unique opportunity to reimagine the way care is delivered and received. Among the long-lasting effects, it highlights the resilience of patients and providers and reveals fascinating transformation in patient health preferences. This transformation has boosted the adoption of telemedicine and emphasised the importance of an integrated care model. The advent of remote and wearable digital health technologies has enhanced preventative health practices and spurred patient and family satisfaction. Telemedicine has ensured that patients enjoy continuity of care while keeping them safe from exposure to the virus.



Proliferation of digitally enabled virtual care could further contribute to the rise of personalised and intuitive care. An example comes from one of the AI-SPRINT use cases on the development of an automated system for personalised stroke risk assessment and prevention using continuous, non-invasive monitoring of heart activity.

In this case, AI systems perform a central role. AI applications operationalize the insights coming from connected devices and better engage patients in their health personal journey. Advanced data mining, such as AI, helps reveal patterns and trends useful to healthcare providers and other stakeholders, to improve diagnoses, treatments. Many data analytics tools currently used focus on descriptive analytics, which provide insights into the past. Leveraging AI allows the analytics to move toward prescriptive analytics which make recommendations to advise on possible outcomes. AI can predict the future of a patient's health with better accuracy, to prevent the risk of contracting specific diseases as a stroke, for example, health systems must now process massive amounts of data closer to data-gathering devices to reduce latency and enable real time decision-making.

To scale this virtual and personal patient service and manage the medical devices, providers must bring AI workflows closer to the source with the support of edge computing.

The European organisations' spending on Edge-AI solutions for personalized healthcare will account for €295 million in 2022 and will reach €432 million by 2025, with a 15.7% five years CAGR (see Figure 2.12).

The spending will be driven by AI applications that automatically can learn, discover, and make recommendations or predictions. These applications are AI-centric applications (AI technologies are central and critical to the function of the application and if you eliminate the AI technologies, the application will cease to exist) and include a mix of machine learning (supervised, unsupervised, reinforcement, etc.) and some sort of user/data interaction (e.g., NLP/NLG, Q&A processing, image/video analytics, and vision) or knowledge representation capability. All the data collected is processed locally, directly on the device and only relevant data will be sent to the cloud. The Edge AI technology will enable real-time decision making, secure data processing, providing low-latency and real-time analytics. In this way, data transfer to the cloud will happen instantly, enabling an automated response time, which is critical for personalised healthcare use cases.

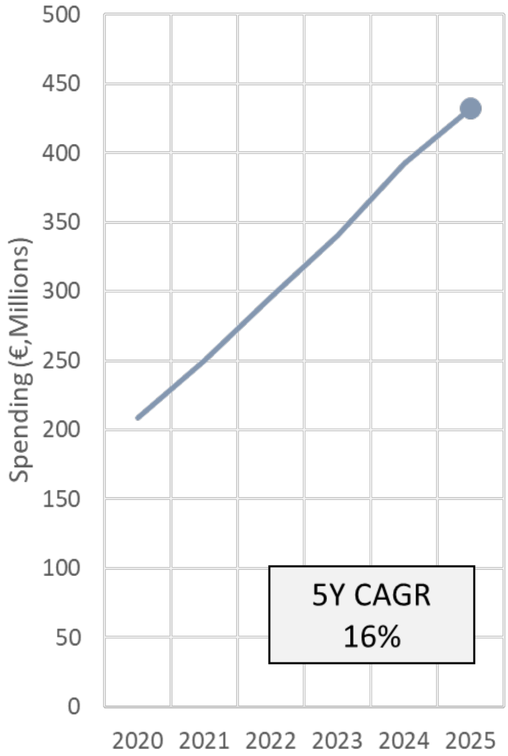


Figure 2.12 - Personalized healthcare five-year forecast (Source: IDC Worldwide Edge Spending Guide - Enterprise Forecast 2021 [1])

2.2.5.3. Farming 4.0.

As many other industries, agriculture is under increasing economic, environmental, and social pressure to enhance their digital transformation investments as agriculture organisations need to increase performance and efficiency, to streamline processes by planning, monitoring and optimising different activities with the aim to reduce costs and to gain competitive advantage and customer loyalty.

Digitisation of agriculture or the so-called Farming 4.0. can help organisations achieve all these benefits by capturing real-time on-field data, value chain data and consumer data that can enable the development of new and exciting solutions in agriculture. In this scenario, as a foundation for Farming 4.0., precision agriculture is one of the fastest growing digital environments in the agriculture industry. The digital mission in precision agriculture is to enable farmers and other stakeholders to gain more insights and information using technology in order to make more informed planting, growing, and harvesting decisions to improve production consistency and quality, and manage resources efficiently to reduce cost and impact on the environment and people.

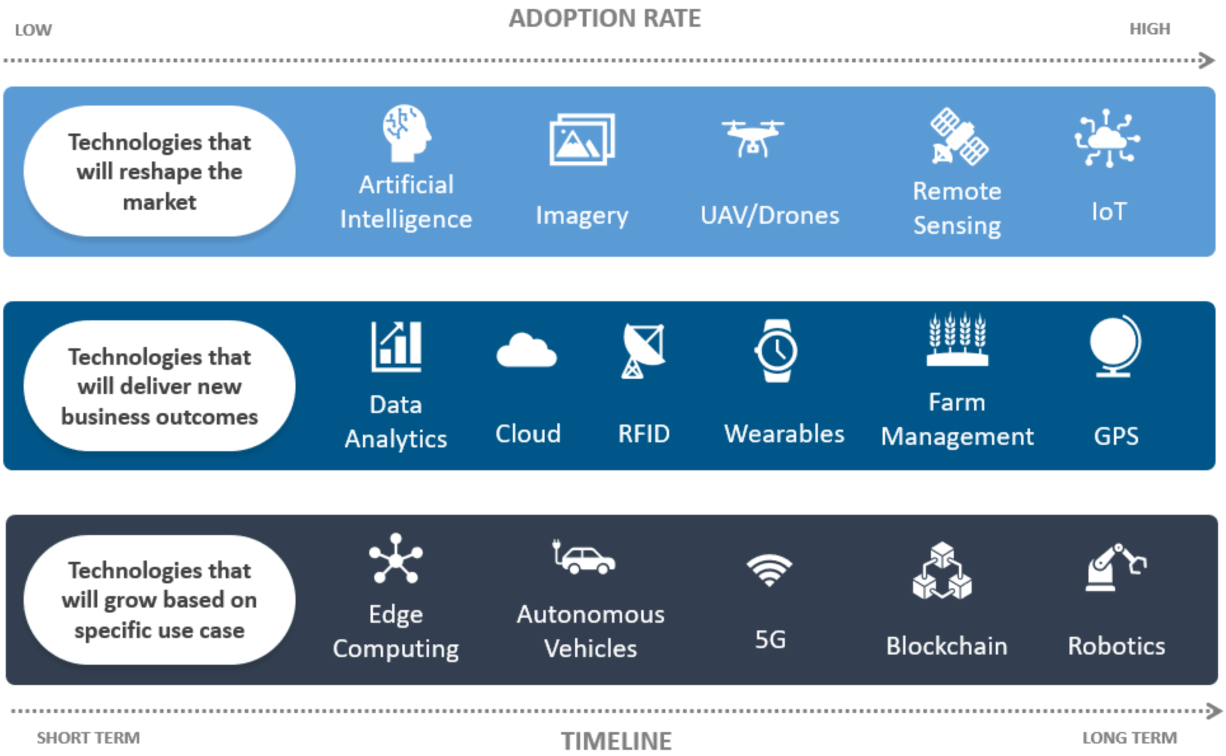


Figure 2.13 - Emerging technologies framework for Precision Agriculture (*Source: IDC European Edge Practice , 2021 [2]*)

As seen in the Figure 2.13, precision agriculture requires a diverse set of emerging technologies, each of them having a specific adoption rate and timelines, based on their impact on the organisation and assessing the relative adoption levels within their respective categories.

This model could be used as a framework for agriculture companies to assess the progress of their own technology adoption efforts in comparison with their peers, identify new technologies that should be considered in their technology road map or to add new insights to increase the robustness of their own technology decision framework.

The need for increased efficiency and performance in agriculture becomes extremely important and therefore, interest in precision agriculture will increase significantly in the next few years. From individual farmers to large agriculture organisations, the adoption of precision agriculture technologies will be critical to improve yield, reduce input costs, and to become more sustainable.

A key part of the precision agriculture industry is farming, as a complex process requiring various inputs throughout the planting, growing, and harvesting stages. During the farming cycle, data is collected and used to optimise operations. This is an extremely complex activity dealing with massive data sets that are traditionally poorly integrated and held within organisational silos. The ability to process large data sets (including images), so that decisions to rely on fact-based data rather than model-based data, is driven by the use of advanced cognitive, machine learning, artificial intelligence, and optimisation techniques to provide insights.

Reducing time and cost spent on processing data is critical for farm owners to allocate resources in order to maximise output and return on investment. Here comes the benefits of edge, in collaboration with AI tools, as a key enabler for improving the data collection, processing and management even in rugged environments without stable connectivity and direct access to cloud environments.

More precise, artificial intelligence has tremendous capabilities in agriculture by supporting organisations make planting, growing, and harvesting real-time decisions, which is made possible from the large amounts of data gathered by the various precision agriculture technologies described in the framework. To assist farmers in identifying abnormal conditions in the fields, AI can alert farmers of these conditions using data collected from other precision agriculture technologies such as robots, drones, IoT sensors and so on, and therefore, to help farmers to make more informed farming decisions. However, because of the limitations of networks and connectivity, especially in remote areas, agriculture organisations' ability to leverage the data is hampered. In this case, edge computing has the power to redefine infrastructure boundaries that enables data to be more actionable where it is collected and reduces the need for unnecessary data movements across the wide area network, which further reduces latencies and network congestion.

In this case, IDC estimates the spending from European organisations on edge-AI solutions specifically for the Farming 4.0 portion to account for €147 million in 2022 and will reach €264 million by 2025, with a 12.4% five years CAGR (see Figure 2.14). Investing in precision agriculture technologies can be a complex decision to make for agriculture organisations but this is only the first step towards the full digital transformation of this industry and the future of agriculture - Farming 4.0.

Understanding the advantages and disadvantages of the various technologies available in the market and how these technologies can interact with one another will help agriculture organisations choose the right fit for them and therefore, achieving both the economy of scale and the necessary improvements in performance and efficiency.

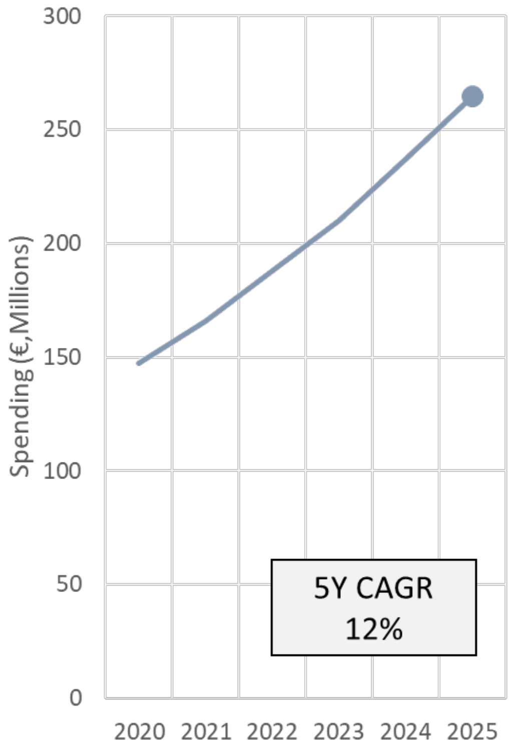


Figure 2.14 - Farming 4.0 five-year forecast (Source: IDC Worldwide Edge Spending Guide - Enterprise Forecast 2021 [1])

2.3 Market drivers

This sub-chapter highlights various trends that could positively influence the adoption of Edge-AI solutions in Europe, focusing on the main reasons and business goals that European organizations find as crucial when choosing to adopt edge related solutions.

When organisations start their journey towards the adoption of new emerging technology solutions, several drivers can be identified as crucial for making the first step. In this context, the pandemic and the disruption that organisations faced during the last months are indeed fundamental to consider in order to have a clear and comprehensive picture of what is moving organisations towards their innovation path.

Specifically looking at edge computing, the main reasons moving organisations towards this solution is to achieve higher performance. This is mainly linked to one of the main advantages that edge is bringing to its adopters, i.e., reduced latency, faster operational responsiveness and the possibility to establish new data-driven processes. Indeed, by locating key processing tasks closer to end users, edge computing is able to reduce the time needed for data to move across the network, thus delivering faster and more responsive services. Moreover, with data analysed at its sources, organisations can make decisions and take actions based on the most current data at any different time.

Another important driver behind edge computing adoption is to push for innovation. In fact, edge computing represents the foundation of several innovative ways of conducting old processes in a new and more efficient way, as well as allows 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.

As already mentioned, the pandemic represented a real challenge to businesses across all sectors mainly from an economic standpoint, for example due to the restrictive measures which significantly hit organisations in both manufacturing and retail industries, thus resulting in severe economic damage. From this perspective, edge computing played an important role in supporting companies, for example by allowing cost reduction (e.g., by helping organisations sending only pertinent information to the cloud, significantly minimised the need for data storage on the network).

If from one side it is possible to identify some general drivers to edge adoption linked to the application of the technology, at the same time it is possible to also identify some specific driver according to the industry considered.

This can be observed, for example, in the utility industry, where organisations aim at minimising unplanned maintenance downtime and reduce maintenance expenditure, by implementing predictive maintenance solutions (PdM) for critical rotating equipment. In this regard, connected sensors, coupled with predictive analytics algorithms, have emerged as strong assets to maximise reliability and performance.

On the other side, healthcare providers are automating their processes with IoT sensors, which generate vast amounts of data, and then adding AI tools to further help optimise insights for better clinical decision-making. Computing at the edge of the network is essential for speed, scale, reliability, security, performance, and real time insights. It supports advanced remote-patient monitoring by processing data from medical devices. In fact, the exponential growth of endpoint devices generating data is one of the big factors fuelling edge computing needs.

For agriculture and farming, the adoption of technologies such as edge, artificial intelligence, machine learning, IoT or automation is driven by European agriculture organisations' need to go beyond the traditional approach and start transforming their existing processes, unlocking a more digitised, collaborative and smarter way of working and doing business. Leveraging the critical role of data and identifying new ways to make decisions in real time based on specific insights and information, even in environments with discontinued connectivity and accessibility, will help organizations optimise their operations and increase their productivity and efficiency without impacting the society and environment. There are many benefits for organisations adopting these solutions, such as increasing the return of investments through utilising data analytics across data sets, including sensor data, geospatial data, and real-time insights, enabling access to a more consistent information stack through a platform-based approach, or increasing predictability by actively inspecting and monitoring agriculture assets.

2.4 Market barriers

This sub-chapter highlights various reasons and challenges that could negatively influence the adoption of Edge-AI solutions in Europe, hampering European organizations plans to adopt edge related solutions.

Along their adoption journey, organizations must face several barriers which are hampering their innovation process. Similar to the drivers described above, barriers show some common trends across verticals, as well as present some peculiar features when focusing on specific industries.

The lack of qualified workforce and skills to properly exploit edge and AI solutions is indeed the major barrier organisations face. According to the IDC Europe Emerging Technologies Survey (July 2021, N=653 [3]), almost one third of the organisations do not own or are not able to find the right workforce to implement and properly use emerging technologies, either we refer to general IT skills or to more job-specific skills, such as programming skills.

IDC research highlights that in the vast majority of cases OT personnel are dependent on external support to handle topics such as operations cybersecurity, application development in low code environments, advanced analytics and machine learning, industrial networking, data management including tagging and semantics. To overcome these obstacles, organisations are moving more and more towards integrated organisational models, where control systems and execution systems investment decisions are made through a shared services organisation, a centre of excellence, or a corporate function.

The other two major barriers that organisations face in their adoption journey are related to the lack of funding and difficulties adapting established processes to new technologies.

For the former, the pandemic worsened this phenomenon by bringing a real economic disruption regardless of the industry considered. The pandemic also reduced the disparity between organisations of all sizes, making the lack of resources one of the major issues for both SMEs and large enterprises (with 30% and 27% of organisations respectively facing this barrier).

On the other hand, adapting established processes to new technologies is also a significant challenge for organisations. Legacy systems and consolidated work processes are often difficult to let go, or simply to adapt to new technology.

Like the drivers described above, there are also some industry specific barriers to consider when analysing an organisation's emerging technology adoption journey. For example, taking back the industries considered before, organisations in the manufacturing industry often face issues from a technical perspective, due to the high complexity of achieving real-time integration that requires new technical standards to be embedded with technical specification for each of the new production assets.

When moving to the healthcare providers, other factors are keeping edge deployments on hold: from different investment priorities (e.g., medical devices and diagnostic equipment that deliver immediate impacts on patient care), to the need to first integrate other tools and devices into daily activities (e.g., AI-enabled tools and IoT devices), to the need to develop strong data governance policies and strategies for initiatives that use edge computing (e.g., to protect sensitive patient data and identify the right data needed for each use case), those are just some of the main challenges that healthcare providers faces when moving toward edge computing solutions.

For agriculture organisations, one of the main challenges is to create operational environments that can respond to change and uncertainty. Besides industry-specific challenges related to climate change, rapid urbanisation, population growth, the operation of equipment, or the supply chain continuity, there are several concerns related to digital transformation and the adoption of agriculture-specific technology that are slowing down the building of this operational environment.

COVID-19 has significantly disrupted agriculture organizations' digital transformation journey, as according to IDC's Worldwide Agriculture Survey [9], 52% of agriculture organizations experienced a decrease in IT spending in 2020.

Unclear return of investment, delayed deployment cycle, limited data storage or connectivity capabilities, cybersecurity concerns, lack of trusted technology providers to work with, resistance to change fostered by the very traditional leadership specific to agriculture industry or even limited know-how about the positive impact of technology on business are few of the barriers for technology adoption in the agriculture industry.

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.

3. Market context

This chapter provides a brief analysis of the significant edge market developments since the beginning of the forecast in 2020 until the end of the forecast in 2025 as well as providing an overview of the edge value chain development that sees various edge ecosystem players at the core of the edge landscape in Europe. The end of the chapter will provide more details about the AI-SPRINT tools baseline and technological added value, describing the addressed limitations and the added-value compared to the commercial solutions in the market.

3.1 Edge Ecosystem players

The European edge landscape is clearly developing, especially through the build-up of the edge value chain that sees different types of global tech vendors (service providers, infrastructure providers, telecom providers, system integrators, etc) at the core of edge evolution in Europe. 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. According to IDC, most players moving into the edge market are specialised in a limited set of edge related areas. Thus, 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.

For example, in the manufacturing and resource industries, even though the predictive maintenance solution is often adopted as a stand-alone solution, most vendors offer this solution as an integral part of their asset performance management (APM) offering, enabling risk and reliability-centred maintenance strategies for customers.

The predictive maintenance tech-suppliers arena is highly competitive, with many players and specialist solutions. Amidst this complex backdrop the following major categories of vendors go to market individually as well as on a partnership basis.

- **Specialty Software Vendors.** Strong specialisation in core asset processes. New products and features releases are focused on improving assets performance with a specific focus on oil and gas and utilities industries. Some examples include Aveva, AspenTech, Bentley Systems, C3.ai, Hexagon AB.

- **Analytics Software Vendors.** Advanced analytics software solutions. Partnerships with IT vendors/industrial automation players and end-users. Constant development of analytics software applications with focus on multiple industries. Examples of key players include, SAS, Seeq, Uptake, Moblize, Splunk.

- **Enterprise Software Vendors** Wide range of enterprise applications software solutions providers. Partnerships with IT vendors and end-users. Constant development of new features with focus on multiple industries. Large enterprise application portfolios. Examples of key players include SAP, Oracle, IFS, Infor.

- **Industrial Automation Vendors.** Deep expertise in Industrial processes and in asset performance and reliability services. Proprietary technologies, software and domain experts. Broad coverage of market geographies. Wide coverage of use cases in the energy industry. Examples of key players include Siemens, GE Digital, Honeywell, Emerson, Rockwell Automation.

- **IT Services and System Integrator Vendors.** Business process acumen. Systems implementation and integration. Strong partnership ecosystem. Applications & API development capabilities. Broad coverage of markets (geographies, industry verticals). Examples of key players include Accenture, IBM, TCS, Infosys, Capgemini.

Even before the pandemic, the healthcare industry was one of the most attractive areas where services providers and technology vendors started to shape their message to offer a more industry-specific offering. Starting from providing only a small portion of the solution to the full stack of technology capabilities for healthcare use cases, there are various tech providers at the horizon able to cover the broader universe of edge related technologies for healthcare:

- **Edge AI**: AI at the edge that can deliver immediate insights, optimising patient care and realising the promise of smart hospitals. Application framework and partner ecosystem that accelerates the development and deployment of smart sensors and sensor fusion anywhere in a hospital or health system. Examples of key players Nvidia, Intel, Qualcomm.

- **End-to-end remote health monitoring**: Medical grade monitoring devices that measure a wide range of biometrics and vital signs (e.g., heart rate, blood pressure, blood glucose levels); services include clinical support via coaching and intervention when necessary. Examples of key players are Philips and Honeywell.

- **Predictive analytics – machine learning**: using machine learning algorithms to predict future events across domains of healthcare operations, finance and clinical. Examples of key players IBM Watson Health, HealthCatalist.

Same situation for agriculture and farming, as tech vendors enter the digital agriculture space, they either offer single capabilities or are expanding new partnerships to create common industry specific solution to provide a more comprehensive portfolio of products and services.

- **Farm management**: This is the foundation space for precision agriculture, allowing farmers to harness efficiency and performance and to enable a more collaborative way of working between tech providers, farmers and end users. There are various tech vendors in this space, having a focus on specialised software (software connected to a specific service such as accounting, markets, cooperatives or agronomy services), on input and production software (software providing agronomic advice with emphasis on the correct application of seed, fertiliser, pesticides and other applications) or cross-functional applications (applications that are not specific to agriculture but are commonly used due to their cross functionality, e.g. supply chain, customer relationship management). Examples of vendors: FarmersEdge, Akira.AI, Climate FieldView, etc.
- **Outsourcing**: Tech vendors providing industry-specific IT services for all aspects of farm operations, from simple inspections to full outsourcing of operations as well as equipment provision on a contract basis. Examples of vendors: Capgemini, Accenture, Hexagon Agriculture etc.
- **Analytics, monitoring and automation**: Tech vendors that provide specialised analytics services, automation capabilities for farm equipment and specific innovative technologies to determine soil health, texture, water content, and/or plant-available nutrients. Examples of vendors: FarmWise, SAS, Advian etc.
- **Networks and infrastructure**: Tech vendors offering edge, AI or IoT related hardware, software and services, security technologies and expertise in all aspects of farm operations, cloud services, connectivity and infrastructure for network connectivity. Examples of vendors: Telit, Dakota Micro, Advantech etc.

These are only a few examples of players actively involved in providing technology solutions for specific industries and use cases described in this document. There are also various technology vendors addressing the specificity of other industries, such as financial (e.g., NEC, Nvidia, IBM), utilities (e.g., Barbara IoT, Micro.ai, FogHorn), public sector (e.g., Red Hat, HPE, Atos) and so on.

Despite many of them not being Europe-born, they have shaped their offering and capabilities in order to address European specific requirements, partnering with local players or even global large players with extended expertise and presence in Europe (such as Microsoft, Amazon, Google, IBM, Dell, HPE, etc). By leveraging partner ecosystem advantages, vendors are able to better understand the European emerging technology scenario and to address specific demands from their clients, in this way enhancing their customer loyalty and experience and gaining advantage in a very competitive environment.

3.2 Significant market developments

Starting with 2020, society has been highly impacted by COVID-19, imposing new norms such as "remote everything" that will probably shape the future even after the pandemic ends. Despite the heavy impact on expected IT spending and the innovation plans of many organizations, the new scenario highlighted the importance of having distributed capabilities to enable tasks and workloads in locations that are different from the usual core datacentres.

There are different edge players across the stack that continue to work, delivering new solution portfolios around the edge, announcing new products, partnerships, or mergers and acquisitions (M&As) that will result in the further expansion of possibilities in the edge market for all three technology categories, hardware, software and services.

In this scenario, IDC sees the market for AI processing on the edge to continue to gain traction and attract further investment for the years to come. Many established vendors, from leading processor firms to microcontroller suppliers, have begun to launch AI-efficient solutions into the market. While some organisations are competing in the high end of the market to handle the fastest, most demanding AI workloads, others are focused on providing basic support for limited AI functionality such as wake words, identifying or categorising limited sensor data sets.

Edge AI and use cases around it are still emerging as the market is still in early stages of maturity across the European region.

For the next few years, it will be crucial for organisations to fully understand how to apply the tremendous capabilities of AI and how they can extract value from the Edge AI deployments. Understanding that there is no perfect model for developing and deploying edge and AI, and assessing the different capabilities, related costs and challenges of deploying AI systems at the edge will be critical for successful deployments across all industries.

3.3 AI-SPRINT Tools Baseline and technological added value

AI-SPRINT wants to define an integrated approach to simplify application development and runtime management while supporting AI application QoS during the whole lifespan of the application. In the following an overview of key technology baseline for AI-SPRINT is presented by describing the limitations that they will address and the added-value they will bring compared to the commercial solutions in the market.

It should be noted that the aim of AI-SPRINT tools is not to compete with big players such as Google or AWS but to allow the end-users to use cloud systems without lock-in and to rely on core open source solutions (Python, Pytorch, TensorFlow, Keras, etc.) to foster application evolution and portability**.** This will allow to link the edge with the core cloud providing the possibility to trade-off performance, privacy, security and costs. It is planned that an overview of analysis of the alternative tools that are available in the market will be included in the next deliverable D6.7.

PyCOMPSs

A tool owned by BSC and a baseline to Design abstractions and programming runtime environment for edge/fog/cloud. The tool addressed the lack of performance models to drive tasks assignment and scheduling. It provides parallel execution of sequential code, transparently with respect to the execution platform thanks to the interoperability of the runtime with different backends, including public and private clouds. The power of the programming framework is leveraged by dislib, a library fully compliant with scikit which includes ML algorithms implemented in COMPSs able to run on distributed computing platforms. The code seamlessly runs, without changes, on traditional batch systems or on clouds using a FaaS model.

OSCAR

A tool owned by UPV and a technology baseline for offering function as a service systems across the computing continuum. It supports serverless computing for compute-intensive applications and can also be deployed in low-powered devices such as Raspberry PIs. OSCAR can interoperate with other instances of SCAR to support workflows along the computing continuum and to support workflows along on-premises and AWS (public Cloud). It can support both synchronous and asynchronous (long-running) invocations/executions.

SCAR

A tool owned by UPV. It supports the execution of containers out of Docker images from Docker Hub in AWS Lambda. SCAR is Interoperable with AWS Batch to support GPU-based computing as well as interoperable with OSCAR for serverless workflows.

Infrastructure Manager - IM

A tool owned by UPV. It provides support of OASIS TOSCA standard, support of multiple IaaS Cloud backends. It can be deployed on on-premises, public and scientific Clouds, and container orchestration platforms. It is open source and uses Ansible DevOps tool for infrastructure contextualisation.

SCONE

A tool owned by TUD and a baseline for executing applications in trusted execution environments (TEEs). SCONE allows applications to run in Intel SGX based systems. In addition to letting applications run in these enclaves, it also provides secret management and provisioning such that no human has access to keys unless absolutely necessary. By intercepting system calls, SCONE also supports file systems as well as network encryption in a transparent manner. The SCONE framework is cloud provider agnostic, hence the only requirement is that the cloud provider provides the appropriate hardware (Intel SGX capable CPUs). Within AI-SPRINT, SCONE will be extended to support additional CPU vendors other than Intel. For instance, in future it will support arm64 CPUs which are often used at the edge. Furthermore, measures for secure execution of training and inference in GPUs will be investigated such as leveraging secure boot as well as measured boot to provide a safety net also for systems that do not provide hardware support for TEEs.

SPACE4AI-D

A tool owned by POLIMI able to identify the minimum cost deployment solution for placing AI application components in computing continua while guaranteeing performance requirements (namely, requirements on the maximum admissible response times of single components or sequences of components). It also Supports resource selection (i.e., which VM flavour to run/which AI device to buy) minimising operational costs (i.e., energy costs for in-house systems or resources renting costs in case of public clouds).

Performance Models

These models are owned by POLIMI and support the AI-SPRINT runtime components in selecting an appropriate configuration to: (i) avoid applications performance violations, (ii) avoid under or overestimation of the continuum resources utilisation, and (iii) predict the execution time of Deep Learning components on a target configuration. Performance models are based on the a-MLLibrary machine learning library which generates the most accurate regression model for a specific task through feature selection, hyperparameter tuning, and model selection. The generated regression model is used to predict the execution time of inference components or pipelines or training jobs, with the goal of supporting the selection of the most appropriate system configuration for executing them fulfilling QoS requirements while minimising operational costs.

AI models architecture search

Owned by POLIMI, this component (also named POPNAS) receives as input a set of configuration parameters and an annotated dataset, e.g., images with labels. Its goal is to look for the best neural network architecture for the given classification/regression task. The algorithm searches for the best network configuration to achieve the higher accuracy in the lowest possible time by searching the Pareto front of the time-accuracy trade-off. Architectures on the Pareto front are then proposed as possible candidates to select among. This component allows non machine learning expert owning application specific data to generate automatically efficient models to be deployed on the edge.

Scheduling for accelerated devices

Owned by POLIMI, it determines the best scheduling and component allocation to minimise the execution costs of Deep Learning training jobs on accelerated devices (in the public or private cloud), while meeting deadline constraints. It requires as inputs the list of submitted jobs (as Docker containers) with their characteristics (expected execution times, priorities, and deadlines), and a description of the system with all the available resources. Based on this information, it determines which jobs to run in the current time slot and on which type and number of GPUs, so as to minimise energy costs (in private GPU-accelerated clusters) or execution costs (in the public cloud), while meeting the deadline constraints. Disaggregated hardware architectures and remote GPUs can be accessed relying on rCUDA.

Monitoring system

Owned by 7BULLS, the monitoring sub-system supports multiple deployment models (hierarchical and central) depending on the cluster size and complexity. It allows monitoring edge-based AI applications, the hosting container and specific application level metrics. Additionally, predefined metrics can be customised. It allows for complex monitoring data analytics at the whole computing continuum stack in order to emit alerts and trigger infrastructure reconfiguration. Finally, it also supports logs collection and management.

KRAKE

Owned by C&H, It is an orchestrator engine for containerised and virtualised workloads across distributed and heterogeneous cloud platforms. It creates a thin layer of aggregation on top of the different platforms (e.g., Kubernetes) and presents them through a single interface to the cloud user. The user's workloads are scheduled depending on both user requirements (hardware, latencies) and platform characteristics (energy efficiency, load). The scheduling algorithm can be optimised for example on latencies or energy. Krake can be leveraged for a wide range of application scenarios such as central management of distributed compute capacities as well as application management in edge cloud infrastructures.

rCUDA

Owned by UPV, rCUDA provides the possibility of using remote GPUs. That is, rCUDA is a middleware for remote GPU virtualisation. In this regard, a CUDA application can be executed in a node without GPU but using a GPU installed in another node. rCUDA forwards CUDA calls to the remote GPU and returns back the result of the CUDA functions to the application. This process is transparent to applications, which do not need to be modified in order to use rCUDA.

Federated Learning

Owned by POLIMI, federated learning provides a secure tool to jointly train machine learning (ML) models among the parties in the computing continuum. The tool leverages federated training algorithms to extract the information from local distributed data to improve ML models globally. The tool is designed to reduce as much as possible the exchange of sensible and private data among the learners, by exploiting advanced algorithms to avoid directly sharing the weights or the gradients. Novel techniques exploiting artificial data generation are under investigation in order to share data in compliance with the differential privacy requirements among parties and overcome some of the risks of current differential privacy approaches.

Privacy Preserving Continuous Training

Owned by POLIMI, privacy preserving continuous training provides AI applications with a secure mechanism to update the model after the deployment, due to availability of a new model, i.e., new weights or internal state, or due to the application redeployment, triggered, for instance, by the availability of a new partition or by the user. The Differential Privacy component allows users to update the model by preserving the privacy of the users using the AI-SPRINT application. This is done by applying tools to measure the differential privacy level of each layer of the ML model, thus quantifying the amount of information that could leak in the face of an attack, e.g., membership inference or model inversion.

4. European data market

This chapter aims at providing an overview of the European data market through measurement of value of data market as a whole, divided by member states and divided by industries. It also depicts the forecast of the European data market for different industries within the next 5-10 years including the three main domains that are the focus of the AI-SPRINT project through the use-cases that are being developed. While the previous chapters were focused on presenting an analysis of edge-market regarding technologies such as AI, this chapter considers the concept of data market since technologies such as Edge and AI can significantly impact the size and value of the data market through accelerating and facilitating the data collection process. Thus, considering the presented forecast of edge market growth in Europe, it could be considered a major driver behind the growth of the EU data market.

In this chapter, an analysis of the European data market is reported to provide insights about the potential impacts and interdependencies that exist between the growth rate of uptake of emerging technologies such as Edge and AI with the growth rate of the data market.

This chapter is structured as the follows. First the definition of data market and the measurement method of the market are described. Then the status-quo of European data market by Member States and by Industry are presented. Finally, the forecast of data market for the next 5 and 10 years are presented taking into account three scenarios of challenge, baseline and growth. The provided data in this chapter are as of November 2021.

4.1 Definition and Measurement

The Data Market is the marketplace where digital data is exchanged as “products” or “services” as a result of the elaboration of raw data.

The Data Market captures the aggregate value of the demand of digital data without measuring the direct, indirect and induced impacts of data in the economy as a whole. Further, the Data Market represents a wider concept than the market of Big Data & Analytics (BDA) as it includes not only the value generated by pure data players developing BDA technologies but also the value created by data-related research, businesses, information, and IT services. The digital data exchanged as “products” or “services” in the Data Market refer exclusively to data that is collected, processed, stored, and transmitted over digital information infrastructures and/or elaborated with digital technologies. This definition includes multimedia objects which are collected, stored, processed, elaborated, and delivered for exploitation through digital technologies (for example, image databases). The value of the Data Market is not exactly equal to the aggregated revenues of the European data companies because it includes imports (data products and services bought on the global digital market from suppliers not based in Europe) and excludes the exports of the European data companies.

Table 4.1 gives the overview of the latest estimates for the value and growth of the data market. The market grew by 3.8%in 2020 to a value of € 60,635,000 and is expected to reach € 63.6million by 2021. 2020 and 2021 were difficult years across Europe but the data market remained healthy, benefitting from an increased focus on the digital economy for both work and services. Those companies and countries that were able to invest or utilise existing investments and expertise benefited from them.

Market	Name	Description	2019	2020	2020	Growth 2020/2019
EU27	Value of the Data Market	Estimate of the overall value of the Data Market	58,427	60,635	63,627	3.8%

Table 4.1 - Value and growth of the data market (Euro Millions) 2019-2021 and growth 2020 (%)

4.2 Data Market by Member States

The data market by member state remains correlated with the economic strength of each of the member states. Those organisations which are active in the data market, generating data revenues, are also those organisations which are actively monetising their internal data.

Across the countries, the UK is the biggest data market as a result of its focus in attracting service industries to the country. These include banking and finance, and professional services. In addition, a strong retail presence boosts the size of the market as retail is a significant use of data tools and services.

Among the member states, the data market is strongest in Germany, which is similar in size to the UK. Germany accounts for 28% of the EU27 data market, reflecting the strong manufacturing and finance base to its economy. However, the data market in Germany grew slightly less than average in 2020. Overall, most of the countries grew well in 2020 as each build on existing investment in the data economy. Table 4.1 gives the details by member state, and Figure 4.1 ranks the country markets, showing growth in 2020 for each country.

Member State	2019	2020	2021	CAGR 2019-2020
Austria	1,539	1,547	1,547	0.5%
Belgium	1,910	1,984	2,043	3.9%
Bulgaria	289	312	328	7.8%
Croatia	240	254	266	6.0%
Cyprus	178	189	197	6.0%
Czechia	732	739	742	0.9%
Denmark	1,591	1,666	1,780	4.7%
Estonia	269	291	310	7.9%
Finland	1,243	1,311	1,359	5.5%
France	9,494	9,986	10,769	5.2%
Germany	16,367	16,966	17,931	3.7%
Greece	517	535	545	3.5%
Hungary	527	549	573	4.1%
Ireland	1,388	1,397	1,431	0.7%
Italy	5,613	5,764	6,028	2.7%
Latvia	175	185	194	6.0%
Lithuania	270	286	299	6.0%
Luxembourg	171	181	189	6.0%
Malta	71	74	78	4.1%
Netherlands	4,378	4,514	4,665	3.1%
Poland	2,086	2,179	2,308	4.5%
Portugal	1,062	1,069	1,080	0.7%
Rest of EEA	2,228	2,249	2,332	0.9%
Romania	667	719	757	7.8%
Slovakia	479	508	531	6.0%
Slovenia	168	178	186	6.0%
Spain	3,996	4,053	4,209	1.4%
Sweden	3,007	3,199	3,280	6.4%
Switzerland	3,592	3,648	3,810	1.6%
United Kingdom	17,123	17,845	19,134	4.2%
EU27	58,427	60,635	63,627	3.8%
EEA	5,821	5,897	6,142	1.3%
Total All Countries	81,371	84,377	88,903	3.7%

Table 4.2 - European Data Market 2019-2021 (Euro M), Growth 2019-2020 (%)

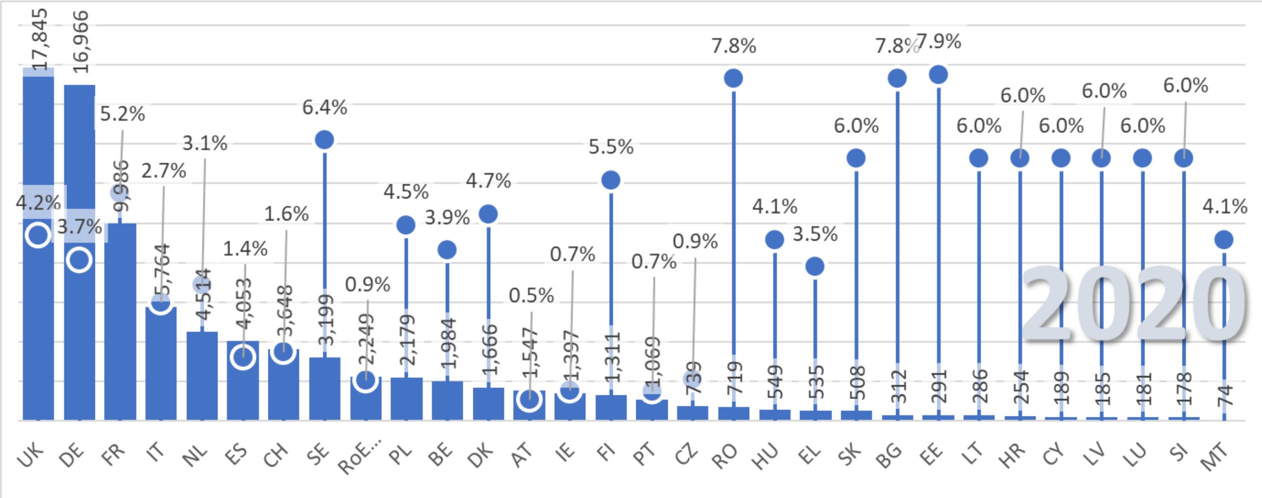


Figure 4.1 - European Data Market 2020 (EuroM), Growth 2019-2020 (%)

4.3 Data Market by Industry

Table 4.3 and Figure 4.2 show the data market industries by size for 2019 to 2021, as well as the share for finance and manufacturing, which accounts for over 41% of the data market. These are traditional data markets, and adding professional services, retail and wholesale, and information and communication accounts for nearly three quarters of all spending on data tools and services.

	2019	2020	2021	CAGR 2019-2020
Agriculture	214	242	244	13.3%
Construction	253	256	318	1.2%
Education	1,522	1,614	1,627	6.0%
Finance	12,176	12,782	13,427	5.0%
Health	1,794	1,943	2,031	8.3%
Information & Communication	6,131	6,446	6,771	5.1%
Mining, Manufacturing	12,252	12,240	13,066	-0.1%
Professional services	7,819	7,326	7,453	-6.3%
Public Administration	3,158	4,307	5,330	36.4%
Retail and Wholesale	6,202	6,507	6,580	4.9%
Transport	2,697	2,632	2,649	-2.4%
Utilities	2,415	2,610	2,690	8.1%
Home	1,794	1,730	1,440	-3.6%
Total EU27	58,427	60,635	63,627	3.8%

Table 4.3 - Data Market by Industry - 2019-2021 (Euro M), Growth 2019-2020 (%)

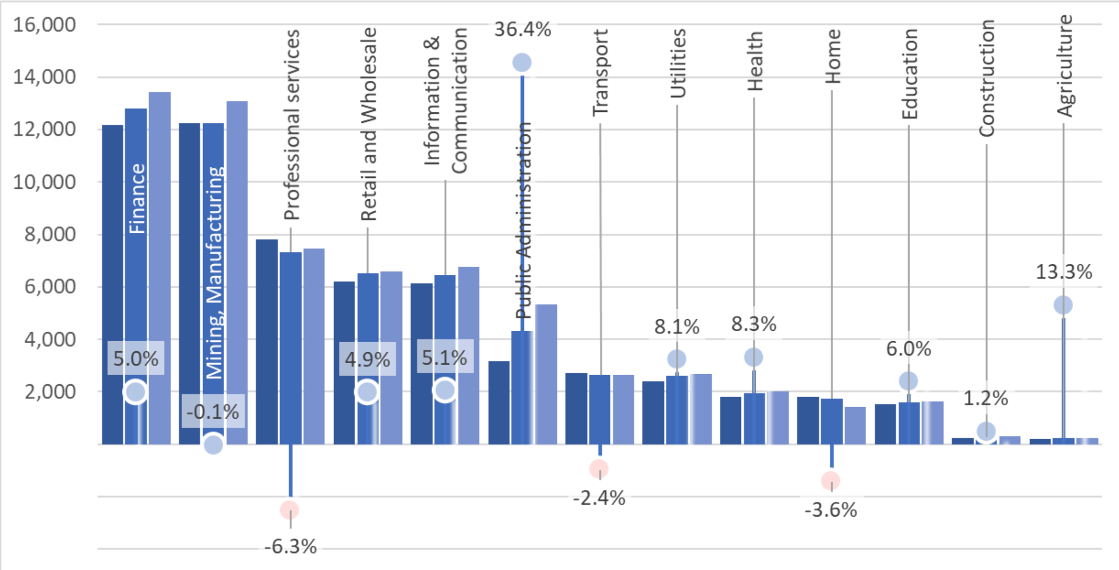


Figure 4.2 - Data Market by Industry - 2019-2021 (Euro M), Growth 2019-2020 (%)

4.4 Forecasting the Data market

The data market for the EU27 will grow to € 105.6 million by 2030 (baseline), a compound growth of 3.2% over the period 2025 to 2030. Table 4.4 shows the size and growth for the market for the three scenarios for 2030.

	2025	2030 Challenge Scenario	2030 Baseline Scenario	2030 High Growth Scenario	CAGR 2020-2025	CAGR 2025-2030 Challenge	CAGR 2025-2030 Baseline	CAGR 2025-2030 High Growth
EU27	90,121	94,218	105,619	125,238	8.2%	0.9%	3.2%	6.8%
EEA	8,453	8,822	10,327	12,316	7.5%	0.9%	4.1%	7.8%
Total All Countries	125,221	130,640	145,335	171,087	8.2%	0.9%	3.0%	6.4%

Table 4.4 - The data market forecast 2025, 2030 three scenarios (Eur 000's), and compound growth (%)

4.4.1. Data market by member states

Among the member states, Germany shows the largest market, growing to 25.4% of the EU27 total by 2030 (Baseline). However, the country grows below average with a compound growth of just 1.9 % from 2025 to 2030, compared with 3.2% for the EU27 as a whole. Germany is easily the largest member state, followed by France with nearly 10 percentage points less, representing just 16.3% of the EU27 total. Germany's strength in the larger industries of manufacturing and finance ensure it will maintain its lead position among the member states.

Outside the member states, in continental Europe as a whole, the UK leads Germany in the size of its data market, with greater investment in leading data market industries of finance, public administration and information and communication, and professional services. Figure 4.3 shows the forecast detail for all countries and member states and the three scenarios.

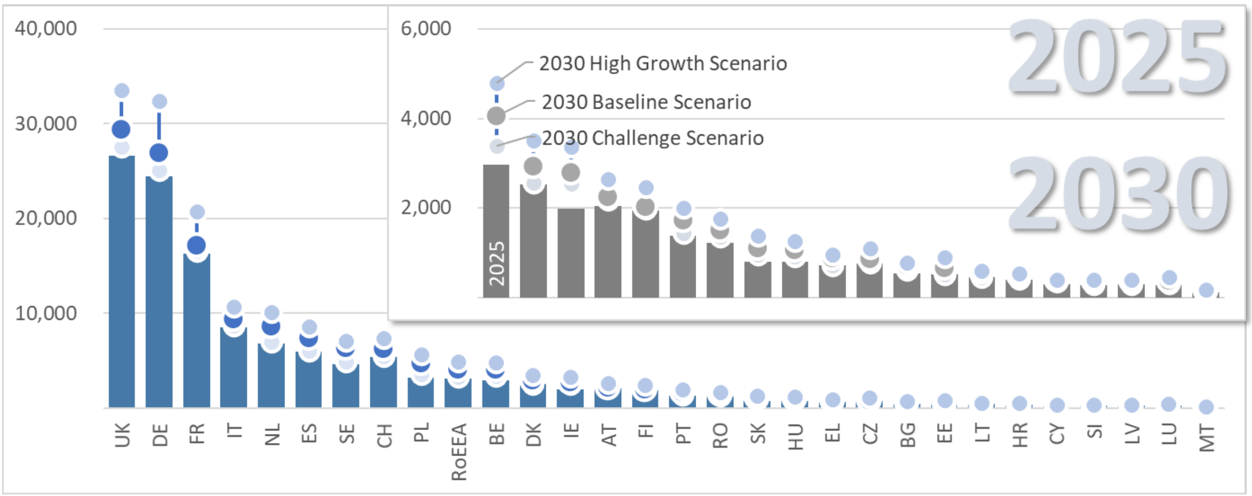


Figure 4.3 - European Data Market forecast by member state 2025, 2030 three scenarios (Eur M), Compound growth (%)

While the UK, Germany, France, and Italy all grow below average for either the EU27 total of all countries, the size of these countries means their lower growth still adds more to the data market over the forecast period, in spite of this lower growth.

4.4.2. Data market forecast by Industry

The largest industries within the data market by 2030 (baseline) are manufacturing and finance, together accounting for 41% of spending in the data market. Public administration makes a notable contribution too, ahead of information and communication, and professional services. These five industries make up 75% of spending in the data market. Those countries with a strong presence in these industries will benefit substantially from growth in the data market. Table 4.5 and Figure 4.4 summarise the detail for each of the industries in the EU27.

	2025	2030 Challenge Scenario	2030 Baseline Scenario	2030 High Growth Scenario	CAGR 2020-2025	CAGR 2025-2030 Challenge	CAGR 2025-2030 Baseline	CAGR 2025-2030 High Growth
Agriculture	271	307	337	393	2.3%	2.6%	4.4%	7.7%
Construction	687	704	744	859	21.8%	0.5%	1.6%	4.5%
Education	1,892	2,027	2,330	2,738	3.2%	1.4%	4.2%	7.7%
Finance	18,414	19,855	21,784	25,866	7.6%	1.5%	3.4%	7.0%
Health	2,729	2,962	3,244	3,868	7.0%	1.7%	3.5%	7.2%
Home	1,013	1,046	1,195	1,426	-10.2%	0.7%	3.4%	7.1%
Information & Communication	9,288	9,340	10,987	13,611	7.6%	0.1%	3.4%	7.9%
Mining, Manufacturing	18,917	18,972	22,090	25,306	9.1%	0.1%	3.1%	6.0%
Professional services	8,992	10,008	10,970	13,681	4.2%	2.2%	4.1%	8.8%
Public Administration	13,181	13,502	14,135	16,328	25.1%	0.5%	1.4%	4.4%
Retail and Wholesale	7,902	8,467	9,604	11,553	4.0%	1.4%	4.0%	7.9%
Transport	2,915	3,047	3,630	4,253	2.1%	0.9%	4.5%	7.9%
Utilities	3,919	3,978	4,571	5,357	8.5%	0.3%	3.1%	6.5%

Table 4.5 - Data market forecast by industry 2025, 2030 three scenarios (Euro M), CAGR (%)

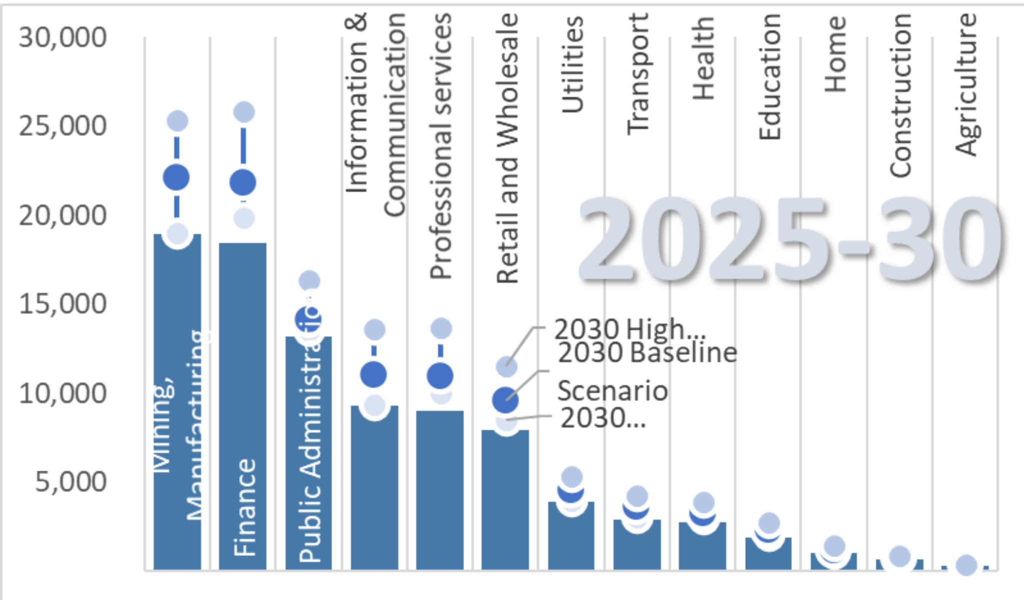


Figure 4.4 European data market forecast by industry 2025, 2030 three scenarios (Euro M)

The industry contribution to overall growth from 2020 to 2030 (Baseline) shows a more even balance across industries. Manufacturing and Public Administration contribute the most to the growth seen between 2020 and 2030 (as seen in Figure 4.5), Public administration is only the third largest but its above average growth means it adds more to the market overall. The order of the industries though reflects closely the size of each industry, but again this shows where the focus lies in looking for those industries that add the most to the data market over the ten years from 2020 to 2030.

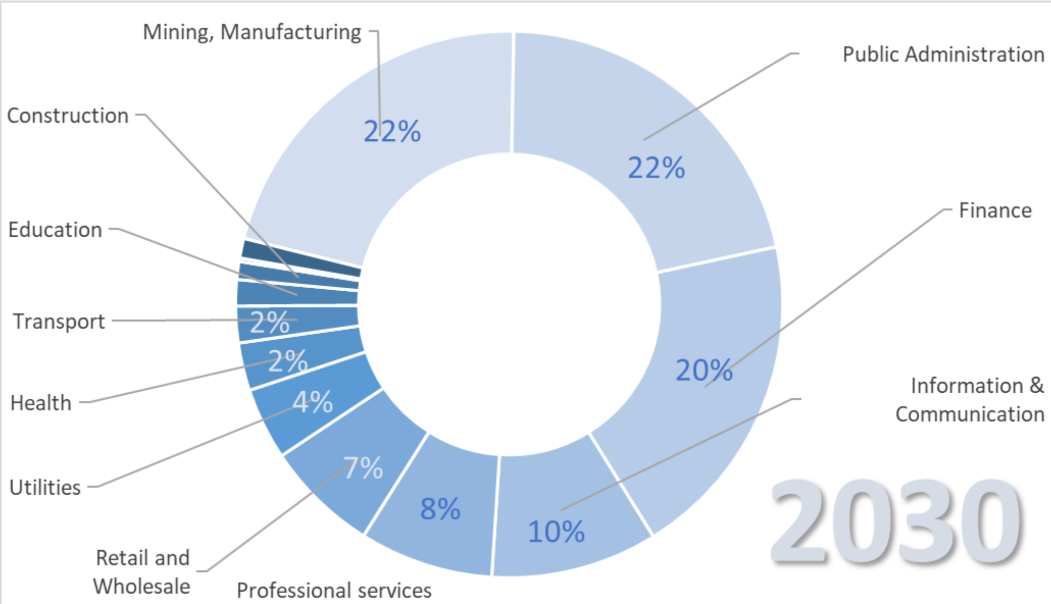


Figure 4.5 - Industry contribution to overall growth 2020-2030 (%)

5. Conclusions

This deliverable provides a detailed assessment of the market status-quo and market forecast for edge computing with a specific focus on AI and other enabling technologies. It also gives a deep dive into the market forecast of the three main use-cases of the AI-SPRINT project. In the following a summary of the major conclusion of this report are described.

In the second half of 2021, Europe shows an interesting level of adoption of Edge technologies, but maturity is still low, with only 26% of European organisations implementing edge computing solutions in their daily business, with this number expected to double over the next two years. At the same time, most of these organisations are implementing edge computing solutions in a pilot or educational phase (47% and 35% respectively), with only a small share of them adopting them in a more structured way.

Edge supports a wide array of other emerging technology markets, which are driving the overall edge market and are generating value outside of core data centres. These domains are Internet of Things (IoT), augmented reality (AR)/virtual reality (VR), artificial intelligence (AI), robotics and drones.

AI is the second largest domain, following only IoT, and its spending within the European edge market is driven by the need to process the data in real time, in order to transform the most valuable data into actionable insights. The AI component of the edge is expected to become increasingly important over the next few years, driving 10% of the market and doubling its market share by 2025.

While AI model training is mainly performed in core locations, the case for edge AI inferencing is becoming more prominent. With the advancements in the silicon industry and the ability to run increasingly efficient AI models on small footprint devices, edge is becoming the preferred environment where AI models will be applied, with benefits in terms of time-to-value, continuity and cost effectiveness of the use cases.

European enterprise edge spending is expected to reach €24 billion by 2022 and to grow at €39 billion in 2025, driven by the role of edge in enabling low latency use cases, deployments in locations that are either remote or without IT support staff, and support from many new vendor propositions and a supply chain that is being built up.

Concluding, key aspects should be considered for edge development in Europe in the next couples of years:

- Focus on business value outcomes. When dealing with edge, technology is not the only aspect driving the conversation. Edge is increasingly more about the use cases — different features that may need a different approach — and its benefits to each one. Different use cases may require different technologies, architectures, deployments, and partnerships to deliver the solution. Edge is considered as an incubator for emerging technologies such as IoT, AI, robotics, and AR/VR, which enable specific use cases.
- AI as differentiator in selected fields. Even though presenting tremendous capabilities, Edge AI and the use cases around it are still emerging. There is a need for an education and awareness process, driven by tech providers, in order for end- users to see the opportunities around it and to figure out how they can apply, enable and derive value from AI.
- Edge in a cloud-to-core-to-edge continuum. Edge will not absorb or exclude clouds in the future — rather, it will complement it. Cloud represents a strong opportunity for edge as cloud players are expanding their presence to the edge with new infrastructure capabilities and partnerships, building up the service providers value chain for delivering the hybrid edge for the "millisecond war," leveraging new types of infrastructures.
- More ecosystems and alliances tailored to the use cases. Partnerships and alliances are fundamental to deliver end-to-end edge solutions across all layers of the stack. Starting with 2020, different edge-related partnerships emerged; others will pop up in the future as the value chain continues to build up. Various tech vendors will focus on the entire use case solution to bring value to customers and

to avoid becoming a commodity provider. Hardware and software providers will seek partnerships and alliances with system integrators or telecom providers to optimise their edge solutions' time to market and consistency. As the market matures, it will be key to target specific customer needs and use cases leveraging ad hoc partnerships.

- Adapt to the broad global technology proposition to the local European scenario. Europe has a very fragmented scenario, with a mix of connectivity, languages, integrators, skills, and regulations. Adapting the technology proposition to specific go-to-market motions for European countries' peculiarities will be a key differentiating factor for all providers.

Finally, the market forecast of the European data market shows a steady growth even though with a different rate among different sectors. The value of the European Data Market will reach €63.6 billion for EU27, with a growth rate of 4.9% in 2021. The larger industries, accounting for the greatest number of companies, represent the largest share of the Data Market. In terms of adoption by industry, the highest rates of Data Technology tend to be in Manufacturing, Finance, and Public Administration. Thanks to their size, these industries are the biggest consumer of data technologies, partly because of the significant number of companies and their early investment in data tools and services. The forecast for the Data Market shows which industries make the biggest contribution to the overall market growth, and the key industries of Manufacturing, Public Administration, Finance, Information Technology, and Professional Services account for close to 82% of the total market growth from 2020 to 2030 (Baseline), with more than 60% coming from the three main industries of Manufacturing, Public Administration, and Finance.

The next deliverable of task T6.3 will provide an updated status of the current report, including also other relevant topics of interest for AI-SPRINT (i.e., federated learning, existing alternative tools based on AI-SPRINT technological baseline, etc.) which will be discussed and defined in the next period within the consortium to identify the main analysis criteria.

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