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Glossary of terms

Item	Description
CEI	Cloud-Edge-IoT
5G	Fifth-generation technology standard for broadband cellular networks
AGV	Autonomous Guided Vehicles
AI	Artificial Intelligence
AlaaS	AI as a Service
App	Application
ARM	Advanced RISC Machine
CEI	Cloud-Edge-IoT
CO2	Carbon dioxide
CoAP	Constrained Application Protocol
CPU	Central Processing Unit
DLT	Distributed Ledger Technologies
EC	European Commission
EU	European Union
EU Cloud Edge IoT	European Cloud, Edge and IoT Continuum
GDP	Gross Domestic Product
GPU	Graphics Processing Unit
HE	Horizon Europe
HPC	High Performance Computing
HTTP	Hypertext Transfer Protocol
HVAC	Heating, ventilation, and air conditioning
IaaS	Infrastructure as a Service
ICT	Information and Communications Technology
IoT	Internet of Things
IT	Information Technology
KPI	Key Performance Indicator
LPI	Logistics Performance Index
LPP	Low power processor
LSPs	Large Scale Pilots
MEC	Multi-access Edge Computing
MetaOS	Meta-Operating Systems for the Next Generation IoT and Edge Computing Cluster
ML	Machine Learning
MQTT	MQ Telemetry Transport
NGIoT	Next Generation Internet of Things
OEM	Original equipment manufacturer
OS	Operating System
OT	Operational Technology
Paas	Platform as a Service
QoS	Quality of Service
R&D	Research and Development
R&DI	Research and Development and Innovation
RIA	Research and Innovation Action
RISC	Reduced instruction set computer
SaaS	Software as a Service

SG	Stakeholder Group
SME	Small and medium-sized enterprises
Telco	Telephone Company
TF	Task Force
TSN	Time-sensitive networking
VCA	Value Chain Adopter
VP	Value Proposition
WP	Work Package
YoY	Year-on-year

Keywords

Cloud-to-Edge-IoT; Computing; Demand-Supply Dialogue; Communication; Engagement

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Executive Summary

This report provides an extensive analysis of the European Cloud-Edge-IoT (CEI) continuum, focusing on market readiness and the strategic adoption of CEI technologies across key sectors. Part of the UNLOCK-CEI project, this document encompasses strategies designed to establish an accurate route to market and assess the commercial impact of the technologies being developed. To do so, it offers valuable insights derived from the CEI-LING assessment application (formerly known as the CEI-LING tool), enabling organisations to evaluate their readiness to integrate CEI solutions. Key findings indicate that most organisations currently occupy preliminary readiness levels, highlighting a widespread need for technology infrastructure, organisational, financial awareness, risk and compliance and strategic frameworks to support CEI adoption.

Market routes for CEI technologies reveal both conventional and innovative approaches. While traditional routes such as direct sales and reseller agreements remain relevant, emerging market routes—such as partnerships with system integrators, digital marketplaces, and public sector collaborations—are proving essential for navigating the CEI ecosystem. These dynamic routes support tailored approaches for sectors including agriculture, healthcare, manufacturing, and smart cities, all of which have demonstrated substantial potential for early CEI adoption and impact.

In advancing CEI adoption, the CEI-LING application and the MetaOS cluster play pivotal roles. The MetaOS cluster, comprising projects like aerOs, NEMO, and ICOS, showcases real-world applications that demonstrate the transformative potential of CEI technologies. These projects span diverse use cases—from predictive maintenance in energy to precision agriculture—driving innovations that can increase operational efficiencies, advancements in data processing and environmental sustainability across European industries.

Despite these opportunities, several challenges persist, such as the need for standardisation, skills development, and infrastructure upgrades to enable comprehensive CEI adoption. Addressing these barriers through collaborative ecosystems, strategic partnerships, and alignment with regulatory standards will be essential to realising the full potential of the CEI continuum and advancing Europe's digital transformation agenda.

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1. Introduction

1.1 Context

The ambition of UNLOCK-CEI is to accelerate the deployment of the Cloud-to-Edge-IoT (CEI) computing continuum by focusing on the demand-side drivers of adoption and identifying the challenges associated with the full exploitation of these technologies across the EU economy. This report is part of the broader work completed under Work Package 4: Tech Developer Engagement. It encompasses strategies designed to establish an accurate route to market and assess the commercial impact of the technologies being developed.

In particular, this deliverable (D4.4) reflects on the progress made by technology developers regarding market readiness and the challenges in defining their exploitation routes. It also describes the routes to market that will lead to the commercial potential of the technologies being developed. These route-to-market approaches were validated with the Value Chain Adopters Groups and through the development of the CEI-LING application (formerly known as the CEI-LING tool). Embodied in a simple-to-use self-assessment application, CEI-LING is designed to assist companies in assessing their readiness for advanced cloud-to-edge IoT solutions. It provides a common structure for conversations around how and when CEI solutions could be adopted by end-users. This is a first step in understanding the barriers to integrating CEI in a given environment.

1.2 Target audience

While the primary audience for this document is developers specialising in edge and MetaOS technologies, its usefulness will hopefully extend beyond this direct target group to a broader range of stakeholders to earlier stage developers and researchers that might need to consider how their CEI solutions will reach their intended markets. Consequently, it may be of interest for the following audiences:

- Edge solution developers (research)
 - Insights into cutting-edge research and potential collaborations.
- Edge solution developers (tech providers)
 - Information on market needs and technology gaps needed to be addressed.
- Edge solution adopters
 - Gain insights into technology developments to gain competitive advantage and add value to their organisations.
- Policy makers
 - Understanding of project statuses to inform future initiatives and legislation.

1.3 Structure

Section 2 of this report will explore the purpose and objectives of the CEI-LING application, providing a conceptual overview that highlights its framework, principal categories, and the process for data collection.

Section 3 analyses the principal outcomes from the CEI-LING application and its insights. This section will delve into response profiles, sectoral overviews, organisational types, and other relevant aspects.

Section 4 assesses the impact on routes, offering an overview of the MetaOS use cases, the market opportunities that exist, and highlighting the barriers and challenges that the use cases may encounter.

Section 5 offers the principal recommendations on the market routes for the MetaOS use cases to guide future work.

1.4 Related deliverables and publications

This document is complemented by further deliverables which address market potential, purpose of CEI technologies and value chain members respectively:

- Deliverable 1.2 Cloud Edge-IoT Demand Landscape

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- Deliverable 3.1 CEI ecosystems overview with the value chain adopter groups
- Deliverable 4.1 Technology scoping paper
- Deliverable 4.2 Commercial Feasibility Tool CEI-LING
- Deliverable 4.3 Pilot Factory Outcomes

2. The CEI-LING framework

2.1 The purpose

The rapid advancement of the Internet of Things (IoT) and the growing dependence on data-intensive applications have led to a shift from centralised cloud computing to edge computing. This change seeks to reduce latency, optimize bandwidth usage, improve overall system performance, and enhance security by bringing computation nearer to data sources. However, the adoption of edge computing technologies has complex considerations, requiring a comprehensive evaluation to assess technology readiness. To address these challenges, the CEI-LING framework sought to establish common parameters to assist developers and companies in evaluating their readiness for advanced cloud-to-edge IoT solutions while helping to identify and mitigate potential points of failure.

The framework has been incorporated into a simple application that can be accessed through a web browser. The assessment takes around 10-15 mins to complete. The application then returns a high-level diagnostic with a benchmark against the sector average, and a series of concrete recommendations to improve CEI readiness.

2.2 Conceptual overview

2.2.1 Principal categories

CEI-LING offers a feasibility framework to assess CEI technologies and services and understand and mitigate potential points of failure. It has been designed with versatility and adaptability at its core, recognising the diversity of CEI solutions and the environments in which they will be deployed. In the context of the MetaOS portfolio, the CEI-LING application aims to enable early identification of problems and requirements to understand the financial and technical feasibility of a given CEI technology or service and its successful integration through a 5-dimension CEI-readiness framework covering 21 parameters:

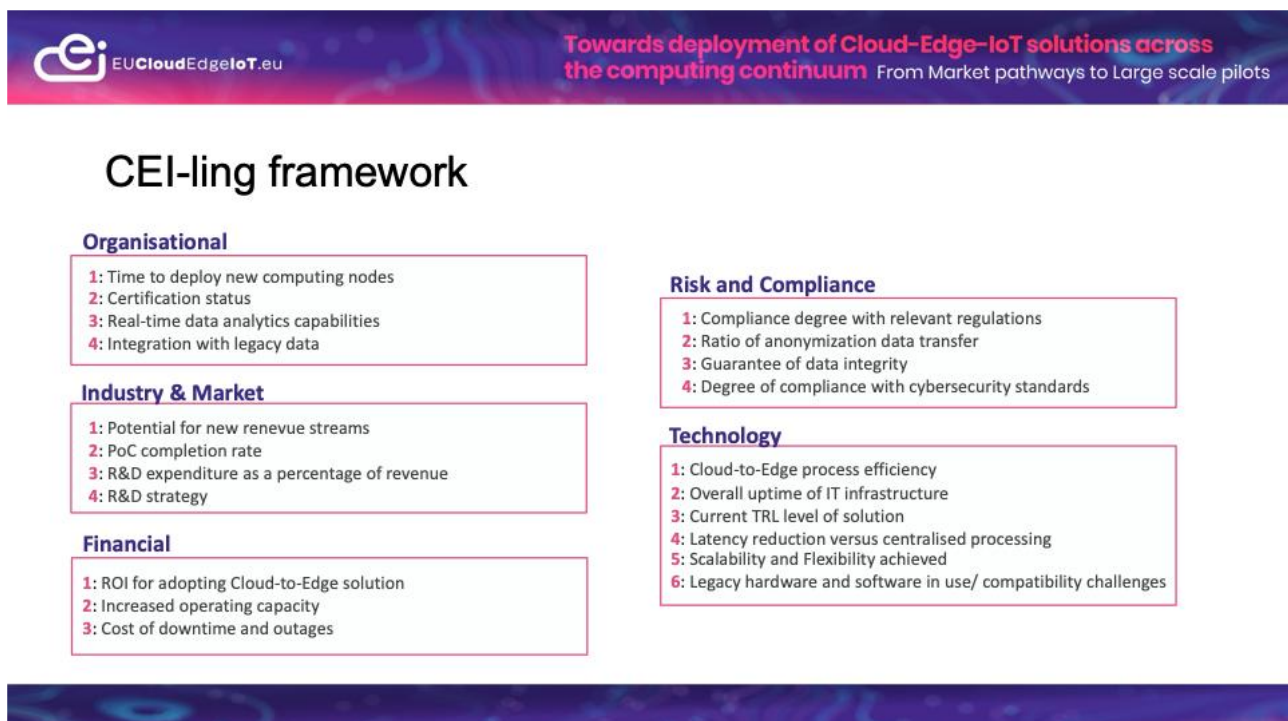


Figure 1. CEI-LING CEI readiness framework

2.2.2 Organisational

The organisational dimension plays a crucial role in how a company adapts to technological advancements, particularly in the context of Cloud-Edge-IoT (CEI) technologies. By aligning technological adoption with the

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prevailing organisational status, companies can facilitate smoother transitions and more effective integration of new systems. The organisational dimension evaluates:

- Time to deploy new computing nodes
- Certification status
- Real-time data analytics capabilities
- Integration with legacy data

2.2.3 Industry & Market

The industry and market dynamics is an important dimension to consider for adopting CEI technologies. By leveraging potential new revenue streams and key performance indicators, organisations can drive innovation and enhance competitiveness. The industry & market dimension evaluates:

- Potential for new revenue streams
- PoC completion rate
- R&D expenditure as a percentage of revenue
- R&D strategy

2.2.4 Financial

The financial dimension measures how to make informed decisions about CEI technology adoption and optimisation. Metrics, such as return on investment (ROI), operating capacity, and the cost of downtime, provide insights into the economic viability of edge technologies. High uptime reflects system availability, crucial for productivity and profitability, while ROI informs suppliers about market demand and pricing strategies. The financial dimension evaluates:

- ROI for adopting Cloud-to-Edge solution
- Increased operating capacity
- Cost of downtime and outages

2.2.5 Risk and Compliance

Compliance with legal and regulatory requirements is essential when adopting CEI technologies, as these often involve the collection, storage, and processing of personal data. International laws, such as the GDPR in the EU, are designed to protect this data. Businesses must also adhere to anti-discrimination and intellectual property laws to avoid legal complications. Given that CEI technologies frequently operate across borders, ensuring ethical deployment and respecting others' IP rights is crucial. The risk and compliance dimension evaluates:

- Compliance degree with relevant regulations
- Ratio of anonymization of data transfer
- Guarantee of data integrity
- Degree of compliance with cybersecurity standards

2.2.6 Technology

The existing IT infrastructure is essential for the effective implementation of edge technologies by both suppliers and end customers. Its condition directly impacts the ability to create, deploy, and support modern technologies, influencing the pace of implementation, costs, innovation, and customer service. The capacity of end users to integrate and fully utilise edge technologies without significant investments depends on the compatibility, modernity, and scalability of their IT infrastructure. An outdated or incompatible infrastructure can hinder adoption and require costly upgrades. Conversely, a robust and flexible IT infrastructure facilitates a seamless transition, enhances operational efficiency, and supports business continuity. The technology dimension evaluates:

- Cloud-to-Edge process efficiency
- Overall uptime of IT infrastructure

- Current TRL level of solution
- Latency reduction versus centralised processing
- Scalability and Flexibility achieved
- Legacy hardware and software in use / compatibility challenges

2.3 Data collection

The CEI-LING application is accessible through the [EUCloudEdgeIoT.eu](https://eucloudedgeiot.eu) website, specifically within the market and sectors section. Users begin by providing basic information, including their job function, company name, and sector. They then progress through five key dimensions, assessing their company's current level of CEI readiness. Each dimension features five levels of assessment—approaching (1), identifying (2), comprehending (3), deepening (4), and exploiting (5)—allowing respondents to evaluate their company and projects effectively. Upon completing the CEI-LING application assessment, users receive a tailored report, stating the results and recommendations for each dimension, aimed at enhancing their CEI readiness and facilitating potential technology adoption. The fitness-for-purpose of the application was first tested through the partners involved in the MetaOS use cases whose CEI-LING assessment served to identify how their current organisations are scoring in terms of CEI readiness, but not the MetaOS use cases. The results of this testing are summarised in the paragraphs that follow:

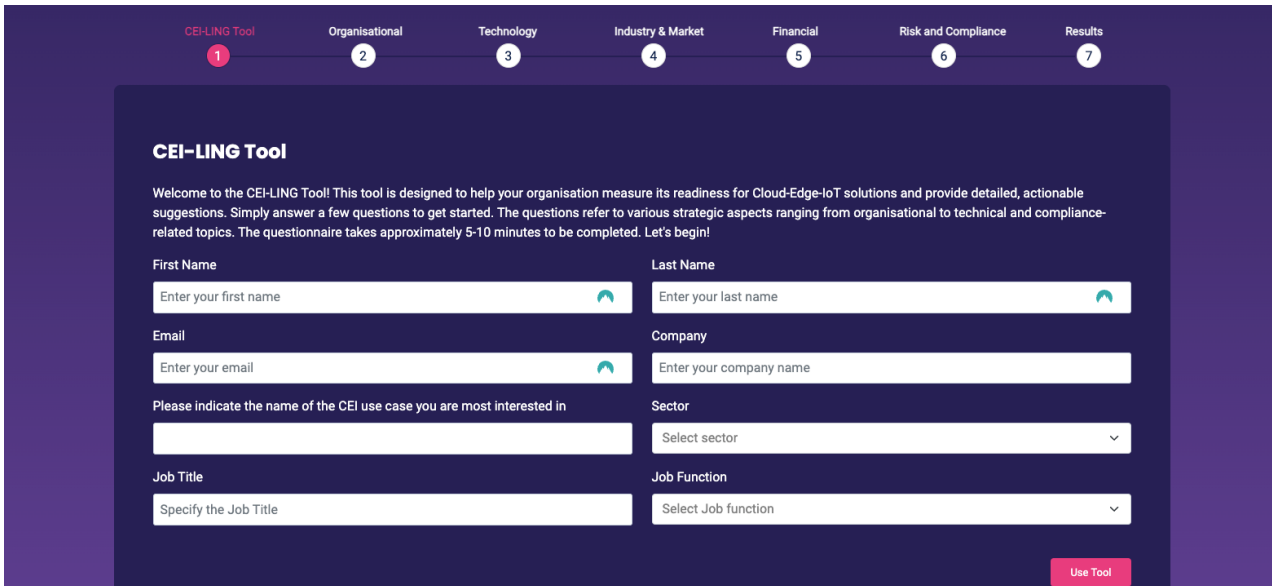


Figure 2. CEI-LING CEI assessment overview

3. Principal outcomes

3.1 Response profiles

Since the introduction of the CEI-LING application and its publication on the UNLOCK website, a total of 50 respondents, including end-users from various industries, have engaged with the assessment to evaluate their readiness for Cloud-Edge-IoT (CEI) technologies. Before delving into the outcomes of the tool, it is worth noting that while the CEI-LING framework is comprehensive, it is not exhaustive; the analysis derived from it is strictly based on the responses received so far. The value of the CEI-LING framework is two-fold:

- It facilitates a shared understanding between suppliers and users of CEI technologies regarding the adoption process, highlighting any actions needed to support successful outcomes.
- It references current best practice in the field of CEI deployment to identify what actions are likely to be most successful in each environment.

As an overview, the CEI-Market Readiness index captures the distribution of responses to the CEI-LING application. The majority of participants and their respective organisations are positioned in the “Identifying” and “Comprehending” readiness levels (74%). This finding suggests that most organisations are in the preliminary stages of CEI technology integration with a focus on awareness and early adaptation efforts. Although organisations show a willingness to explore CEI solutions, the adoption is still in its foundational stages, which suggests a need for resources and strategic partnerships to support organisations advancing through “Deepening” and “Exploiting” CEI readiness levels.

CEI-Market Readiness

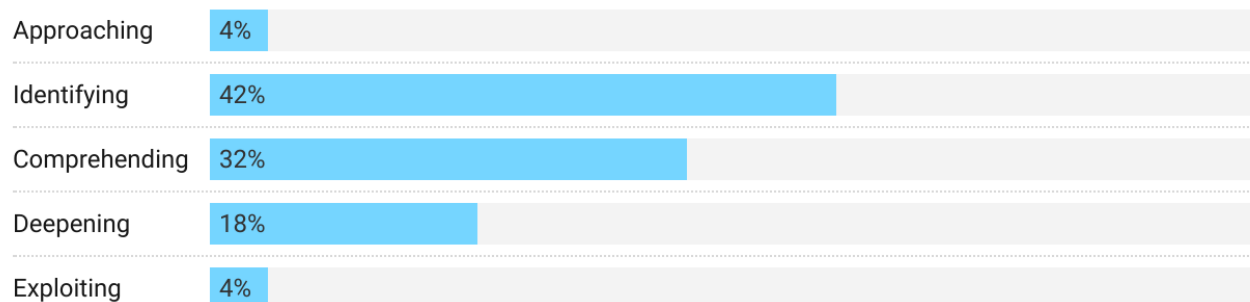


Figure 3. CEI-Market Readiness

A survey conducted with 700 European companies from January to March 2023 asked organisations if they are currently using or planning to use any of the following types of solutions in the next 24 months: IoT, Cloud, and Edge technologies. In terms of extensive usage, cloud adoption is the most used with 36%, followed by IoT at 17%. However, only 7% of respondents are extensively using Edge technologies. This limited adoption can be attributed to the fact that Edge solutions often require both IoT and Cloud capabilities, necessitating greater technological and organisational preparedness before firms can fully leverage Edge technologies.

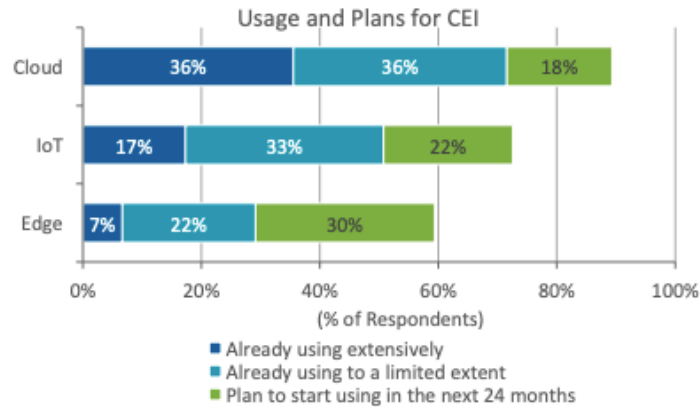


Figure 4. Usage and Plans to Use CEI (Source: UNLOCK-CEI Survey, March 2023)

The survey results, as illustrated in Figure 4, align with the CEI Readiness scores obtained from the CEI-LING application, where the majority of companies fall within the Identifying and Comprehending levels. While extensive use of Edge technologies remains low (7%), approximately 30% of respondents express intentions to adopt these solutions within the next 24 months. This indicates a strong interest into Edge technologies and its applications.

Although many companies have successfully integrated Cloud and IoT solutions, advancing to Edge technologies necessitates significant improvements in both technological infrastructure and organisational capabilities. To move beyond the Identifying and Comprehending levels and reach the Exploiting and Deepening stages, organisations must address these gaps comprehensively.

3.2 Sectoral overview

The CEI-Ling results demonstrate engagement from respondents across eight key sectors- ICT, Manufacturing, Research, Agriculture, Transportation, Energy, Telecommunications, Healthcare and Other- confirming the framework's broad industry appeal. Nonetheless given the number of responses per category it was considered that four main categories will be analysed: ICT & Telecommunications, Manufacturing, Research and Others. Notably, the ICT sector accounts for one of the largest shares of participants (32%), which is expected given its strategic alignment with CEI technologies. This sector's engagement reflects its reliance on processing substantial data volumes, either at the edge or in the cloud, making CEI adoption particularly advantageous. Following ICT, the Manufacturing and Research sectors also show substantial representation, indicating a cross-industry recognition of CEI's potential to drive innovation and operational efficiency.

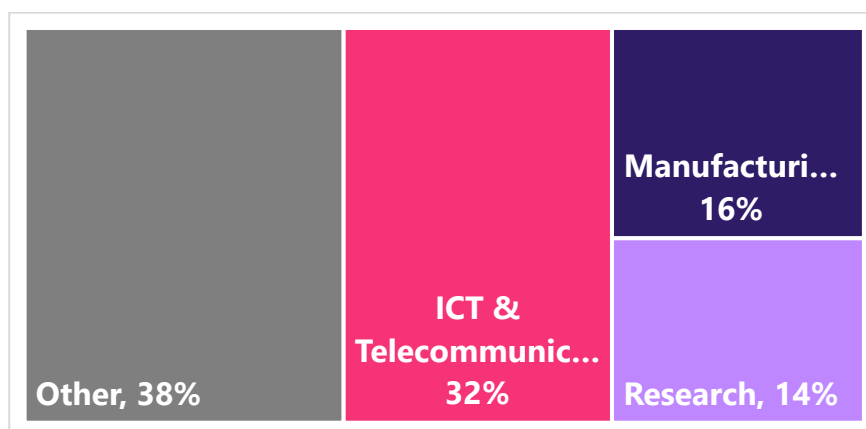


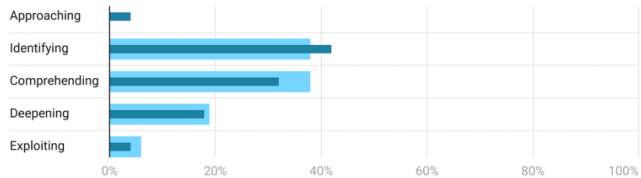
Figure 5. CEI-LING application results-sector

We can also assess the CEI readiness levels within the Manufacturing and ICT sectors, where the majority of respondents fall into the "Comprehending" category for manufacturing and the "Identifying" category for

ICT. These results reflect similar outcomes to those presented in the general CEI Market Readiness graph in Section 3.1. This suggests that, while companies in these sectors have made initial steps in engaging with CEI technologies, further development is required before full exploitation can be achieved. Nevertheless, the fact that the Manufacturing and ICT sectors exhibit the highest engagement with the CEI-LING application is a suggests that these sectors can serve as early adopters.

ICT CEI-Market Readiness

ICT & Telcomms - CEI READINESS
General CEI Market READINESS



Manufacturing CEI-Market Readiness

Manufacturing CEI Market Readiness
General CEI Market READINESS

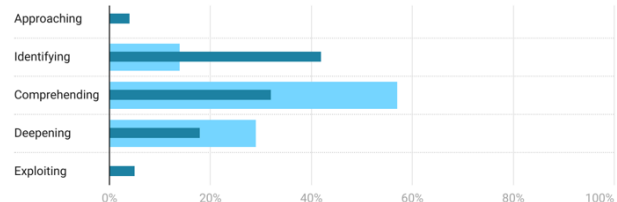


Figure 6. ICT – Manufacturing CEI-Market Readiness

3.3 CEI readiness

3.3.1 Analysis by readiness dimension

The analysis of CEI readiness by sector highlights the performance of each sector across the five dimensions of the CEI-LING framework:

CEI Readiness by Sector

	RISK & COMPLIANCE	FINANCE	INDUSTRY & MARKET	TECH	ORGANISATIONAL	AVERAGE
Manufacturing	2.9	3.3	3.7	3.4	2.8	3.3
ICT & Telecommunications	2.8	2.6	3.1	3.0	2.7	2.9
Research	2.3	2.0	2.6	2.4	2.2	2.3
Other	2.8	2.2	2.7	2.9	2.3	2.6

Figure 7.. CEI Readiness by Sector

Organisational

- **Manufacturing (2.8):** Manufacturing has foundational organisational processes, including deployment timelines and analytics capabilities. Advancing towards real-time monitoring and streamlined processes would support faster response times and operational agility.
- **ICT & Telecommunications (2.7):** Organisational readiness is moderate, with basic deployment timelines and analytics frameworks. Enhanced coordination and real-time data integration would enable more efficient CEI implementation.
- **Research (2.2):** Organisational readiness is quite low, suggesting minimal deployment and analytics capabilities. Establishing foundational frameworks for deployment and real-time tracking is essential to support CEI-related goals.
- **Other (2.3):** Organisational maturity is limited, with a need for better deployment and analytics processes. Investing in these areas would provide a more structured foundation for effective CEI integration.

Industry & Market

- **Manufacturing (3.7):** Manufacturing is highly capable in identifying and implementing CEI-aligned revenue opportunities, with some strategies already partially deployed. Scaling these initiatives across operations would unlock additional growth potential and strengthen the sector's competitive edge.

- **ICT & Telecommunications (3.1):** This sector is actively exploring market strategies related to CEI, identifying opportunities for revenue generation. Extending these strategies across the organisation and executing them effectively would help the sector capture measurable returns.
- **Research (2.6):** Market strategy readiness is limited, with minimal exploration of CEI-related revenue streams. Aligning research objectives with commercial opportunities through partnerships or proof-of-concepts would better position the sector for CEI-driven growth.
- **Other (2.7):** This sector shows a developing but limited market strategy, with some foundational plans to explore new revenue streams. Refining and implementing these strategies would provide measurable returns and increased competitiveness.

Financial

- **Manufacturing (3.3):** Manufacturing shows strong financial readiness, likely with effective ROI models and cost-benefit analyses. Expanding these models to capture the full impact of CEI over the long term would support strategic decision-making and investment planning.
- **ICT & Telecommunications (2.6):** Financial readiness here is limited, with early-stage forecasting models that lack robustness. Strengthening financial assessment frameworks and validating assumptions would enhance this sector's ability to make informed CEI investments.
- **Research (2.0):** Financial readiness is very low, with limited capabilities in ROI calculation or cost forecasting for CEI. Developing basic financial assessment processes would be crucial to support decision-making and resource allocation for CEI initiatives.
- **Other (2.2):** Financial planning in this sector is slightly more developed than in research, with some initial cost assessments in place. However, a more detailed approach to forecasting and financial modelling would clarify CEI's potential impact.

Risk & Compliance

- **Manufacturing (2.9):** Manufacturing has a solid foundation in risk and compliance, with protocols for data integrity, cybersecurity, and regulatory compliance. However, these protocols may not yet be fully integrated across CEI processes. Enhanced standardisation and deeper embedding of compliance measures would elevate the sector's readiness.
- **ICT & Telecommunications (2.8):** This sector has some basic compliance frameworks, particularly around data security, but lacks fully integrated risk management aligned with CEI standards. Enhancing cybersecurity and regulatory protocols tailored to CEI would address these gaps.
- **Research (2.3):** Compliance readiness is minimal, suggesting limited measures for data integrity and cybersecurity. Building more robust compliance processes would significantly strengthen the sector's ability to manage risk and meet regulatory standards.
- **Other (2.8):** While foundational compliance protocols are present, deeper integration of these measures within CEI processes would improve readiness. Basic data integrity and cybersecurity standards are in place, but there's room to align more closely with CEI frameworks.

Technology

- **Manufacturing (3.4):** Manufacturing's tech readiness is relatively high, with established cloud-edge processes, though real-time tracking may still need improvement. Full integration of real-time capabilities and interoperability within CEI systems would further enhance efficiency.
- **ICT & Telecommunications (3.0):** This sector has some cloud-edge integration but lacks comprehensive real-time tracking. Enhancing IT infrastructure uptime and reducing latency would support higher operational efficiency and better CEI alignment.
- **Research (2.4):** Tech capabilities in research are underdeveloped, indicating basic infrastructure reliability but limited alignment with CEI. Improvements in process efficiency and real-time tracking would significantly boost the sector's readiness.
- **Other (2.9):** Foundational tech readiness is present, with initial efficiency processes established. However, the absence of real-time tracking and advanced interoperability limits the full potential of CEI adoption.

3.3.2 Analysis by sector

Manufacturing

Manufacturing leads in CEI readiness, with strengths in market strategy, finance, and technology. The sector shows strong capabilities in generating new revenue from CEI, as well as in financial forecasting and tech integration. Enhancing real-time infrastructure, risk management, and standardisation across compliance would ensure that manufacturing remains competitive and resilient in its CEI adoption.

ICT & Telecommunications

This sector is balanced but moderate in CEI readiness. It shows potential in market strategy and has foundational tech processes in place. However, lower financial and organisational readiness indicate areas for improvement, particularly in financial forecasting and real-time deployment capabilities. Addressing these gaps would position the sector to fully capitalise on CEI opportunities.

Research

Research trails other sectors, with notable gaps in finance, tech, and organisational readiness. The sector lacks foundational capabilities in financial forecasting, tech infrastructure, and deployment frameworks, all of which are essential for effective CEI adoption. Strengthening these areas would provide a more robust foundation for growth and innovation in CEI-related research activities.

Other

The "Other" sector displays modest CEI readiness, with relatively higher scores in tech and risk & compliance. While foundational frameworks are in place, the sector lags in financial and organisational capabilities. Addressing these weaknesses would better position it to realise CEI's potential benefits in growth and operational efficiency.

3.4 A deeper look at correlated factors that affect CEI readiness

An in-depth analysis of the CEI-LING application results was conducted, examining the correlations between the 21 parameters across the 5 different dimensions, as well as how different industries ranked within each dimension. For the correlation analysis, only parameters with a correlation coefficient higher than 0.70 were considered¹.

Strongest areas of readiness:

- IT Infrastructure uptime (3.8)
- R&D Expenditure/Strategy (3.5/3.2)
- Legacy hardware & software in use (3.2)

Weakest areas of readiness:

- Certification (1.9)
- Financial ROI definition (2.1)
- Legacy data integration (2.3)

¹ Pearson's correlation coefficient was used to measure relationships between the variables. Values range from -1 to +1, indicating the strength and direction of the relationship.

Average Scores of CEI Readiness - Parameters

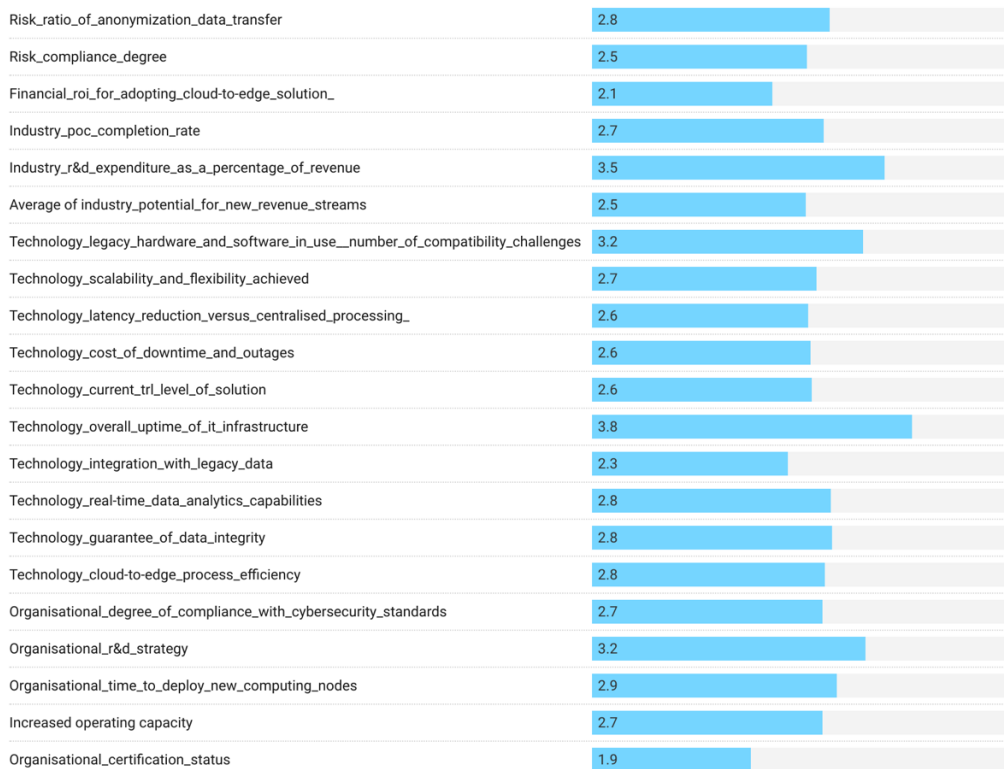


Figure 8. Average Scores of CEI Readiness – Parameters

The correlation between factors such as flexibility, scalability, and legacy integration suggests that organizations possessing these capabilities may be better prepared for successful CEI adoption. The adoption of CEI technologies can, in turn, provide a critical advantage in competitive positioning, particularly in navigating rapidly evolving technology landscapes. Some conclusions that could be drawn from the analysis of these correlations include:

1. INFRASTRUCTURE INVESTMENT AS A PRODUCTIVITY CATALYST

Firms with advanced IT infrastructure and higher uptime demonstrate a clear link between CEI readiness and productivity. This suggests that investment in resilient infrastructure is not only foundational for CEI adoption but also amplifies workforce efficiency by reducing downtime.

2. STRATEGIC R&D AND ORGANISATIONAL READINESS

Organisations with strong R&D investments are typically more prepared for CEI due to a forward-looking approach that includes continuous improvement and technological experimentation. Strategic CEI investments in areas like edge computing and AI-driven analytics deepen organisational readiness by building internal capabilities that can quickly adapt to new technological requirements. This strategic alignment creates a strong foundation for rapid scaling and efficient deployment of CEI solutions across various business functions.

3. LEGACY SYSTEM INTEGRATION: A DOUBLE-EDGED SWORD

Legacy hardware and software present both a challenge and an opportunity. Organisations that navigate these complexities gain a competitive edge by extending the utility of existing assets while avoiding disruptive, large-scale overhauls. Successful legacy integration maximises resource efficiency and facilitates smoother transitions to CEI systems. However, the organisations that struggle with this integration are likely to experience delays in CEI adoption and miss out on data-driven insights that could drive innovation.

4. FLEXIBILITY AND SCALABILITY AS REVENUE DRIVERS

Advanced flexibility and scalability in technology stacks empower organisations to respond to market changes and customer demands more dynamically. This adaptability is crucial for tapping into novel revenue streams, such as customised CEI solutions, data-as-a-service, or enhanced customer experiences. Firms that scale their CEI capabilities effectively can introduce new revenue channels with lower incremental costs, capitalising on CEI's potential to drive recurring, servitisation-based income.

5. FINANCIAL ROI AND OPERATIONAL RELIABILITY

New revenue streams emerging from CEI adoption, such as those driven by data monetisation or predictive maintenance, offer a significant boost to perceived ROI. Importantly, these revenue streams are not purely additive; they often result from streamlined operations that CEI readiness enables, such as reduced downtime and proactive issue management. Lower downtime also preserves business continuity and reduces the risk of customer attrition due to service interruptions, indirectly increasing financial returns from CEI investments.

6. ROLE OF COMPLIANCE AND CERTIFICATION IN CEI READINESS

Organisations with high certification and regulatory compliance tend to exhibit greater CEI readiness, reflecting their robust governance frameworks and disciplined risk management. Compliance often requires well-documented processes, secure data handling, and reliable infrastructure—all prerequisites for CEI integration. This alignment also positions these firms favourably for partnerships, as stakeholders are more likely to engage with entities that demonstrate a commitment to security and regulatory standards.

3.4.1 Limitations

In reviewing the findings from the CEI-LING application, it is important to acknowledge that, as a pilot study with a limited sample of 50 responses gathered over 4 months, there are inherent limitations regarding the analysis of market routes. The data collected through this tool does not provide the level of granularity necessary to offer direct, sector-specific insights into market routes at this stage. As a pilot, the focus of the CEI-LING application was on assessing CEI readiness factors across various sectors and providing actionable insights within the five dimensions it assesses. Therefore, while the analysis reveals important trends and correlations related to CEI readiness, these insights remain general in nature and do not extend to identifying specific market routes at this point.

4. Market routes

4.1 Diverse routes to market

The European landscape for Cloud-Edge-IoT (CEI) solutions presents substantial growth opportunities, especially for companies that can strategically navigate a mix of traditional and emerging routes to market. While conventional routes such as direct sales, channel partnerships, and reseller agreements remain relevant, CEI solutions demand approaches that are more agile, collaborative, and ecosystem-driven to effectively reach diverse industries.

Traditional Routes to Market include

1. **Direct sales:** Selling directly to end customers, public or private, often requiring a dedicated sales force with expertise in specific industries or technologies. While viable, this approach can be resource-intensive for CEI providers, particularly in sectors where solutions need customisation or integration.
2. **Channel partnerships:** Engaging with channel partners who distribute and support the product can extend market reach. In a CEI context, however, traditional channel partners may lack the specific technical knowledge to effectively position and support these complex solutions.
3. **Reseller agreements:** CEI providers can license their technology to resellers who market it under their brand, providing rapid access to customers. However, resellers may not always have the deep technical understanding required for integrating and supporting CEI technologies.

While these traditional models offer foundational market access, CEI solutions often benefit more from market routes that leverage partnerships, ecosystems, and co-development models to address the complexity and interdependence of the technology. These might include:

1. **Strategic partnerships with Industry-Specific ICT providers:** Given the sector-specific nature of CEI deployments, aligning with established ICT providers in fields like Manufacturing, Logistics, and Healthcare can accelerate market access. These partners bring deep industry knowledge, established customer relationships, and can integrate CEI technology into sector-specific solutions, easing adoption.
2. **System Integrator (SI) Partnerships:** System integrators play a crucial role in managing complex deployments across the cloud, edge, and IoT layers, ensuring seamless integration with existing enterprise systems. Collaborating with SIs enables CEI providers to address customer challenges holistically, which can be especially valuable in enterprise contexts that require custom solutions and scalability.
3. **Digital Marketplaces and Platform Ecosystems:** As organisations increasingly rely on multi-vendor technology stacks, digital marketplaces (e.g., cloud provider marketplaces) have become a popular route to reach customers. CEI providers can list their solutions on established platforms (e.g., AWS Marketplace, Azure Marketplace) where customers can easily procure and deploy technology. This route is particularly advantageous for small and medium-sized enterprises (SMEs) looking to avoid heavy up-front costs associated with direct sales or channel partnerships.
4. **Joint Ventures and co-development models:** The CEI market often requires co-created solutions to meet specific industry demands (eg. for Defence). Joint ventures with complementary technology providers can allow CEI companies to develop integrated offerings that align with sector standards and requirements. Co-development not only improves market fit but also enables sharing of resources, reducing entry barriers for smaller CEI firms.
5. **Embedded Solutions and White-labelling:** Embedding CEI technology within existing industry platforms (such as industrial IoT platforms or healthcare informatics systems) can provide a route to market that reduces friction for end users. White-labelling agreements allow established vendors to

integrate CEI capabilities directly into their solutions, enhancing customer reach without requiring end customers to adopt new stand-alone platforms.

6. **Government and Public Sector Initiatives:** Many European governments are investing in digital transformation, smart city projects, and IoT infrastructure as part of broader innovation agendas. CEI providers can tap into these initiatives by forming public-private partnerships or responding to government tenders, which can offer substantial revenue streams and a platform for scale

Other actions can bolster market access. These include joining industry consortia, such as AIOTI, allows CEI providers to influence and align with emerging standards, which can be crucial for compatibility and interoperability in multi-vendor environments. Participation in consortia also enhances credibility, builds trust, and facilitates connections with large-scale customers who prioritise compliance with sector standards.

4.2 From Meta OS to market

4.2.1 The MetaOS use cases

The EUCloudEdgeIoT initiative has coordinated a varied portfolio of project clusters, each specialising in distinct CEI areas, collectively encompassing a total of 59 projects. One of these clusters is the MetaOS cluster, which specifically addresses Europe's need to strengthen its supply and value chains in cloud-to-edge computing. The aim is to achieve this by integrating essential elements of computing, connectivity, IoT, AI, and cybersecurity. By leveraging network functions such as ad-hoc cloud and fog communication, extending beyond 5G capabilities, the MetaOS cluster has developed meta-operating systems for the edge that facilitate seamless orchestration between cloud and edge computing environments.

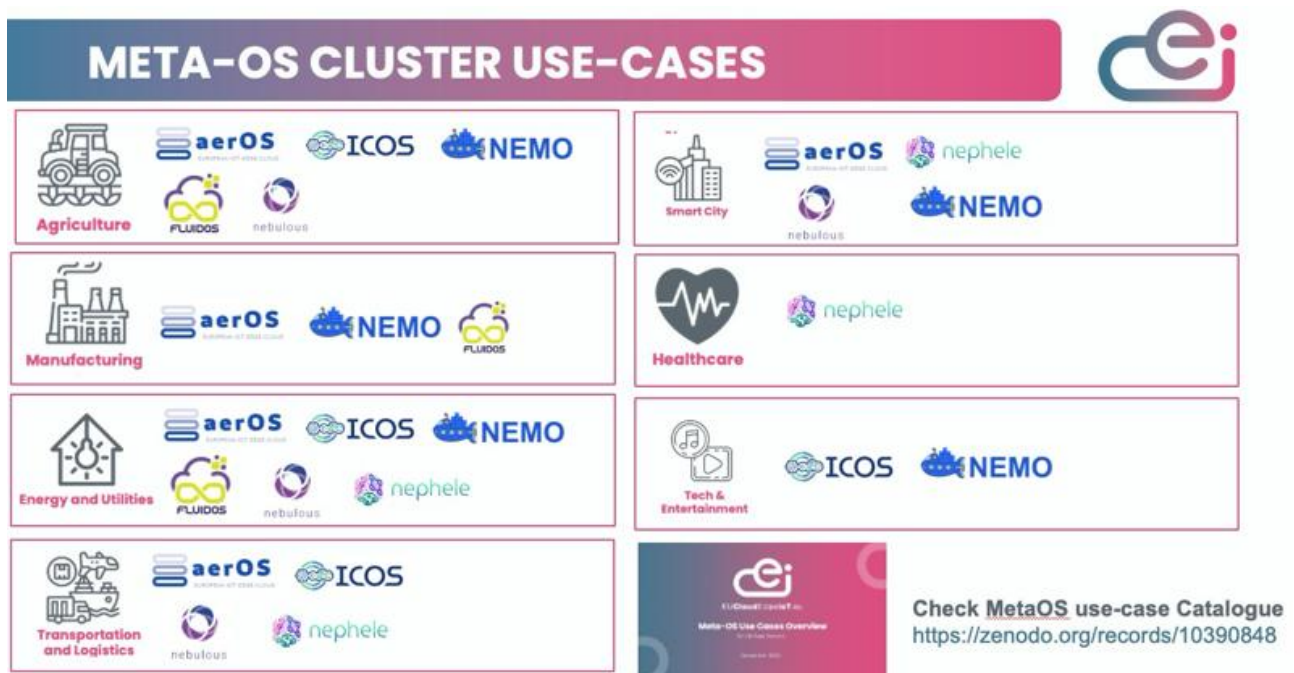


Figure 9. MetaOS – Cluster use cases

Launched in September 2022, the MetaOS cluster comprises six projects: AerOs, ICOS, NEMO, FLUIDOS, NebulOuS, and Nephele. These projects contribute technologies that advance the Cloud-to-Edge continuum by bringing computation, data, and intelligence closer to the sources of data generation, such as sensors and devices. This proximity enables efficient management of the associated volume, variety, interoperability, and velocity of data. The advancements made within the MetaOS cluster will facilitate viable AI training and inference at the edge, paving the way for next-generation, internet-enabled automation concepts that virtualise computing and networking functions. Additionally, this strategy supports multi-state analytics and digital twinning of underlying objects, ultimately enhancing end-to-end response times, optimizing CO2 footprints, and leveraging renewable energy sources.

The collective investment in these six MetaOS projects amounts to €64 million and involves approximately 120 partners, all collaborating to harness the opportunities presented by the CEI continuum.

4.3 Market opportunities

4.3.1 Beachhead value chains

The Cloud, Edge, and IoT market is segmented into a diverse array of use cases across various industries. The extensive applications of these technologies can lead to a growing trend in adoption. Initially, UNLOCK-CEI aimed to highlight MetaOS use cases within five primary domains: agriculture, energy, manufacturing, transportation, and healthcare. While this constituted the initial scope, two additional domains—smart cities and technology & entertainment—were subsequently included. These target markets represent sectors where the projects can establish a strong foothold, making them particularly promising for the early adoption of MetaOS solutions.

Agriculture

The integration of Cloud-Edge-IoT technologies is driving a transformative evolution in the agriculture sector, with a range of service requirements facilitating its modernisation. The agricultural sector is crucial for global communities, contributing significantly to economies worldwide. Therefore, it is essential to implement CEI technologies to usher in a new era of precision farming and data-driven decision-making. An agricultural value chain encompasses all steps involved in bringing food from farm to plate, including cultivation, storage, processing, transportation, and retail. These value chains are inherently complex, involving various stakeholders such as producers, agro-dealers, suppliers, food processors, transporters, traders, retailers, and exporters. In examining the foundations of agricultural value chains, the frequency of data collection emerges as a critical factor. Continuous monitoring of diverse elements affecting crop health and agricultural productivity is vital for influencing subsequent stages of the chain. The opportunities for MetaOS projects reside in real-time data acquisition from IoT devices embedded in fields, the vast volumes of data collected, and the ability to analyse and process this data at the edge.

Healthcare

The healthcare value chain encompasses all activities involved in the development, delivery, and management of healthcare services. The integration of Cloud-Edge-IoT technologies within this sector represents a transformative shift, enabling real-time monitoring of patient health—a critical advancement for facilitating timely interventions and personalised care. The MetaOS projects have the potential to create significant impact by supporting high-frequency data collection from wearable devices and medical sensors, thereby providing invaluable health information. Processing real-time data at the edge is essential for both patients and healthcare professionals, as it allows for the capture of key metrics and the prompt detection of when interventions are required. Collecting valuable data not only aids in immediate health assessments and interventions but also contributes to identifying trends over time. The edge continuum offers a framework through which MetaOS projects can eliminate barriers related to hardware capabilities, empowering the healthcare sector to make better-informed decisions. Ultimately, this integration enhances patient outcomes while improving scalability and flexibility within the healthcare value chain.

Go-to-Market

Strategic partnerships

Figure 10 NEMO- use case

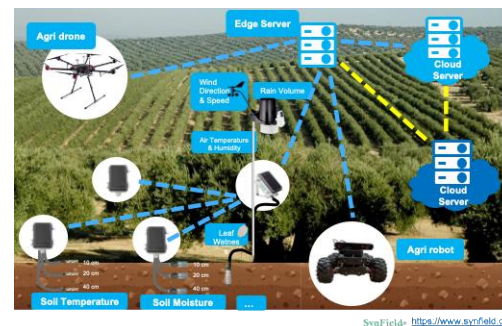
USE CASE №1 | PRECISION FARMING

The Problem

- Crop production lost to pests
- EU soil health is deteriorating
- Climate change

The Solution

Precision biospraying



EU Agriculture Market Size

- 225.6 billion in 2023

Go-to-Market

Strategic partnerships

Manufacturing

The integration of Cloud-Edge-IoT technologies in the manufacturing sector is revolutionising production processes by emphasising the importance of high-frequency data collection for optimising operations and maintaining quality control. Embedded sensors continuously monitor key parameters such as temperature and pressure, providing real-time insights from production lines that can facilitate quick identification of anomalies and enable immediate corrective actions. This extensive data collection also supports predictive maintenance, allowing manufacturers to detect potential machinery failures early, thus minimising downtime and reducing costs. The analysis of manufacturing data can occur at the edge or in the cloud, offering unique advantages for process improvement. The convergence of Cloud-Edge-IoT technologies within the manufacturing value chain presents substantial opportunities for the MetaOS projects to enhance operational efficiency, drive innovation, and foster a more agile manufacturing environment.

Energy

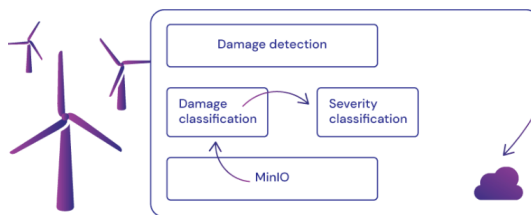
USE CASE N°2 | WINDMILL MAINTENANCE

The Problem

- Last minute maintenance - costly
- Longer turbine lifespan desired
- Costly replacement parts

The Solution

Predictive maintenance with drones



EU Electricity Generation Market Size

- Expected to reach 68.9 billion - 2029

Go-to-Market

Strategic partnerships, Bundle as a software

In the energy and utilities sector, the integration of Cloud-Edge-IoT technologies is essential for enhancing the management and efficiency of energy resources. By combining Cloud-Edge processing with renewable energy sources and sensor data, real-time adjustments to energy production can be made based on analytical benchmarks. Continuous monitoring through sensors in smart meters, transformers, and other infrastructure enables utility providers to swiftly respond to demand fluctuations, optimise energy distribution, and prevent overloads. Additionally, this wealth of data supports predictive maintenance, allowing early identification of anomalies before they escalate into critical failures. By leveraging these capabilities, MetaOS projects can significantly enhance grid stability and resilience, ensuring a reliable energy supply while extending the lifespan of critical infrastructure components within this vital value chain.²

Transportation

In the transportation sector, the integration of Cloud-Edge-IoT technologies is beneficial for enhancing networks, traffic management, and the advancement of autonomous driving systems. High-frequency data collection from connected vehicles and infrastructure serves as the

foundation for a safer and more efficient transportation ecosystem. Sensors embedded in vehicles and along roadways continuously capture critical data, including speed, location, and environmental conditions, providing real-time insights. The transportation sector significantly contributes to the global value chain by improving delivery times, efficiency, reliability, and flexibility, as well as increasing visibility. Therefore, integrating Cloud-Edge-IoT technologies within this sector is of importance. These advancements present substantial opportunities for MetaOS projects to establish a strong presence within this vital value chain.

Smart Cities- Tech & Entertainment

The MetaOS projects have uncovered significant opportunities within the Smart Cities and Tech Entertainment sectors, even though these areas were not included in the initial mapping of five key industries. The Smart Cities sector harnesses information and communication technologies (ICT) to interconnect municipal infrastructures, thereby creating a cohesive digital ecosystem. This interconnected

² Wind turbine operation and maintenance market report [2029]. Wind Turbine Operation and Maintenance Market Report [2029]. (n.d.). <https://www.fortunebusinessinsights.com/wind-turbine-operation-and-maintenance-market-102757>

infrastructure facilitates access to valuable data, fostering a robust network of partnerships among government entities, businesses, non-profit organisations, community groups, universities, and healthcare facilities—all united in the common goal of developing smarter urban environments.

Similarly, the Tech and Entertainment sector benefits from advanced network management and improved data flow from various sources, including buildings, transportation, and energy systems, driven by integrated business and technology development approaches. By integrating Cloud-Edge-IoT (CEI) technologies, Smart Cities can enhance a range of sectors such as energy, transportation, water management, and waste sanitation. The digital transformation in this realm demands a collaborative approach, leveraging shared resources, skills, and strategic partnerships to enhance competitiveness. This targeted digitalisation not only strengthens the local economy but also lays the groundwork for innovative value-added processes. Consequently, the application of CEI technologies offers an opportunity to significantly contribute to the evolution of Smart Cities and Tech Entertainment.

4.3.2 Market drivers

The European landscape for Cloud-Edge-IoT (CEI) solutions presents significant growth potential, particularly for companies that align with key market drivers propelling CEI adoption. Our previous research, the work completed through the UNLOCK-CEI Value Chain Adopter groups, as well as direct interaction with the MetaOS use cases has highlighted several critical drivers that influence the uptake of CEI technology across sectors:

1. **Technological advancement:** Technological innovations in AI, data analytics, sensor technology, and connectivity enable organisations to harness the full potential of CEI solutions. Access to these technologies is fast becoming ubiquitous. The capabilities to process vast amounts of real-time data and apply advanced analytics are increasingly becoming prerequisites for sectors such as manufacturing and agriculture. According to Gartner's 2023 technology trends, pervasive cloud and AI-driven analytics are transforming business models by enabling real-time insights and automation, which directly benefit CEI adoption
2. **Regulatory pressures:** European Union regulations, such as the GDPR and sustainability directives, are pushing organisations towards digital solutions that support transparency, data security, and environmental compliance. Regulatory requirements are significant drivers for adopting IoT and edge solutions in areas like energy management and environmental monitoring. These regulations compel organisations to adopt digital tools that allow precise tracking and reporting, particularly relevant in sectors where compliance is stringent
3. **Data sovereignty:** Organisations are increasingly prioritising data sovereignty, aiming to retain control over their data rather than relying on external providers. This drive for autonomy is often motivated by regulatory requirements, such as the EU's GDPR, but also reflects broader concerns around data privacy, security, and business continuity. Edge computing is particularly appealing in this context, as it allows organisations to process data closer to its source, reducing dependency on centralised cloud providers and enabling tighter control over data flows. Sectors handling sensitive data, such as healthcare and finance, view data sovereignty as essential to maintaining trust and compliance while ensuring their data governance standards are upheld.
4. **Security:** With the growing number of connected devices and expanding edge networks, cybersecurity risks are becoming more pronounced. Regulatory standards and industry best practices emphasise the importance of secure and compliant CEI solutions. Organisations are prioritising CEI technologies that incorporate robust security features to address vulnerabilities unique to IoT and edge environments. In critical infrastructure sectors, such as energy and smart cities, security is a primary driver, with organisations adopting CEI solutions that protect against cyber threats, data breaches, and operational disruptions.
5. **Ecosystems:** The growth of digital ecosystems and collaborative platforms provides new routes for CEI providers to reach markets. Ecosystems and partnerships allow CEI technology to be integrated into broader solutions tailored to specific industries.

6. **Competitive pressures and efficiency gains:** In an increasingly competitive environment, companies are adopting CEI solutions to achieve operational efficiencies and maintain a competitive edge. Across the use cases, digital transformation, driven by cost reduction and process optimisation goals, is a critical market driver. For example, predictive maintenance enabled by IoT in windmills reduces downtime and costs, which can provide a competitive advantage.

Table 1. Market summary for selected MetaOS use cases

Sector	Value Chain	Market Growth	Key Benefits	Go-to-Market Focus	Technology Adoption Barriers	Regulatory Compliance
Manufacturing (aerOS)	Production Lines	Industrial automation market grow is estimated to grow at a CAGR of 9.45%	<ul style="list-style-type: none"> Enhanced AGV orchestration Real time monitoring 	Integration within existing products from industrial firms such as Siemens.	<ul style="list-style-type: none"> High investment in hardware (AGV) components There's the need for interoperability 	Compliance with industry safety and robotics standards
Energy (NebulOS)	Wind Farm Maintenance	The energy sector saw a 50% increase in installations in 2023 compared to 2022, with 117 GW	<ul style="list-style-type: none"> Real time damage assessment Predictive maintenance 	Targeted to wind farm operators, and other energy sectors.	<ul style="list-style-type: none"> IoT costs Harsh environmental conditions Data transfer limits 	Compliance with EU energy and safety regulations
Agriculture (ICOS)	Smart Agriculture and Data Synchronisation	Global smart agriculture market is expected to grow at a CAGR of 10.8%	<ul style="list-style-type: none"> Reduction of decision-making latency Predictive maintenance 	Partnership with agricultural equipment manufacturers.	<ul style="list-style-type: none"> Low connectivity in rural areas Skills gap in IoT infrastructure use 	Compliance with agricultural regulations such as EU Common Agricultural Policy
Agriculture (NEMO)	Crop Management and Pest Control	Increasing demand for organic farming, along a growing population.	<ul style="list-style-type: none"> Optimized bio spraying Reduced pesticide use Lower CO2 	Partnership with agriculture farms, offer it to large crop production firms.	<ul style="list-style-type: none"> Limited infrastructure in rural areas High IoT costs 	EU agricultural standards for pesticide use such as General Food Law

4.4 Barriers and challenges

4.4.1 Barriers to development and adoption

Despite the promising opportunities within the Cloud-Edge-IoT landscape, several weak points hinder the effective adoption of MetaOS solutions across identified value chains.

1. **Lack of standardisation:** One major challenge is the lack of standardisation in technology and protocols, which can lead to interoperability issues among different solutions, devices and platforms. This fragmentation complicates integration efforts, deterring stakeholders from investing in new solutions. Additionally, the rapid pace of technological advancement often outstrips regulatory frameworks, leaving gaps in compliance and security. This uncertainty can create hesitation among organisations to fully embrace new technologies, particularly in sectors like healthcare and transportation where data privacy and security are vital.
2. **Supply chains:** Reliable access to hardware and software required to deploy advanced Cloud-Edge-IoT technologies can pose a significant barrier for small to medium enterprises (SMEs) and organisations with limited budgets. Smaller CEI developers may lack the necessary resources or networks or bargaining power to manage supply systems effectively.
3. **Skills shortages:** As demand for CEI solutions grows, the shortage of skilled talent to implement and manage these technologies is becoming a significant barrier. This skills gap is driving organisations to form partnerships within CEI ecosystems, leveraging external expertise to fill internal resource gaps. Collaborative models, such as partnerships with system integrators and managed service providers, are emerging as effective ways to bridge the talent gap. This driver is particularly relevant in highly specialised sectors, like manufacturing and logistics, where specific skills in IoT, edge computing, and data analytics are critical to CEI deployment.

4.4.2 Infrastructure as a key enabler

In addition to internal weak points, there are significant gaps and distances within the broader ecosystem that hinder the successful deployment of CEI technologies and MetaOS projects. One notable gap is the disparity in infrastructure readiness across different regions. Urban areas may benefit from advanced connectivity and resources, while rural and underserved regions lag behind, limiting the equitable

deployment of Cloud-Edge-IoT technologies. This geographic imbalance creates challenges in achieving nationwide smart infrastructures, interoperability and global standards.

There's a notable distance between technology developers and end-users in various sectors. Many organisations are unaware of the full potential and benefits of integrating Cloud-Edge-IoT solutions into their operations, leading to underutilisation of available technologies. This gap can result in missed opportunities for collaboration and innovation, as stakeholders fail to align their objectives and strategies effectively. Bridging these gaps requires concerted efforts in investment, education, outreach, and partnership-building to ensure that all players in the value chain can realise the benefits of the digital transformation enabled by CEI technologies.

5. Final words

This report shares insights into the Cloud-Edge-IoT (CEI) continuum, capturing the market's readiness and sector-specific adoption of CEI technologies across the European landscape. The majority of organisations are in preliminary stages, identified as "Identifying" and "Comprehending" readiness levels, which indicate foundational awareness and initial technology integration. Only a minority are moving towards advanced "Exploiting" stages. This suggests a widespread interest in CEI but indicates the need for improved infrastructure, financial models, and frameworks that can bolster trust to pave the way for widespread market adoption.

The recent Draghi report stressed³ the critical need for Europe to enhance its industrial competitiveness to maintain economic resilience and strategic autonomy. It highlights that Europe's share of global high-tech exports has declined from 22% in 2000 to 15% in 2020, while China's share has surged from 6% to 26% over the same period. Additionally, the report notes that Europe's investment in research and development (R&D) lags behind, with R&D expenditure at 2.2% of GDP compared to 3.1% in the United States and 2.4% in China. To address these challenges, the report advocates for substantial annual investments of €750-800 billion, equivalent to approximately 4.5% of the EU's GDP, to bolster innovation, digitalisation, and green technologies. It also calls for streamlined regulatory frameworks and enhanced public-private partnerships to facilitate this transformation. In this context, a more agile European CEI ecosystem that interacts with greater flexibility with the market can help balance the technological landscape.

Sector-Specific Engagement

ICT leads in CEI readiness due to its high data-processing needs, aligning with the edge and cloud capabilities offered by CEI. Manufacturing shows promising readiness, driven by its need for real-time monitoring, predictive maintenance, and operational optimisation. Agriculture is leveraging CEI for precision farming, focusing on environmental challenges such as soil health and pest management. Each sector has unique operational requirements that will ultimately reflect in the CEI stack required to deliver solutions at a price-points that end-users can afford.

Drivers for CEI Adoption

Adoption is spurred by regulatory demands (e.g., GDPR), operational efficiency goals, and sustainability imperatives. In the healthcare and finance sectors, data sovereignty and cybersecurity are major drivers, especially given the sensitive nature of data. Competitive pressures to enhance service continuity and reduce costs are also accelerating CEI implementation. The Data Act and the AI Act all set out new obligations that can provide opportunities but also add a layer of cost to technology.

Standards are also being heralded as enablers of compliance and market access. Increasing the participation in European standardisation efforts and collaboration with like-minded international partners for global standard setting is critical.

Security as a core consideration

In addition security threats remain a pervasive challenge across sectors. The new Cyber Resilience Act 2024 sets out new obligations that require manufacturers to *"improve the security of products with digital elements since the design and development phase and throughout the whole life cycle; ensure a coherent cybersecurity framework, facilitating compliance for hardware and software producers; enhance the transparency of security properties of products with digital elements, and enable businesses and consumers to use products with digital elements securely."*⁴

³ The future of European competitiveness – A competitiveness strategy for Europe. 2024. European Commission.

⁴ <https://digital-strategy.ec.europa.eu/en/library/cyber-resilience-act>

<https://www.eucloudedgeiot.eu>



Financial and Compliance Barriers

Organisations often struggle with defining long-term financial benefits, especially in calculating the return on investment for CEI projects. While ICT and manufacturing display stronger financial models, sectors like research face significant limitations in budget forecasting and risk management frameworks aligned with CEI.

Skills and Collaboration Gaps

A pronounced gap exists between CEI technology providers and end-users, indicating a need for enhanced collaboration. Many organisations lack the requisite skills for CEI integration, leading to dependency on third-party providers. The Digital Europe Programme (DEP)⁵ has already invested EUR 294 million so far to support skilling, upskilling and reskilling initiatives to equip the EU workforce with the necessary skills for advanced digital technologies such as artificial intelligence, data science, cloud computing and cybersecurity. The European Data Spaces are also expected to provide opportunities for collaboration and innovation.⁶

MetaOS Cluster and Use Cases

The MetaOS cluster addresses Europe's need for a resilient digital infrastructure, focusing on creating meta-operating systems that enhance data orchestration between cloud and edge environments. With projects like AerOs and NEMO, the MetaOS cluster supports applications in agriculture, healthcare, energy, and manufacturing, proving the viability of CEI solutions across critical sectors. However, the pace of development of the technologies has on occasions not kept up with the market. There is a need for a more agile approach and structures that can help researchers and industry keep up with market needs.

⁵ <https://digital-strategy.ec.europa.eu/en/activities/digital-programme>

⁶ <https://digital-strategy.ec.europa.eu/en/policies/data-spaces>

<https://www.eucloudedgeiot.eu>



Annex 1 – CEI-LING

Table 2. Correlation among CEI-LING application parameters

Increased operating capacity, new cloud, r&d, strat. cert. certification	Balance with cto-edge process/rantee, of data, data, analytics, with log uptime, of it, inrent, tr, level, of, downtime, action, versus, cerfity, and, flexibile, in, use, nu, for, new, revenue, completion, re, as, a, per, cent, of, cloud-to-tree, with, relevancy, optimization, data
Increased oper	1
organisational	0.683209608
organisational	0.584382833 0.585098325 1
organisational	0.372050664 0.42735236 0.46859898 1
organisational	0.462678592 0.394375121 0.400148875 0.632261099 1
technology_clo	0.656776004 0.632668049 0.601964367 0.580231451 0.529868813 1
technology_gsi	0.596321425 0.481882446 0.518252937 0.483687528 0.617340022 0.625098946 1
technology_nst	0.482426436 0.577589511 0.551263644 0.452381071 0.55618524 0.605478985 0.676615806 1
technology_int	0.505406402 0.439517582 0.606330976 0.597922517 0.665593608 0.665403028 0.645328974 0.721261707 1
technology_ov	0.097019042 0.370965325 0.082798105 0.273330022 0.070278818 0.365175758 0.315410785 0.208254158 0.221507516 1
technology_cui	0.293015453 0.363638425 0.362905499 0.537501946 0.479748814 0.561432786 0.429073046 0.459256165 0.631702615 0.257369013 1
technology_coi	0.494484571 0.575226057 0.367762145 0.521172727 0.410874016 0.635598819 0.492834317 0.459272193 0.474272715 0.489749638 0.283981506 1
technology_lsh	0.597107667 0.561726902 0.574159091 0.501768114 0.402740489 0.57049966 0.60522525 0.495399389 0.513883938 0.152240637 0.546259788 0.407357748 1
technology_sci	0.54251501 0.62971735 0.560596326 0.602153368 0.600568134 0.626751224 0.618478913 0.607965593 0.596980485 0.224073818 0.520124039 0.471117879 0.765774187 1
technology_leg	0.437565823 0.464460642 0.426371489 0.558666092 0.579665804 0.520709251 0.471148975 0.571020983 0.681834772 0.273585834 0.481561569 0.365740892 0.399422686 0.554516893 1
industry_poten	0.498666704 0.502906034 0.64990308 0.50962153 0.528772791 0.56297701 0.596724399 0.652185989 0.71746727 0.092661142 0.575312019 0.47512751 0.698808097 0.736609604 0.537141075 1
industry_poc_c	0.606262506 0.583283744 0.452230645 0.390795874 0.528772912 0.601316478 0.632457585 0.689950764 0.606850696 0.04093622 0.365956488 0.387215605 0.586247972 0.531382941 0.569630946 0.614795509 1
industry_r&d_e	0.164925958 0.284749659 0.37940298 0.286521543 0.15346069 0.418383204 0.312433474 0.146279152 0.257963761 0.143841203 0.228961172 0.27423957 0.217728393 0.240505207 0.337750189 0.381485876 0.288504199 1
financial_rti_e	0.492857762 0.59942553 0.549302135 0.58581739 0.544983062 0.52219660 0.500823889 0.642909797 0.707495544 0.190388373 0.602783062 0.537041123 0.535598452 0.665572609 0.568480957 0.712290209 0.515420392 0.218913141 1
risk_complianc	0.506364008 0.526091564 0.487851773 0.553337709 0.520050927 0.538780134 0.571436587 0.566316705 0.501394004 0.330111802 0.376640831 0.48320028 0.53294148 0.606160705 0.365108296 0.501418502 0.522602456 0.100083947 0.632609098 1
risk_ratio_of_ar	0.363293955 0.375730488 0.201203216 0.125706369 0.136956427 0.281404613 0.292747896 0.133640926 0.135718183 0.29020181 0.127655278 0.457865577 0.319293586 0.300647375 0.210877497 0.354241993 0.206736712 0.144462686 0.364194194 0.43457296 1

Table 3. CEI-LING Sample report

RESULTS

COMPANY: EXAMPLE

CEI USE CASE: EDGE PROCESSING

JOB TITLE: ANALYST

JOB FUNCTION: FINANCE AND ACCOUNTING

Thanks for using our tool! Based on the answers received, your CEI market readiness score is **3 out of 5**. This score is intended to help you evaluate your overall readiness. For your reference, we also offer a comparison of your result against the average score within your industry and the overall average of all companies using the tool, regardless of sector. Detailed scores for various aspects of your company, along with tailored recommendations to improve your readiness level, are provided below.

ORGANISATIONAL



Time to deploy new computing nodes for CEI adoption:

Streamline deployment processes based on insights from initial tests and set clear logistics for full-scale implementation. Enhance cross-departmental coordination to ensure all necessary support is available for deployment. Begin tracking deployment efficiency metrics to set benchmarks and identify areas for further optimisation.

Certification status:

Evaluate the new opportunities for business derived from gaining certifications. Explore employee individual certifications.

Real-time data analytics capabilities:

Develop a comprehensive plan for integrating real-time analytics capabilities with existing IT infrastructure, focusing on areas with the highest impact. Start by integrating real-time analytics in a specific department or process to learn and refine the approach. Leverage successes to gain buy-in for organisation-wide integration.

Integration with legacy data:

Proceed with small-scale aggregation projects to fine-tune the process before scaling up. Use lessons learned to develop standardised procedures for data aggregation. Ensure that key stakeholders understand the value of legacy data aggregation and support its continuation.

TECHNOLOGY



Cloud-to-Edge process efficiency:

Invest in advanced efficiency tracking tools and incorporate them into your regular business reviews. Use the insights gained to foster continuous improvement and integrate them into your CEI strategy. Prepare for broader implementation by ensuring all staff are trained on new systems and processes.

Overall uptime of IT infrastructure:

Further develop infrastructure stability by implementing mitigating strategies such as a content back-up system. Evaluate critical asset duplication possibilities.

Current TRL level of solution:

Evaluate impact to current process. Determine potential hurdles in technology implementation

Latency reduction versus centralised processing:

Execute the integration of real-time analytics with CEI solutions in select business areas, monitoring the impact closely. Use the results to optimise processes and to demonstrate the value of real-time analytics to stakeholders. Train relevant teams to use these new tools effectively, enhancing decision-making processes.

Scalability and Flexibility achieved:

Create a checkpoint for the data review of CEI implementation at scale. Continue the periodical evaluation of data to find new areas for improvement and expansion.

Legacy hardware and software in use / number of compatibility challenges:

Define the new products and services that will be enabled by the implementation of CEI technologies. Create development plans for these new products and services

FINANCIAL



ROI for adopting Cloud-to-Edge solution:

Validate preliminary ROI calculations with more comprehensive datasets and refine assumptions based on industry insights. Collaborate with financial analysts to ensure that ROI calculations are robust and reflect the true potential of CEI. Use feedback to create a dynamic model that can adjust to organisational changes and market conditions.

Increased operating capacity:

Execute capacity expansion strategies in select areas of the business, setting clear benchmarks for success. Use data collected from these areas to adjust overall capacity plans and prepare for broader implementation. Engage staff in the change process to ensure smooth adoption and to gain valuable insights.

Cost of downtime and outages:

Evaluate the cost saved by the applications of CEI technologies according to the expected failure rate. Implement into TCO and ROI calculations

RISK AND COMPLIANCE



Compliance degree with relevant regulations:

Develop the risk mitigation strategy. Create a compliance record, keep track of non-compliance.

Ratio of anonymization data transfer:

Generate contingency plans in case of data leakage in CEI continuum, prioritising the stages where non-anonymised data is present.

Guarantee of data integrity:


Start integrating data integrity measures with CEI technologies on a small scale to understand the impacts and necessary adjustments. Conduct regular training sessions for staff to raise awareness of data integrity practices within the context of CEI. Set up a monitoring system to track the effectiveness of these protocols and identify areas for improvement.

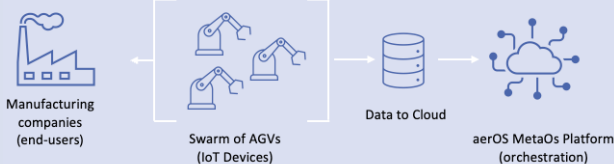
Degree of compliance with cybersecurity standards:

Engage with CEI cybersecurity experts to define main areas of focus. Develop a CEI cybersecurity implementation plan.

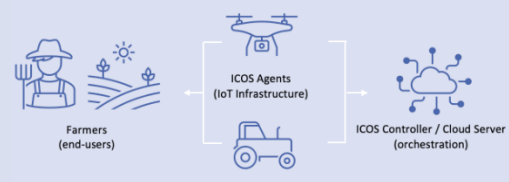
Annex 2 – MetaOS Use Cases

Table 4. Selected use cases

Project	Windmill Maintenance	Sector	Partner
Presenter	Michał Kłosiński	Energy	TTAnalysis
Lead Organisation	NebulOuS		
Location	Poland		
Description	Focused on windmill maintenance, this project deploys continuum-integrated survey drones and integrates cloud-edge processing with inspection tools. It utilizes AI image recognition software to optimise inspections and generate predictive maintenance alerts. The objectives include enhancing maintenance efficiency, enabling timely alerts for predictive maintenance.		
Key Components	Drones, cloud-edge computing, AI image recognition, predictive maintenance software, data analytics.		
Value chain	 <pre> graph LR A[Energy companies (end-users)] --> B[Drones (IoT Infrastructure)] B --> C[NebulOuS Platform (assessment/analitics)] </pre>		

Project	Data-driven Cognitive Production Lines	Sector	Partner
Presenter	Ignacio Lacalle	Manufacturing	Siemens
Lead Organisation	aerOS		
Location	Germany		
Description	Development of Data-Driven Cognitive Production Lines that integrate cloud-edge technology with production systems. This solution improves remote interaction between monitoring tools and equipment, tracks energy efficiency, and orchestrates AGVs for optimized material transport. The project aims for real-time error compensation, zero-defect manufacturing, net-zero energy production, and automation.		
Key Components	Cloud-edge computing, IoT sensors, data exchange ecosystems.		
Value Chain	 <pre> graph LR A[Manufacturing companies (end-users)] --> B[Swarm of AGVs (IoT Devices)] B --> C[Data to Cloud] C --> D[aerOS MetaOs Platform (orchestration)] </pre>		

Project	Agriculture Operational Robotic Platform	Sector	Partner
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Presenter	Marcin Kotliński	Agriculture	Poznan
Lead Organisation	ICOS		
Location	Poland		
Description	Development of an Agriculture Operational Robotic Platform that integrates cloud-edge processing with agricultural practices. The project aims to increase farming efficiency and scalability through localized data collection, product quality stabilization, and resource optimization.		
Key Components	Cloud-edge computing, IoT sensors, data exchange ecosystems.		
Value Chain			

Project	Smart Farming and Precision Agriculture	Sector	Partner
Presenter	Theodore Zahariadis	Agriculture	Synelixis
Lead Organisation	NEMO		
Location	Greece		
Description	Addresses crop loss from pests and poor soil by leveraging multi-modal AI analytics and IoT data to improve field awareness and monitor grove health. Real-time drone video analysis aids in controlling fruit fly populations and optimizing bio-spraying.		
Key Components	Multi-modal AI analytics, IoT sensors, drones, data analytics .		
Value Chain	