Executive summary

This Research & Innovation Roadmap, developed under the NexusForum.EU project and supported by Horizon Europe, outlines a research and innovation trajectory towards achieving a federated European multi-provider, AI-driven computing continuum, to enable and support data-driven innovation and AI deployments in Europe. It complements the technology developments of the European Alliance for Industrial Data, Edge and Cloud and the new IPCEI-CIS, providing a long-term vision bridging industry needs with excellent research in cloud, edge, and AI technologies. The roadmap also addresses the current EU policy and legislative framework, the implications of which for future technological developments are further analyzed in NexusForum policy reports.[1]

This is the second public version of the Cognitive Computing Continuum Research and Innovation Roadmap for Europe. A final version will be released close to the end of the NexusForum project in mid-2026, and will further identify strategic areas for collaboration with South Korea and Japan. NexusForum will implement a public consultation process to gather and incorporate feedback from the broader community and stakeholders in cloud, edge, AI, and industry sectors that could benefit from these technologies. Relevant experts and stakeholders are welcome to actively participate in the NexusForum working groups, where the roadmap will be further discussed and elaborated.

Towards a European Cognitive Computing Continuum

The European Union stands at a critical juncture in shaping its digital future. The importance of cloud and edge computing, together with artificial intelligence (AI), is well-recognised as a strategic enabler for innovation and competitiveness in an increasingly digital and data-driven society. Despite this strategic importance, the market for cloud services and AI is currently dominated by a few mostly non-European players, and the European cloud market remains highly fragmented.

There is a need for organisations and citizens in the EU to consolidate their IT systems and data, and gain control over how they are collected, stored, and used, in line with European rules. The European data strategy aims to address this need and establish a single unified (European) market for data, where data can move more freely and the benefits of them can be better shared. This unified single market will hopefully reduce vendor lock-in and data silos, and ultimately lower the barriers for data-driven innovation across sectors.

To realize a European Cognitive Computing Continuum, the EU must overcome market fragmentation, foster interoperability, and ensure compliance with European regulations, values, and ethical AI principles.

A Strategic Vision for European Digital Sovereignty

The European Cognitive Computing Continuum should be an interconnected, federated ecosystem in which European cloud and edge service providers collaborate to deliver secure, high-performance, and energy-efficient data processing capabilities, with the possibility of provision from suitable other jurisdictions such as Japan and Republic of Korea.

[1] https://eucloudedgeiot.eu/wp-content/uploads/2024/10/D3.1%E2%80%93DigitalPolicyReport-_Final.pdf A

This roadmap offers an in-depth overview of the technology areas and associated subjects aimed at developing a competitive, secure, energy-efficient, climate-neutral, and AI-powered Cognitive Computing Continuum.

The current version focuses on addressing the key priorities of recent EU policy initiatives (Competitiveness Compass,[2] Connected Collaborative Networks[3]), on responding to the current geopolitical landscape and market conditions (A competitiveness strategy for Europe,[4] Much more than a market[5]), on the regulatory framework (NIS2 Directive,[6] Cyber Resilience Act,[7] Chips Act,[8] EUCS[9]) and on societal needs in Europe, pursuing mainly:

- The enhancement of European competitiveness in the Edge and Cloud domain to balance the current market dominance of the three non-European hyperscalers, while balancing sovereign cloud initiatives with access to essential technologies.
- EU digital sovereignty in the Computing Continuum domain, where technology sovereignty is essential for security and regulatory compliance.
- The generative AI race and meeting computing requirements to support the future needs of foundational AI models.
- Achieving carbon neutrality and ensuring energy-efficient computing resources and software.
- Incorporating perspectives from international partner countries with strong positions in the cloud computing continuum.

Key Recommendations

This roadmap highlights the following strategic research and innovation priorities to realise the vision of a European Cognitive Computing Continuum.

1. Create the Foundations for a Secure, Interoperable, and Sovereign European Computing Continuum

- Adopt a holistic and systems-centric approach to cybersecurity, analysing cascading risks and systematic risks in the European Computing Continuum.
- Harmonise the markets and regulations within Europe, and support the development of ecosystems and mechanisms for interoperability, to ensure seamless service integration and data portability.
- Strengthen governance and compliance mechanisms aligned with European regulations (NIS2, Cyber Resilience Act, EUCS).
- Consider open-source hardware and software technologies as a geopolitical concern, and ensure transparency and long-term sustainability of European digital infrastructure by supporting open-source governance models, for example based on RISC-V.

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[2] *https://ec.europa.eu/commission/presscorner/detail/en/ip_25_339*
[3] *https://digital-strategy.ec.europa.eu/en/library/white-paper-how-master-europes-digital-infrastructure-needs*
[4] *https://commission.europa.eu/topics/eu-competitiveness/draghi-report_en#paragraph_47059*
[5] *https://www.consilium.europa.eu/media/ny3j24sm/much-more-than-a-market-report-by-enrico-letta.pdf*
[6] *https://digital-strategy.ec.europa.eu/en/policies/nis2-directive*
[7] *https://digital-strategy.ec.europa.eu/en/policies/cyber-resilience-act*
[8] *https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-chips-act_en*
[9] *https://www.enisa.europa.eu/publications/eucs-cloud-service-scheme*

- As the supply of European semiconductor technologies is strengthened, develop an early focus for their uptake by creating a strong demand and market for them in advance.

2. Invest in Intelligent, Autonomous, and Resilient Management of a Multi-provider Computing Continuum

- Develop AI-driven orchestration frameworks that optimize workload distribution across federated cloud-edge infrastructures.
- Advance federated computation models to support privacy-preserving AI, ensuring data security across multiple providers.
- Enable hyper-decentralized architectures that enhance resilience, scalability, and self-management of computing resources.
- Invest in confidential computing and homomorphic encryption techniques to secure data and computations.
- Support AI-powered predictive maintenance, debugging, and self-healing cloud-edge infrastructure to enhance reliability and reduce operational costs.

3. Enable Data-driven Innovation, and the Development and Deployment of AI in the Computing Continuum

- Expand the development of **Common European Data Spaces** to facilitate cross-border data sharing in compliance with GDPR, the AI Act, and the Data Act.
- Enable **portable AI applications and services** that can run seamlessly across different cloud-edge providers, including EuroHPC infrastructure.
- Develop **middleware solutions** and compiler technologies to improve portability, interoperability, and security in heterogeneous multi-provider cloud-edge systems.
- Advance research in **federated training and deployment of generative AI models** across distributed datasets.
- Explore integration of **quantum and neuromorphic computing capabilities** to drive future AI acceleration.

4. Create a Sustainable and Energy-Efficient European Computing Continuum

- Develop and deploy **carbon-aware computing** strategies to reduce the environmental impact of data centers and AI workloads.
- Leverage AI for optimizing holistic energy consumption across cloud-edge infrastructures, including workload balancing with data center operations.
- Invest in middleware solutions and co-design of software and hardware to optimize code execution and reduce energy use of AI-specialised computing platforms.
- Promote the development of new cooling technologies and **waste heat recovery systems**, and integrate renewable energy into cloud and edge data centers.

5. Converging Telecommunications, Computing, and AI Infrastructure

- Invest in an **Open Radio Access Network (O-RAN)** and next-generation telco-cloud architectures to create a flexible, open, and interoperable network ecosystem.

- Enhance **seamless data connectivity** by improving predictive handover and intelligent network management across different networks.
- Integrate European **high-performance computing (HPC)** to enable advanced AI and scientific computing workloads.
- Integration of **Information Technologies (IT) and Operational Technologies (OT)** to drive digital transformation in industrial sectors.

Key priorities include the acceleration of sector-specific digital transformation through the development, and implementation of various next-generation technologies, such as: the AI-powered computing in automotive for connected and autonomous vehicles; AR/VR technologies to enable immersive industrial, healthcare, and training applications; cyber-physical convergence through digital twins and smart environments for real-time decision-making; Industry 4.0-ready cloud-edge solutions that support smart manufacturing, logistics, and critical infrastructure.

Conclusions

To ensure Europe's digital sovereignty and competitiveness in the global AI and cloud landscape, it is critical to accelerate strategic investments and collaboration within Europe and with suitable external partner countries, to align key digital technological advancements with European values. It is also critical to develop in Europe strong demand alongside strategic investments in strengthening supply of strategic technologies.