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Overcoming Barriers in the EU's Computing Continuum: Challenges and Future Directions

Policy brief based on the outcomes of UNLOCK-CEI final event

Policy Brief

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1. Future CEI challenges in the EU context

A recent report from Mario Draghi[1] addresses Europe's role in emerging digital technologies, including edge computing, which is critical to the continent's broader digital and industrial strategy. The report highlights that while Europe is increasingly lagging behind global leaders like the U.S. and China in key areas such as cloud computing and 5G deployment, it still has the opportunity to recover and lead in the field of edge computing. Europe's advanced industrial base provides a foundation for edge computing to play a vital role in sectors such as autonomous vehicles, smart cities, and Industry 4.0. However, Draghi stresses that infrastructure development and coordinated investments are urgently needed to achieve this potential.

One of the key challenges outlined in the Draghi report is the lag in infrastructure, including cloud and edge computing. Although Europe is behind in meeting its 2030 targets for the deployment of edge nodes, there remains an opportunity to recover ground, particularly in areas requiring technological sovereignty such as security, encryption, and AI. To address these issues, the report advocates for stronger coordination between policies and investments, emphasising the need to integrate edge computing with AI and 5G networks to boost Europe's competitiveness. It also calls for enhancing Europe's semiconductor industry, a fundamental component for the development of edge devices, and increasing R&D funding to advance edge computing solutions.

Today the computing continuum infrastructure spans a wide spectrum, ranging from micro edge to far edge and encompassing the cloud continuum. On the other hand, the growing array of intelligent devices demands the orchestration of all edge devices. The complexity of this continuum lies in the technical challenges of developing edge cloud infrastructure as a seamless, virtual infrastructure that orchestrates workloads effectively. For organisations seeking to operate their infrastructure efficiently, this orchestration is essential. The lack of tech infrastructures remains a critical bottleneck for the computing continuum, especially as the need for edge computing grows. More robust and widespread infrastructure is needed to support the expansion of edge and IoT technologies. On the other hand, Edge computing requires greater computing capacity at the edge to deliver on its promise, and efforts should be concentrated on enhancing this capability.

To overcome these challenges, in the European context, several research and innovation (R&I) projects are being launched, with initial implementations appearing in the market. The primary goal of such initiatives is to create an open framework, with particular interest in identifying the open-source communities in Europe that can contribute to delivering services for the computing continuum. Most of the research efforts in this field are brought together in the umbrella initiative "The European Cloud, Edge, IoT Continuum – EUCloudEdgeIoT". As part of this cluster, for instance, the Meta Operating Systems (MetaOS) projects, are collectively advancing cloud-edge-IoT solutions in various sectors, including energy, media, manufacturing, smart buildings and mobility. These projects are demonstrating the important role of edge computing in these sectors, where real-time data processing is key to improving efficiency and resilience. They also reflect the importance of collaboration and open frameworks for addressing technical challenges and enhancing CEI adoption across industries. The next wave of funded projects in this area will include large scale pilots aimed at further integrating CEI technologies into Europe's digital ecosystem.

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1   EU competitiveness: Looking ahead: https://commission.europa.eu/topics/strengthening-european-competitiveness/eu-competitiveness-looking-ahead_en

2. Current challenges and access barriers

Europe faces the urgent need for a "radical change" to improve its competitiveness in the digital landscape, as outlined in the Draghi report, which emphasises the critical role of edge ecosystems in maintaining technological sovereignty. Such needs are reflected in the EU Digital Compass 2030, outlining Europe's vision for a digitally sovereign future, focusing on four key objectives: digital skills, digital infrastructures, digital transformation of businesses, and digitalisation of public services. By 2030, the EU aims to ensure that at least 80% of adults possess basic digital skills and that there are 20 million employed ICT specialists. For infrastructure, the target includes the deployment of 10,000 edge nodes, widespread gigabit connectivity, and 5G coverage, as well as advancements in quantum technologies. The EU also seeks to have 75% of companies using cloud, AI, and big data, with over 90% of SMEs reaching basic digital intensity levels. Public services are a priority, with the ambition of 100% of key services being available online, alongside comprehensive digital identity solutions for citizens. These initiatives aim to enhance Europe's digital leadership, competitiveness, and resilience within the global digital economy.

During the final event of UNLOCK-CEI, held on 23rd September 2024, these crucial topics were discussed in a dedicated panel with representatives of HiPEAC, Chips Joint Undertaking (JU), AIOTI, BDVA and the AI, Data and Robotics Association (ADRA). The discussion highlighted the following key challenges and possible remedies.

Infrastructure and investment

One of the most pressing challenges discussed at the UNLOCK-CEI final event on 23rd September 2024, and as highlighted in the Draghi report, is the need for significant investment in digital infrastructure. Europe must invest in 5G, fibre, and edge computing infrastructure to close the gap with global competitors. While Europe has made strides, the lag in infrastructure deployment, particularly for edge computing, remains a major barrier. Increased investments are required to strengthen infrastructure and ensure the computing capacity at the edge meets future demands. Insights from the "Gap Analysis and Strategic Opportunities" white paper[2] by UNLOCK-CEI highlights the key gaps and how Europe can bridge technological gaps by fostering open-source solutions and increasing collaboration across CEI ecosystems.

Market fragmentation and complexity

Market fragmentation is another challenge affecting the adoption of CEI solutions in Europe. Companies face significant barriers in navigating the various programmes and initiatives aimed at supporting digital transformation. While the proliferation of such programmes is designed to support policy agendas, the complexity and overlap of these initiatives can make it difficult for businesses to access funding and resources effectively. The Wackler and G+D success story collected by UNLOCK-CEI[3] illustrates how businesses struggle with complex logistics and fragmented systems when integrating CEI technologies across supply chains. Greater clarity and coordination are needed to reduce confusion and facilitate smoother market access for companies looking to innovate with CEI technologies.

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2   The full paper is accessible at this link: https://doi.org/10.5281/zenodo.13364675
3   UNLOCK-CEI success stories are accessible at this link: https://eucloudedgeiot.eu/success-stories/

Standardisation

One of the key challenges discussed at the final event, but missing in many sectors, is the issue of standards and interoperability. The lack of common standards across cloud, edge, and IoT technologies creates significant roadblocks for companies looking to integrate solutions across different platforms. The absence of interoperability limits the potential for scalable solutions and creates fragmented ecosystems where solutions cannot work together efficiently. Ensuring that standards are developed and widely adopted is crucial for fostering a more connected and collaborative digital infrastructure. This issue has been highlighted by multiple CEI projects, including the MetaOS projects, which stress the importance of open frameworks to ensure seamless integration across industries and sectors.

Regulatory and financial barriers

Regulatory hurdles and financial constraints also play a role in slowing down the adoption of CEI solutions. Many businesses face uncertainty around return on investment (ROI) for digital transformation efforts, and venture capital in the CEI space remains limited. Poor R&D decisions and a lack of strategic direction further compound this issue, making it difficult for companies, especially SMEs, to scale up and commercialise new technologies. The need for clearer regulations, stronger venture capital investments, and more strategic R&D funding was a key takeaway from the discussions

Alignment of technological innovation with business models

Another challenge lies in aligning technological advancements with actionable business models. Many companies struggle to find a clear market focus or concrete business cases for CEI technologies. The absence of scalable business models hinders the commercialisation of innovations, particularly in sectors where technological solutions have been developed but lack market traction. Greater attention must be paid to ensuring that CEI projects are not only technically innovative but also commercially viable.

3. Recommendations and remarks

Standards and interoperability

Ensuring compliance with EU values, particularly around data privacy and security, is fundamental to promoting a truly interoperable system. Only through harmonised regulations and standards can Europe build a functional digital single market, facilitating smoother cross-border operations and ensuring that digital products and services are widely adopted. The creation of interoperable frameworks will also help to foster trust in European solutions, further supporting the go-to-market process.

Introperability remains a key factor in fostering the adoption of cloud, edge and IoT solutions. Technologies, especially in the domains of cloud, edge, and IoT, need to be interoperable to create seamless integration across systems. This would enhance their uptake by companies and consumers alike, stimulating further innovation and driving the growth of these markets. IoT nodes and edge computing, in particular, hold significant potential to bring value to the market, but they require better infrastructure and collaborative efforts to realise their full impact.

Open source and data sovereignty

Other key opportunities and benefits currently available in the European context revolve around open source, data sovereignty, and the automotive and energy sectors, which are seen as critical domains for CEI adoption. Infrastructure optimisation, semantic interoperability, and tech sovereignty reflect the needs for European companies to access improved systems that enable seamless integration, efficient resource management, and greater control over data.

An important emerging opportunity lies in the development of RISC-V[4], an open-source hardware instruction set architecture that offers the potential to become a reference architecture in Europe. Projects under the Chips Joint Undertaking (JU) are already exploring the use of RISC-V as a foundation for common solution development, particularly in the context of CEI technologies. The adoption of RISC-V could facilitate more standardised, interoperable solutions across industries, while also promoting European independence in key technological areas, including chip design and manufacturing. This aligns with the EU's broader goals of achieving data and technological sovereignty.

Furthermore, the potential for new services, time to market, and the role of novel chips also reflect how CEI technologies can open doors to innovation and faster product development cycles.

Overall, while the current EU scenario suggests substantial opportunities for cloud, edge and IoT applications in sectors like energy and automotive through concepts like open source, compliance and interoperability, only overcoming structural barriers—particularly in terms of business focus, regulation, and financial clarity—will ultimately drive effective adoption.

Driving innovation, entrepreneurship and leadership

Europe's ambition to become a global leader in digital technologies requires a significant shift in mindset. A critical factor in achieving this goal is fostering an environment that nurtures

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4   More information available here: https://riscv.org/

entrepreneurship and innovation. Education systems should not only equip individuals with technical expertise but also inspire creativity and the drive to bring new ideas to market.

In addition, rather than focusing solely on challenges, projects' emphasis should be on identifying and implementing solutions. Shifting attention to future opportunities will foster momentum, driving innovation forward. Projects should not merely catalogue obstacles but should focus on showcasing success stories, creating roadmaps for sustainable growth, and promoting collaboration across ecosystems. Drawing insights from both within and outside individual project scopes will enhance the potential for broader impact and accelerate the development of cloud, edge, and IoT technologies.

Large-scale pilots recently funded across Europe are set to play a critical role in deploying CEI solutions, helping to validate technologies and showcase their real-world applications. These pilots will allocate a substantial portion of their funding to open calls, aimed at involving companies and elevating the innovations to the next level. Additionally, there is growing momentum in the telecommunications sector with the development of network software slices for 5G and 6G contributing to decentralised, connected and collaborative computing networks. The pilots will support the practical adoption of CEI technologies while fostering collaboration between public and private sectors, ultimately driving the integration of cloud, edge, and IoT systems across various industries.

Joint efforts and a holistic approach

To enhance the EU's competitiveness, joint efforts from strategic initiatives in cloud, edge, and IoT must be aligned with complementary technologies such as AI. Europe needs a clear vision that fosters increased collaboration, not only within the EU but also with international partners through more international projects[5].

For Europe to achieve digital autonomy, it is essential to develop the entire technological stack, from research and innovation to market delivery. A holistic approach is crucial—projects must address not only individual components but also work across the whole stack to ensure competitiveness in critical areas such as edge computing, which demands more infrastructure and computing capacity at the edge.

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5   One example is the Discover-US project, which represents a pivotal collaboration between EU and US research institutions, focusing on advancing distributed computing and swarm intelligence.