STRATEGIC RESEARCH & INNOVATION AGENDA (SRIA)

2026 - 2032

Charting the Path to
Next-Generation Connectivity

www.celticnext.eu

Foreword

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Having been involved with the CELTIC-NEXT cluster since its start 22 years ago, I am very familiar with its unique value proposition, whereby industry and national interests can be aligned to have focused projects that really do have an impact on the advancement of the digital society in the supporting countries and provide a strong return for the participating organisations.

This newly revised CELTIC-NEXT Eureka Cluster's Strategic Research and Innovation Agenda (SRIA) now outlines our shared vision for the next generation of ICT communications that will be necessary for growing a secure, trusted, and sustainable digital society over the next five years. The vision reflects that CELTIC-NEXT is an industry-driven initiative involving all the major ICT industry players and many SMEs, service providers, and research institutions. The CELTIC-NEXT activities are open to all organisations that share the CELTIC-NEXT vision of an inclusive digital society and are willing to collaborate to their benefit, aligned with their national priorities, to advance the development and uptake of advanced ICT solutions.

The future of the Information and Communications Technology (ICT) domain will require concerted investment across a wide range of ICT topics, supported by new high-performance communications networks that enable data-rich applications and advanced services, both within the ICT sector and across all vertical sectors. The unique CELTIC-NEXT approach is to consider advanced ICT services from an End-to-End perspective, ensuring all aspects of ICT infrastructure, service development, deployment and support may be included.

The EUREKA Cluster structure is a high-value public-private collaborative research mechanism that starts with project ideas for industrial needs, validates these needs with national interests, and then supports projects that produce both national and industrial returns on investment. To date, more than 11500 private and public organisations – including prominent industry players, small & medium-sized enterprises, and academic/research institutions – have participated in and benefited from CELTIC-NEXT projects.

This revised SRIA outlines our vision of the types of challenges that could be addressed in future CELTIC-NEXT projects, and we suggest you use it to help formulate your project ideas and proposals for the future CELTIC-NEXT calls. However, don't let it limit you – if you can suggest exciting, innovative ICT projects that can provide social, industrial and national returns, we'd love to hear from you.

Best wishes,

David Kennedy

Chairman

CELTIC-NEXT Eureka Cluster

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CELTIC-NEXT is an industry-driven, ICT[1] Cluster, operating under the Eureka Clusters Programme (ECP). It acts as a collaborative mechanism for advancing ICT innovation across Europe and the wider EUREKA members' network. The initiative brings together major ICT companies, service providers, SMEs, research institutions, and academia to enable a secure, trusted, and sustainable digital society. Most importantly, CELTIC-NEXT is committed to securing market, technological, and scientific leadership for the participating partners.

The Strategic Research and Innovation Agenda (SRIA) 2026–2032 provides the basis for the ICT Community to research, develop and innovate in relevant ICT technologies and their fields of applications (Industry Verticals) that are strategic for the EUREKA Countries and beyond.

This document was prepared under the revised Eureka Clusters Programme (ECP) guidelines to capture the agreement between the CELTIC-NEXT community and the supporting National Authorities to instigate and foster a programme of international collaborative projects as an EUREKA Cluster in the ICT domain for a foreseen period of seven years (2026-2032).

The dawn of 6G technology marks a pivotal moment in global telecommunications, promising transformative ICT capabilities that extend far beyond the advancements of 5G. This agenda outlines a comprehensive strategy for 6G research and innovation, providing a roadmap for telecom professionals, researchers, and policymakers. It articulates the 6G vision, establishes key research domains, and proposes innovation strategies, stakeholder roles, and policy recommendations to ensure Europe and the wider EUREKA members' network remain at the forefront of future connectivity.

The evolution from 1G to 5G has fundamentally redefined how societies communicate, work, and innovate. As we approach the era of 6G, the convergence of digital, physical, and biological worlds is accelerating, driven by exponential increases in data, intelligence, and connectivity demands. Global trends—such as the proliferation of artificial intelligence, immersive applications, and the Internet of Everything—necessitate a strategic agenda to guide research, innovation, and deployment of 6G technologies. This agenda aims to provide a unified direction to harness 6G's and the wider upcoming ICT techs' potential for economic growth, societal benefit, and technological leadership.

The CELTIC-NEXT SRIA 2026–2032 sets out a comprehensive roadmap for EUREKA Countries' leadership in ICT, beyond 6G itself, expanding to vertical industry sectors. It builds on CELTIC-NEXT's holistic, bottom-up approach, taking into account the European 6G Vision (6G-IA), the SNS-JU SRIA, and vendor perspectives, in a topical and, over time, TRL-staged manner.

Key messages:

- AI-native networks must be designed from inception. Networks shall use AI, but also provide services to other industries' AI applications, in a mutually beneficial collaboration.
- Sustainability and energy efficiency must be both system intrinsic properties and societal enablers.
- Beyond communication services (sensing, positioning, computing) will define 6G, supporting the always-increasing convergence of digital, physical and biological worlds.
- Eureka Countries' sovereignty in ICT value chains is critical.
- Societal responsibility (ethics, privacy, inclusion, trust) must be embedded.

[1] Information and Communications Technologies

1. Background and Rationale

1.1. CELTIC-NEXT Legacy and Evolution

Since its inception in 2018, **CELTIC-NEXT has been a cornerstone of European collaborative research in telecommunications and ICT** and has witnessed a transformative shift in the ICT landscape since then. Building on the earlier CELTIC and CELTIC-Plus programmes, it has initiated more than 150 projects with a combined financing volume exceeding one billion euros. These projects have mobilised a diverse ecosystem of large vendors, operators, SMEs, and research institutions. In recent years, CELTIC-NEXT has embraced the innovation ecosystems of partner regions and countries, including Canada, Singapore, South Korea, South Africa, Taiwan, and Turkey.

A defining feature of CELTIC-NEXT has been its **bottom-up, industry-driven approach**. Unlike top-down programmes that prescribe research topics, CELTIC-NEXT empowers consortia to propose projects aligned with market needs and technological opportunities. This flexibility has enabled rapid responses to emerging trends in a smart connected world, embracing the rise of artificial intelligence, and the growing importance of cybersecurity, an area where CELTIC, with its Flagship initiatives, has a longstanding history of excellence, underlined by world records. The program adopts an end-to-end, system-centric approach to communications technology that complements other EUREKA Clusters and global initiatives.

SME participation has been particularly strong, reflecting the vibrant innovation landscape across Europe and the wider EUREKA members' network. By lowering barriers to entry and fostering cross-border collaboration, CELTIC-NEXT has helped SMEs scale their innovations and integrate into global value chains. This inclusiveness is not only an economic asset but also a strategic necessity for digital sovereignty.

The revolutionary advancements in communications technologies and the explosive growth of Artificial Intelligence, particularly Large Language Models (LLMs), Agentic AI and distributed AI systems, have fundamentally altered communication paradigms and societal interactions. New challenges, such as effective management of trusted AI system deployments without data poisoning, have emerged, where modern frameworks under the 6G compute continuum can guide towards a trusted, inclusive and sovereign digital transformation that serves as an enabler for socio-economic advancements and cutting-edge technologies.

The shift of data traffic from centralised large data centres to edge and near-edge facilities has introduced critical challenges around latency, security, and privacy, requiring innovative real-time, secure, and trusted communication frameworks. The interconnected world of smart devices, machines, and humans presents unprecedented complexity as well as tremendous opportunities for smart, inclusive, and sustainable digital ecosystems.

1.2. CELTIC-NEXT in the European Research and Innovation Landscape

Horizon Europe (2021-2027) is the EU's €95 billion funding programme for research and innovation, supporting open, collaborative, and cross-disciplinary R&I projects. Horizon Europe aims to boost Europe's competitiveness, tackle societal challenges such as climate change and the digital transition, and foster inclusive growth. CELTIC-NEXT operates synergistically with this framework, especially its digital and ICT priorities.

Operating under the rules of the Horizon Europe programme, European Partnerships and Joint Undertakings (JU), are collaborative initiatives between the EU, member states, and private/public partners to jointly support thematic R&I programs. These partnerships are central to the Horizon Europe framework and aid targeted innovation efforts relevant to CELTIC-NEXT's objectives. Furthermore, the European Innovation Council (EIC) is an accelerator and grant instrument supporting breakthrough technologies and start-ups across all innovation stages, complementing cluster and collaborative research funding.

The European Structural and Investment Funds (ESI Funds, ESIFs) are financial tools governed by a common rulebook, set up to implement the regional policy of the European Union, as well as the structural policy pillars.

National research and innovation programmes are key components of the broader European research and innovation ecosystem, complementing EU-wide initiatives like Horizon Europe. These national programmes generally focus on funding and supporting research and innovation activities within their respective countries, aligned with national priorities and strengths. These programmes enable participation in European collaborative projects by facilitating co-funding and capacity building. They address specific societal, economic, or industrial challenges at the national level, often tailored to regional or sectoral needs, and support excellence in science and technology through grants, scholarships, incubators, and innovation hubs. They usually encourage public-private partnerships and encourage SME and start-up engagement in innovation. Finally, they endeavour to enhance national infrastructures for research and innovation in terms of digital, physical, and human resources.

While structured differently across countries, these programmes collectively contribute to a strong European Research Area (ERA) by ensuring local relevance, enabling cross-border collaboration and knowledge sharing.

CELTIC-NEXT fits within this vibrant ecosystem as an intergovernmental research and innovation cluster under the umbrella of EUREKA, which mobilises industry, SMEs, and academia across Europe and the wider EUREKA members' network, for collaborative projects, bridging research, technology development, and market deployment in telecommunications and next-generation ICT. It complements and enriches the European research and innovation landscape through several distinctive contributions.

Unlike many initiatives that focus on specific technology layers or vertical sectors, CELTIC-NEXT adopts a holistic, end-to-end approach to communications and ICT technology development. It bridges gaps between hardware, software, and service layers, and aligns with real-world business and societal needs. CELTIC-NEXT empowers industry—including a strong representation of SMEs and academia—to propose projects that reflect current market and technological priorities, supporting more agile, market-relevant innovations beyond top-down programme constraints. Based on its agile operational approach, CELTIC-NEXT can easily fill strategic gaps in the ICT roadmap across Europe and the wider EUREKA members' network. This complements broader programmes like Horizon Europe and promotes industrial leadership. A key mechanism of CELTIC-NEXT is the support for large "flagship" collaborative projects that address strategic challenges. At the same time, CELTIC-NEXT continuously strives to evolve its processes for higher flexibility to respond to fast-paced technological change.

1.2.1. The European 6G Vision

The **6G-IA White Paper (2024)**[2] articulates Europe's ambition to shape the global 6G agenda. It emphasises that 6G is not merely a faster network but a **transformational infrastructure** that must embed sustainability, trust, and societal value from the outset.

The white paper presents **six families of representative use cases -** immersive experience, collaborative robots, physical awareness, digital twins, fully connected world, and trusted environments and proposes technological enablers in the area of **AI-native networks**, **integrated sensing and communications (ISAC)**, energy-efficient hardware, flexible topologies, deterministic networking, and network softwarisation. Based on the technological enablers, it discusses architectural innovations focusing on interoperability, AI/ML-driven network intelligence, resource and service awareness, and integration of non-terrestrial networks (NTN) with terrestrial networks (TN). It envisions that **sustainability metrics** (Key Value Indicators)[3] are attached all innovations to effectively measure environmental, social and last but not least economic impact. This vision emphasises Europe's leadership through 6G-IA (6G Infrastructure Association) and SNS-JU (Smart Network and Services - Joint Undertaking) initiatives, aligning R&D and technological progress in Europe with the UN Sustainable Development Goals and the European Green Deal.

1.2.2. Challenges Identified by the SNS-JU SRIA

The **SNS-JU Strategic Research and Innovation Agenda (2023)[4]** provides a candid assessment of Europe's current position. Europe faces a series of structural challenges that risk undermining its leadership in next-generation digital infrastructure. Despite its strong research and industrial base, the continent remains reliant on non-European suppliers for critical technologies such as devices, cloud platforms, and microelectronics **- limiting its technological sovereignty**. **Deployment of** standalone **5G infrastructure has been slow and uneven** across member states, especially when compared to progress in Asia and North America. This delay hampers Europe's ability to test, validate, and scale advanced use cases essential for 6G readiness. Compounding this issue is the **fragmentation of value chains** across telecom, cloud, IoT, and microelectronics, which weakens strategic integration and competitiveness. **Public concerns around privacy, data protection, and electromagnetic exposure** further complicate adoption, highlighting the need for transparent governance and citizen engagement. Finally, current network architectures pose **energy efficiency challenges**, threatening to derail sustainability objectives unless addressed through systemic innovation and policy alignment. These challenges underscore the need for a **coordinated European response** that combines research, industrial policy, and regulatory frameworks.

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[2] Uusitalo, M., Bernardos, C. J., Kaloxylos, A., Bourse, D. A., Norp, T., Lønsethagen, H., Hecker, A., Rugeland, P., Papagianni, C., Bulakci, Ö., Li, X., Ericson, M., Anton-Haro, C., Massod Khorsandi, B., Ramos-Lopez, A., Frascolla, V., Marco, G., Gavras, A., & Trichias, K. (2024). European Vision for the 6G Network Ecosystem. Zenodo. https://doi.org/10.5281/zenodo.14230482

[3] G. Wikström, N. Bledow, M. Matinmikko-Blue, H. Breuer, C. Costa, G. Darzanos, A. Gavras, T. Hossfeld, I. Mesogiti, K. Petersen, P. Porambage, R.-A. Stoica, S. Wunderer, Key value indicators: A framework for values-driven next-generation ICT solutions, Telecommunications Policy, Volume 48, Issue 6, 2024, 102778, ISSN 0308-5961, https://doi.org/10.1016/j.telpol.2024.102778.

[4] Smart Networks and Services Joint Undertaking - Strategic Research and Innovation Agenda 2021 – 2027, 2nd Edition, 2023 https://smart-networks.europa.eu/wp-content/uploads/2023/12/sns-ju-sria-2021-2027-second-edition-2023.pdf

1.2.3. Vendor Perspectives and Lessons from 5G

The **TelecomTV Vendor Report (2025)**[5] provides valuable insights into industry priorities. Vendors are clear that 6G must avoid the pitfalls of 5G, which suffered from excessive complexity and too many optional features. Key industry stakeholders have articulated a clear set of priorities for the development and deployment of 6G, reflecting lessons learned from previous generations and anticipating future demands. At the forefront is the call for **simplification**: technical specifications must be lean, with fewer configuration options and well-defined migration paths. Vendors also stress the importance of launching **standalone 6G architectures** from day one, avoiding the non-standalone (NSA) detour that hindered early 5G adoption. A clean-slate approach will enable full exploitation of 6G capabilities without legacy constraints. **Energy efficiency** emerges as a non-negotiable imperative. With growing concerns over the environmental footprint of digital infrastructure, vendors demand substantial reductions in end-to-end energy consumption. This aligns with broader sustainability goals and positions 6G as a model for responsible technological advancement. Beyond traditional communication functions, vendors envision 6G as a **multi-functional platform** that integrates sensing, positioning, and edge computing, potentially enabling transformative applications across several vertical industries. Finally, the early **standardisation of AI/ML frameworks** is seen as critical for establishing trust, and support secure, intelligent network operations. These vendor priorities resonate strongly with strategic objectives across Europe and the wider EUREKA members' network, reinforcing the need for a cohesive strategy that bridges research, standardisation, and market deployment. By aligning technical ambition with policy foresight, Europe and the wider EUREKA members' network can position themselves as global leaders in shaping the 6G ecosystem.

1.3. ICT sovereignty for EUREKA countries amidst of rising geopolitical tensions

In an era marked by rising geopolitical tensions and rapid technological disruption, EUREKA members must assert their **leadership in the communications and ICT domains** to safeguard strategic autonomy and economic resilience. Taken together, the CELTIC-NEXT legacy, the 6G-IA vision, the SNS-JU analysis, and vendor perspectives converge on this single conclusion.

The pursuit of leadership in the communications and ICT domains transcends technological competitiveness. It is a commitment to uphold and advance the values that define its democratic, inclusive, and sustainable vision. In a rapidly evolving global landscape, Europe and the wider EUREKA members' network have a unique opportunity to shape the next generation of networks not only through innovation but through principled stewardship. This leadership envisions networks and applications that are:

- **Human-centric**: Designed to foster trust, protect privacy, and ensure digital inclusion for all citizens.
- **Sustainable**: Engineered to minimize negative environmental, social and economic first order effects, and maximise positive second order effects through applications in the vertical sectors.
- **Sovereign**: Built to reduce strategic dependencies and secure critical value chains, reinforcing autonomy in key technologies.
- **Innovative**: Driven by dynamic collaboration among SMEs, academia, and industry, unlocking new frontiers in research and entrepreneurship.

[5] Defining 6G Networks Report - What do vendors want - March 2025, available from https://www.telecomtv.com/

Aligning industrial strategies, research agendas, and social goals ensures that future digital infrastructures serve as enablers of a resilient, inclusive, and sustainable digital society. This is a technological roadmap and a values-based blueprint for global leadership in an era where trust, sustainability, and sovereignty are as vital as speed and scale.

By positioning itself as a global champion of sustainable digital infrastructure, Europe and the wider EUREKA members' network can shape the future of communications and enabling applications in the verticals sectors through technological excellence and by embedding values of trust, inclusivity, and environmental responsibility. This leadership agenda calls for bold investment, cross-border collaboration, and alignment with frameworks like the European Green Deal and the UN SDGs.

The proposals for the next Framework Programme (FP10) underscore the urgency of reinforcing Europe's sovereignty in smart networks and services and proactively responding to emerging disruptions such as AI-driven traffic surges and escalating network complexity. The proposals identify key high-level technology domains that must come together and be fine-tuned to enable advanced capabilities for next-generation connectivity and services. Artificial Intelligence will drive intelligent, adaptive, and autonomous networks. Cloud and service infrastructures will provide scalable, resilient, and sovereign digital platforms. Quantum technologies will unlock new paradigms in secure communication and computational power. Microelectronics will underpin energy-efficient, high-performance components.

2. Scope and Strategic Objectives

2.1. Introduction

The **renewed CELTIC-NEXT under the EUREKA Clusters Programme (2026-2032)** signifies a fresh commitment to addressing grand challenges such as empowerment of the digital society, smart environments, and creating business and social value. Network resilience, energy efficiency, quantum-safe security, and AI-enabled automation across next-generation communication networks are technological trends that fuel research and innovation to support the grand challenges. The strategic research and innovation agenda (SRIA) underpins the cluster's agenda to accelerate Eureka and allies' digital sovereignty, sustainability, and societal impact.

The mission of CELTIC-NEXT is to foster a Eureka collaborative RD&I program for the ICT community to accelerate the deployment and take-up of advanced ICT services. The CELTIC-NEXT cluster will assist the Eureka ICT industry players in exploiting the new network concepts of 5G and establishing leadership in developing and implementing 6G. The CELTIC-NEXT ambition is to assist EUREKA National Authorities, EUREKA Industry, and EUREKA Societies in accessing the societal benefits, competitive advantages, and commercial returns of being leading suppliers of the advanced ICT equipment and services needed for the new digital society.

With broadened international support and active engagement in flagship projects like SUSTAINET, CELTIC-NEXT reinforces Eureka Countries' capacity to deliver robust, scalable, and trusted communication systems that empower a digital society aligned with global challenges.

The scope of the Strategic Research and Innovation Agenda (SRIA) reflects the **breadth of Eureka's ICT Industry's ambitions**. It builds on CELTIC-NEXT's five perspectives—end-to-end connectivity, digital transformation of verticals, advanced ICT technologies, sustainability and societal impact, and the innovation ecosystem. These perspectives consider the **European 6G Vision (6G-IA White Paper)**, the **SNS-JU SRIA**, and **vendor perspectives** that highlight lessons from 5G and priorities for 6G. Together, they define a comprehensive framework for ICT leadership of the wider EUREKA members between 2026 and 2032.

2.2. Perspectives for the CELTIC-NEXT programme

As enounced earlier, CELTIC-NEXT works along FIVE perspectives: end-to-end connectivity, digital transformation of verticals, advanced ICT technologies, sustainability and societal impact, and the innovation ecosystem. Those perspectives have been elaborated out of the analysis of the Key Current Technological Trends and the Grand Challenges described in the following chapters of this document. A more exhaustive, categorised view of Enabling Technologies, Main Technical Areas of Research, and, finally, supporting High Level Fields of Applications, can be found in .

2.2.1. End-to-End Connectivity and Networks

At the heart of the SRIA is the evolution of **network architectures**. CELTIC-NEXT emphasises resilient, secure, and energy-efficient infrastructures spanning non-3GPP, 3GPP's 5G, 6G, and beyond, networks. Relevant aspects are *interoperability, integrated sensing and communication (ISAC), and AI-native design*. As societies and businesses wellness depends on the availability of connectivity services, Eureka Countries must overcome slow 5G deployment and fragmented value chains to ensure sovereignty in connectivity.

This perspective ensures that Eureka Nations' networks are not only technically advanced but also **globally competitive and sustainable**.

2.2.2. Digital Transformation of Vertical Sectors

ICT is a **horizontal enabler** across all industries. CELTIC-NEXT identifies health & care, smart cities and critical infrastructures, sustainable/precise farming, Web 4.0, inclusive education, energy, automotive, passengers and goods logistics, space/airborne/ground coordinated communications, and, Industry 5.0 as priority sectors. The Digital Transformation of those Vertical Sectors will rely on use case families such as *digital twins, collaborative robots, and immersive experiences*. Immersive XR, telepresence, and sensing, will drive new billion-user markets.

The objective is to **accelerate digital transformation** across verticals, ensuring Eureka countries' industries remain competitive and sustainable.

2.2.3. Advanced ICT Technologies

CELTIC-NEXT places emphasis on **emerging technologies** such as AI, machine learning, integrated sensing, quantum computing, cloud-to-edge continuum, deterministic networking (incl. Reinvented Core), and, quantum-safe cybersecurity. The integration between microelectronics, cloud, and IoT will strengthen sovereignty. On Vendors side, the accent is put on AI-native RAN, FR3 spectrum (7–24 GHz), and service-based architecture extended to RAN.

Underlying topics of interest are detailed along section 3 and 4 of this document:

- Spectrum and Wireless Technologies:
- Exploration and harmonisation of new spectrum bands, including sub-THz and optical frequencies.
- Development of advanced radio technologies for ultra-high capacity and reliability.
- AI-Native Networks:
- Integration of AI and machine learning at every layer of the network stack for adaptive, self-optimising systems.
- Research into explainable and trustworthy AI in network management and orchestration.
- Network Architecture and Edge Computing:
- Design of decentralised, cloud-native architectures with seamless edge-to-core integration.
- Support for ultra-dense networks and multi-access edge computing.
- Security, Privacy, and Trust:
- Development of end-to-end security frameworks, zero-trust models, and quantum-resistant cryptography.
- Privacy-preserving mechanisms for data and AI-driven applications.
- Sustainability and Energy Efficiency:
- Innovative approaches to reduce network energy consumption and enable circular economy principles.
- Research into materials, hardware, and software for green communications.
- Integration with Vertical Industries:
- Tailored solutions for sectors such as healthcare, manufacturing, transportation, and agriculture.
- Co-design of network capabilities with industry-specific requirements.

The strategic objective is to **lead in key enabling technologies**, ensuring Eureka Countries are not dependent on external suppliers.

2.2.4. Sustainability and Societal Impact

Sustainability is a **cross-cutting priority**. CELTIC-NEXT frames it across environmental, social, and economic pillars. 6G and other new ICT technologies must be sustainable themselves while enabling globally sustainability, enabling other sectors to reduce their footprint. At same time, societal concerns around privacy, ethics, and inclusion must be addressed by upcoming ICT services.

The objective is to ensure that ICT contributes positively to **climate goals, social inclusion, and trust**.

2.2.5. Innovation Ecosystem

CELTIC-NEXT's operational model is **bottom-up and industry-driven**, fostering collaboration among SMEs, academia, and large industry. CELTIC-NEXT has an MoU with 6G-IA and an MoI with ESA in place, ensuring its integration into the innovation ecosystem.

CELTIC-NEXT also promotes the Eureka voice in global standardisation by asking label-awarded projects to disseminate their work into relevant standards.

The Innovation Ecosystem, taken at its broadest sense, encompasses the following stakeholders and roles:

- Industry: Lead technology development, standardisation, and commercialisation; invest in R&D and pilot deployments.
- Academia: Advance fundamental research, train the next generation of experts, and facilitate knowledge transfer.
- Government: Provide strategic funding, align national priorities, and create enabling policy frameworks.
- Standardisation Bodies: Harmonise global standards, facilitate interoperability, and ensure fair competition.
- End Users and Civil Society: Provide feedback on societal needs, ethical considerations, and user acceptance.

The collaboration between CELTIC-NEXT and the Eureka Network of National Innovation Agencies and Ministries provides a powerful playground to achieve this following objective: to **strengthen Eureka's innovation ecosystem**, ensuring agility, inclusiveness, and global impact.

2.3. Strategic Objectives (2026–2032)

From these perspectives, the following five overarching strategic objectives emerge:

The first strategic objective is to strengthen Eureka's digital sovereignty by reducing its dependency on external suppliers. Eureka must lead in critical ICT technologies (and related) such as telecommunications, AI (for and supported by), microelectronics (communication processors), and quantum (like QKD, quantum-resistant cryptography). This first objective is central to CELTIC-NEXT and its SRIA.

The second strategic objective is to Accelerate Innovation Adoption by supporting the elevation from research level to near commercialisation TRL and SME participation. Living Labs and Pilots should also be supported as they establish real-world test environments in urban and rural contexts to validate new ICT concepts and accelerate their adoption (essential to 6G adoption as 5G adoption was not high). Driving cross-sector digital transformation is also essential and can be achieved by fostering

Cross-Disciplinary Research: this goes through encouraging partnerships between telecommunications, AI, hardware, and application domains.

The third strategic objective is to address Societal Challenges by promoting solutions for health, climate, and inclusion. This shall be done by embedding ethics, privacy, and trust in design.

The fourth strategic objective is to Enhance Research-Industry Synergy via Open Innovation Ecosystems by aligning bottom-up research with industry needs. One pathway is to foster collaboration across industry, academia, and startups through open sovereign platforms and shared testbeds. Fostering flexible, rapid innovation cycles, is also one crucial component.

The fifth strategic objective is to prepare for the Future by investing in disruptive technologies (quantum-safe systems, autonomous networks...). This needs Flexible Funding Mechanisms that leverage public-private partnerships, grants, and venture capital to support high-risk, high-reward projects. CELTIC-NEXT wants to support Eureka Countries to be ready for post-2030 challenges.

2.4. Operational approach of CELTIC-NEXT

The **operational approach for the CELTIC-NEXT** programme is based on current proven successful best practices, extending them as needed by the constituency.

CELTIC-NEXT, as a Cluster in the EUREKA cluster program, will also promote and support the Eureka ethos of “business knows best” and we give our community the freedom to create their ideal consortia and to decide on the technological focus of their international R&D projects. The unique value of the clusters is, by negotiation, to help align the business interests with the national ambitions in the Eureka program.

CELTIC-NEXT encourages the ICT community to reach out to the vertical sectors to collaborate on an international and industry-driven R&D projects that cover the whole value chain. All types of players from large companies to SMEs, universities, research institutes and even end users can participate. The Eureka cluster system assists international collaborative projects to access national funding and lets small organisations work in partnership with major industry players on close-to-market projects that generate not only products, but future collaborative eco-systems where the collaborations go long beyond the projects.

Flagship Projects & Collaboration: Launch strategic flagship initiatives to address key industrial challenges and grand societal challenges. CELTIC Flagship projects are special projects, finding birth when both Industry and Public Authorities show a common joint strong interest into developing a specific topic, like CELTIC had with SASER, SENDATE and more recently with AI-NET. Those projects are usually of the range of 50-100 of million Euros for a 3-5 years duration. They are very successful. They are a balance of bottom-up and top-down approaches. One could say that they are at the crossroads of those two models. They are the result of a great collaboration and discussion between all parties involved. CELTIC-NEXT is analysing if it would be possible to increase the rate to one every 2 years.

Industry-Driven, Bottom-up Innovation: Maintain a flexible, industry-led approach that adapts to emerging trends and future market needs.

International Engagement: Broaden international cooperation, including strategic partnerships outside Europe, to leverage global expertise and markets.

2.5. Return on Investment

In an increasingly digital society, CELTIC-NEXT is the key to developing the next generations of enabling telecommunications technologies and end-to-end services. Specifically, CELTIC-NEXT will actively encourage the collaboration of the ICT industry with other industry verticals to facilitate the adoption of advanced ICT technologies into all industry sectors' business models and processes. Over recent years, the environmental aspects of using advanced communications services to monitor and supervise energy-consuming activities and investigate where advanced communications can improve business models and processes by replacing activities with ICT services and reducing carbon footprints for many sectors. CELTIC NEXT activities generate returns on the investment in several major fields:

Industrial Return on Investment impacts

- Retain and develop Europe's and individual Eureka Nations' competitive edge in telecommunications,
- Strengthen Europe's and individual EUREKA nations' vertical industries,
- Unleash open and joint innovation opportunities in a bottom-up way, in larger flagship projects, and finally at the inter-cluster level.

Economic Return on Investment impacts

- Business aspects - Eureka countries and champions' share in the global market,
- Unleash economic opportunities between European nations and Eureka (beyond Europe) countries.

Social Return on Investment impacts

- Support Green Deal objectives,
- Enable the achievement of UN SDGs (Sustainable Development Goals) via ICT solutions,
- Cater for social inclusiveness and create high-value jobs,
- National Security via Cyber projects at the national level, while coherent with EC rules and programs.

Political Return on Investment for Public Authorities

- Trust from their citizens,
- Taxpayers' taxes invested in projects providing demonstrable Social and Economic Return on Investment,
- Target digital autonomy, national and European sovereignty,
- Helping in EC-level decision-making by showing national investment and results.

Standardisation Bodies impacts

- Contributions to standards (future, mid-term),
- Faster time to market for latest standards releases (present, short term).

Regulatory Bodies impacts

- Inform National Regulatory Bodies and Agencies with project-based data and return of experience.
- Bring industrial communities and national regulatory communities closer together to develop a joint understanding of the applicability of technologies and regulations.

2.6. Conclusion

The CELTIC-NEXT SRIA scope and strategic objectives for the 2026-2032 period, supported by the chosen operational approach, will accelerate Eureka and allies' digital sovereignty, sustainability, and societal impact.

3. Key Technological Trends

3.1. Introduction

The coming decade will be defined by a set of **transformative technological trends** that underpin the transition from 5G to 6G and beyond. These trends are not isolated; they are deeply interconnected, shaping the architecture, performance, and societal impact of future networks. Building on **CELTIC-NEXT's** holistic approach, enriched by the 6G-IA European Vision, the SNS-JU SRIA, and vendor perspectives, this section outlines the core technology areas where Europe must invest and lead.

3.2. System & Network Architecture

Advanced system architectures including evolutions in virtualisation, edge computing, programmability, multi-tenancy, control separation, and self-preserving supporting service flexibility, resilience, and intelligent automation. Emerging capabilities such as intent-based networking and fully autonomous, AI-driven network control further raise the level of abstraction at which networks are designed, operated, and optimised.

Dynamic, Composable, and Multi-Tenant Infrastructures: System architecture is evolving toward infrastructures that are highly flexible, dynamically composed, and capable of supporting many stakeholders, such as mobile network operators (MNOs), non-public networks (NPNs), over-the-top (OTT) players, and new verticals. This flexibility is enabled among others by (i) deep virtualization, allowing resources (compute, storage, networking) to be pooled and elastically allocated; (ii) service function chaining, where architecture components are dynamically assembled as service needs evolve; and (iii) Native integration of diverse ICT resources, including AI/ML capabilities, at both infrastructure and platform levels. In addition, intent-based orchestration frameworks allow tenants to specify high-level intents (e.g., performance, security, sustainability goals), which are then automatically translated into low-level configurations across domains.

Programmability and Controllability: Future architectures are designed for maximal programmability at every infrastructure level, leveraging among others (i) Unified controllability frameworks spanning all resources (radio, compute, optical, edge, etc.); (ii) Conflict resolution and scheduling mechanisms, allowing simultaneous, multi-tenant deployments with tailored requirements for each tenant; and (iii) Platform-level AI services (AIaaS) for both system management and user-exposed programmability. Building on these, intent-based control and policy-driven automation, combined with AI-native closed control loops, enable networks that can autonomously route traffic, reconfigure resources, and heal faults without human intervention, while still allowing human-in-the-loop oversight where required.

Advanced Governance and Service Customization: Key themes include robust policies for isolation, security, compliance, and correctness, supporting among others (i) Per-tenant policy and customization, with local adaptation to compliance requirements and data governance; and (ii) Isolation and security mechanisms so that different tenants and applications can safely share resources. Autonomous AI-based control further requires policy mechanisms for explainability, auditability, and safe operation of learning-based functions, ensuring that automated decisions respect regulatory, ethical, and sustainability constraints.

Integration of All Network Domains: The architecture vision integrates all network domains (radio, fixed access, edge, core, optical backbone, and non-terrestrial networks) into a seamless platform. This means among others (i) network elements (incl. user, control, and management planes) across both mobile and fixed domains are seen as composable resources orchestrated to create custom service slices; (ii) over time, end-to-end communication system architectures (with mobile often acting as the main innovation driver) mirror flexible, programmable computer programs running on top of a shared infrastructure. Multi-domain integration also extends to joint communication and sensing, where, for example, fibre-based infrastructures are used simultaneously for high-capacity transport and distributed sensing, feeding rich telemetry into AI-based control loops for improved reliability, security, and sustainability.

System Sustainability and Efficiency: Energy efficiency can be dramatically improved by new technologies, cooperation at the resource level and mechanisms to optimise resource use and energy consumption across domains. Examples are: ultra-low power optical transceivers (e.g., co-packaged optics), transceivers that only consume energy when needed, for example using new fast optical components to enable sleep and awakening modes, energy saving methods based on joint control of signal modulation, coding and processing, energy-aware network planning and control methods, including AI techniques, and enhanced optical communication infrastructure with a capillary network of sensors to enable energy-saving measures. Extended lifetime optical components and sub-systems based on circular-economy compatible materials, modular subsystem designs and where higher reliability is software-enabled by programmability. In this context, fibre sensing integrated with communications can provide fine-grained environmental and infrastructure monitoring, enabling new applications, as well as proactive maintenance and energy optimisation across the network.

Continuous Innovation and Standardisation: These architecture trends require strong, ongoing collaboration to bring together industry, academia, and policy to adapt quickly to technological change and to structure research and innovation to reflect the increasingly interconnected nature of infrastructure and application layers. Standardisation of intent models, interfaces for AI-driven control, and joint communication-sensing capabilities will be essential to ensure interoperability and to avoid fragmentation.

Core Network Evolution: In cellular networks, the core network is the brain of future communication systems, and will likely follow an evolutionary approach rather than a clean-slate redesign compared to 5G. The consensus among the stakeholders in the ecosystem is that the 6G core will build on the 5G service-based architecture (SBA) foundation, extending its principles to new interfaces and functionalities to achieve more flexibility, modularity, and support for multi-vendor deployments. Key innovations extend SBA concepts to RAN-core interfaces, enabling modular composition of network functions and services. This architecture lets operators dynamically configure and optimise networks for diverse use cases. AI-native cores, with embedded KPI monitoring and machine learning, empower networks to autonomously adapt resources and policies to changing demands. Future core networks may evolve from the 5G SBA toward a microservices-based, cloud-native design. This enables highly customizable deployments across private and public clouds, allowing operators to scale, update, and orchestrate fine-grained functions independently. Such flexibility supports rapid innovation, vertical-specific requirements, and seamless deployment from centralised clouds to edge data centres, ensuring ultra-low latency, resilience, and a high degree of autonomous, AI-driven operation.

3.3. AI-Native Networks

AI-native networks are emerging as a transformative foundation for next-generation connectivity, fundamentally shifting how networks are designed, operated, and experienced. Rather than serving as a peripheral optimization layer, artificial intelligence (AI) is becoming the operating principle, integral to all aspects of network management, service delivery, and performance.

AI-Native Evolution: From 5G to 6G: 5G networks incorporated AI and machine learning (ML) mainly as tools for network optimization, addressing functions such as traffic steering, anomaly detection, and resource management. 6G is conceived as "AI-native", meaning AI is embedded from the outset of its definition. In this paradigm, all stages in the network lifecycle (from planning to operation and maintenance) are autonomous, data-driven, and capable of self-optimization and adaptation. Major chip vendors position the industry trend in terms of AI-for-RAN (using AI for radio access network optimisation), AI-on-RAN (deploying AI workloads on RAN infrastructure), and AI-and-RAN (designing the RAN as inherently intelligent), extending intelligence horizontally and vertically across all network layers. Major telecommunications system vendors highlight how network functions on both control and user planes are increasingly powered by AI, enabling intent-based orchestration, closed-loop automation, and real-time self-configuration. Europe underlines trustworthy AI, focusing on frameworks for transparency, explainability, and robust compliance with the EU AI Act. This aligns the push for AI-native networks with European legal and ethical standards, mandating AI systems to be auditable, accountable, and non-discriminatory across all networked applications.

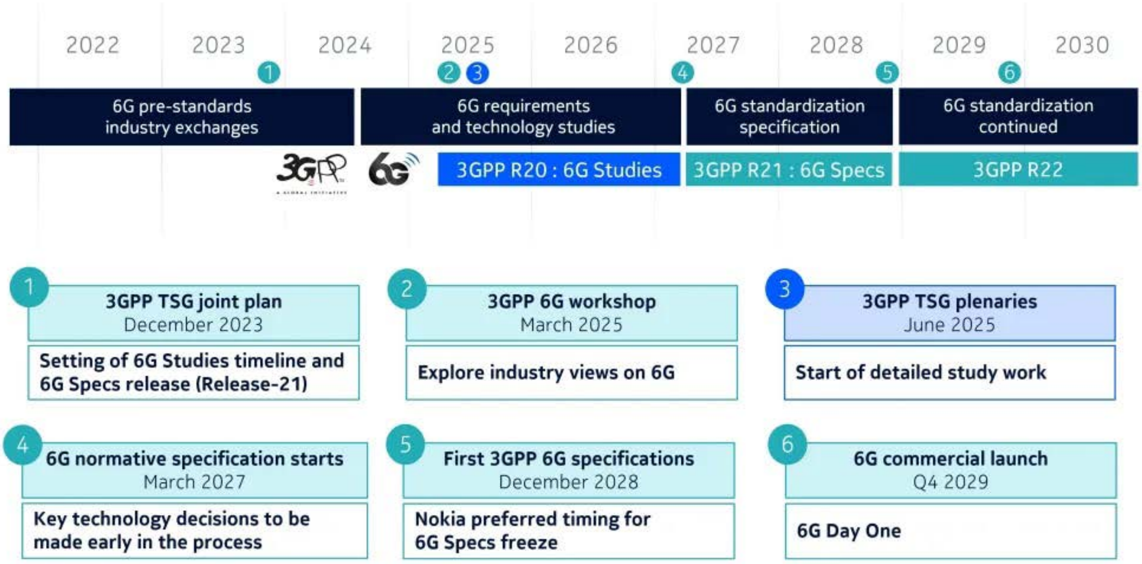


Figure 1 : 3GPP 6G Roadmap (source Nokia)

AI-Driven Resource Management Examples: As an example, in an AI-native network, dynamic spectrum allocation is managed by distributed AI agents that continuously learn and reason from vast network telemetry. These AI systems autonomously optimise frequency usage in real time, maintaining service quality while minimising energy use and ensuring fair coexistence with other services. Decisions are made instantaneously, enabling seamless adaptation to demand surges, interference, or new devices, with oversight for compliance and transparency. In a further example, AI-driven resource optimisation in networks involves the dynamic management of bandwidth and traffic flows to enhance performance and efficiency. AI systems analyse continuous streams of telemetry data from base stations, edge nodes, and core networks, covering metrics such as user demand, interference levels, latency, and device density. Based on predictive analytics and reinforcement learning models, the system autonomously adjusts resource allocations, e.g. to allocate more bandwidth to high-demand sectors or services and conserving energy in low-demand areas. To avoid or mitigate congestion and maintain QoS levels, the system reroutes traffic to underutilised paths. Pre-emptive scaling of computational resources in edge clouds support latency-sensitive applications.

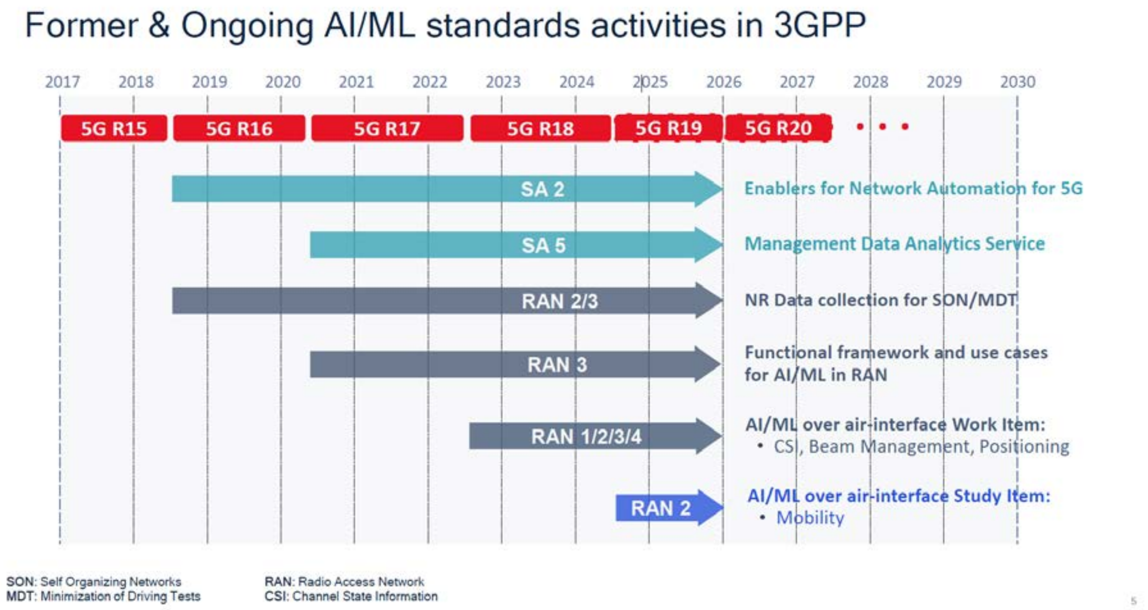


Figure 2 : Former & Ongoing AI/ML standards activities in 3GPP, source [***https://www.3gpp.org/news-events/3gpp-news/ai-ml-2025***](https://www.3gpp.org/news-events/3gpp-news/ai-ml-2025)

3.4. ICT for AI

ICT for AI refers to the design and deployment of information and communication technologies (ICT) that specifically enable, accelerate, and scale artificial intelligence systems. While "networks for AI" focus on connectivity, ICT for AI encompasses the entire digital infrastructure stack, from compute and storage to networking and data management, that supports AI development, training, and deployment.

At its core, ICT for AI is about creating digital infrastructures that are AI-ready by design. This means moving beyond traditional ICT systems toward architectures purpose-built to support the demanding requirements of artificial intelligence across training, inference, and deployment.

Compute: High-performance processors, GPUs, TPUs, and emerging neuromorphic chips form the engines of AI, enabling complex model training and real-time inference. These specialised processors are the workhorses that allow AI systems to scale from research labs to industrial deployments.

Equally important is the **storage and data fabric**. AI thrives on data, and infrastructures must be capable of handling massive, diverse datasets with ultra-low latency. By ensuring seamless access to distributed sources, the data fabric allows models to continuously learn, adapt, and refine their outputs, whether they are powering digital twins, semantic communications, or autonomous systems.

The third pillar is **networking**. Ultra-fast, resilient interconnects are essential to link compute and data resources across the edge-cloud continuum. These networks ensure that distributed AI workloads can run efficiently, whether in centralised data centres, edge nodes close to users, or hybrid environments spanning multiple domains.

Finally, **orchestration and platforms** provide the intelligence to tie everything together. Cloud-native, modular environments allow AI services to be deployed flexibly, scaled dynamically, and tailored to specific verticals. From centralised clusters to edge devices, orchestration ensures that AI workloads are not only efficient but also resilient and adaptive to changing demands.

Building infrastructures that are truly AI-ready comes with significant hurdles. On the **compute side**, specialized processors deliver the computational capacity AI needs, but scaling them sustainably in view of energy demand is a considerable challenge. **Data and storage fabrics** must handle massive, distributed datasets with low latency, yet ensuring quality, privacy, and compliance adds complexity. **Networking** faces the challenge of providing ultra-fast, secure interconnects across edge, cloud, and core, while avoiding congestion and fragmentation. Finally, **orchestration platforms** must manage heterogeneous environments, automate lifecycle processes, and guarantee trust and explainability—tasks that grow harder as AI services diversify.

Across all layers, global issues of **energy efficiency, interoperability, security, cost, and sovereignty** remain central, shaping how ICT for AI can scale responsibly and reliably. Overall, this concept establishes ICT as a proactive foundation for AI innovation, enabling applications to run securely, sustainably, and at scale.

3.5. Sustainability and Energy Efficiency

Sustainability and energy efficiency are increasingly important as technical requirements as well as a societal imperative integral to future communication networks. In the scope of 6G, the SNS JU has introduced sustainability as a dual concept, namely **Sustainable 6G**, which focuses on making the networks themselves energy-efficient, resilient, and environmentally responsible; and **6G for Sustainability**, which emphasizes 6G's role in enabling other sectors, such as transportation, healthcare, and manufacturing, to reduce their own sustainability impacts through digital innovation and smart connectivity. Certainly, this duality of the concept can be transposed to all ICT holistically.

Without innovation, ongoing network densification and the use of new frequency bands risk increasing energy consumption linearly. This creates an urgent need for breakthroughs in network design, resource optimization, and energy management to avoid unsustainable growth in energy demand. Industry leaders advocate for a comprehensive and holistic approach to energy savings. This encompasses improving device-level energy efficiency across the user equipment ecosystem, enhancing network equipment and infrastructure energy performance, and incorporating continuous carbon footprint monitoring and automated reporting systems to support environmental accountability.

Research priorities include the characterization of sustainability KPIs, validation of critical technologies for energy reduction, and piloting of energy-efficient network solutions. These efforts root sustainability in system architecture, operations, and business models. Beyond technical performance, sustainability is viewed as essential for societal well-being, economic competitiveness, and environmental stewardship. Aligning ICT development with European and global ambitions like the European Green Deal and the UN Sustainable Development Goals is a key directive.

3.6. Spectrum Evolution

Spectrum evolution as a key enabler for future smart networks with a focus on increasing spectrum agility, expanding usable frequencies, and adopting intelligent management techniques as foundational steps for future-proof, high-performance, and innovative network architectures. The main topics supporting spectrum agility and usability in future mobile networks are:

Spectrum Diversification: There is a need for exploiting a much broader range of frequency bands, beyond traditional sub-6 GHz and millimetre-wave (mmWave) bands The mid-band range 7–24 GHz - FR3 is emerging as the new sweet spot for 6G deployment. It offers a balance between wide-area coverage (similar to sub-6 GHz) and high-capacity performance (closer to mmWave), making it suitable for both urban densification and broader regional connectivity. In a longer-term perspective, one should also consider bands in the sub-THz and THz range, primarily for very short-range, extreme-capacity and sensing-intensive scenarios. A diversified spectrum portfolio is therefore needed, where lower and mid bands remain key for coverage and massive machine-type communications, while higher bands (mmWave, sub-THz and THz) mainly target extreme throughput and ultra-low latency use cases.

Dynamic and Flexible Spectrum Management is a strategic enabler for high-performance, sustainable, and resilient next-generation networks. It ensures that spectrum evolves from a rigid, scarce resource into a fluid, intelligently managed asset. Dynamic spectrum allocation and sharing mechanisms, including real-time spectrum trading, spectrum sensing, and cognitive radio techniques are tools that enable networks to adaptively and efficiently use available spectrum resources. Leading industry vendors advocate spectrum sharing across several technologies and perhaps even operators. This approach enables 5G, 6G and other wireless systems to coexist in overlapping bands, ensuring a smooth migration path and reducing disruption for operators.

Spectrum Coexistence and Harmonisation are strategic imperatives for next-generation mobile networks, to safeguard performance and ensure equitable access to spectrum resources. While dynamic and flexible spectrum management mainly addresses how different generations and configurations of mobile systems share and adapt spectrum within a given mobile portfolio, coexistence and harmonisation focus on sharing and coordination between different services and technologies (e.g., mobile networks, fixed links, satellite systems, Wi-Fi) and across borders. As new technologies and more services compete for spectrum, robust coexistence strategies to avoid harmful interference, cross-border and cross-service harmonisation of bands and technical conditions, and regulatory frameworks that support such sharing are essential.

Integrated Sensing and Communication: The importance of integrated sensing and communication (ISAC) functionalities is growing. In many envisioned 6G solutions, the same radio resources are used for data transmission as well as for sensing the environment, which directly raises questions of spectrum allocation, coordination, and coexistence between communication and sensing functions. This conceptual framework, therefore, fits naturally under spectrum considerations and allows for the co-design of spectrum usage for both data transmission and environmental or situational awareness, enabling new services such as localisation and mapping.

Research and Policy Recommendations: Europe must reaffirm leadership in spectrum standardisation, policy innovation, and testbeds for emerging radio technologies. Through active participation in ITU standardisation and the WRC-27 negotiations, European stakeholders must secure harmonised allocations of FR3 to support EU's digital sovereignty agenda. Spectrum fragmentation, coordination across multiple bands, and managing the transition from legacy to next-generation spectrum utilisation schemes are related research and innovation challenges.

3.7. Network Enablers

A comprehensive set of network enablers is foundational to the next generation of smart networks and services for future digital infrastructures. These enablers embody Europe's cross-disciplinary strengths, integrating advances from telecommunications, microelectronics, cloud computing, and artificial intelligence.

Deterministic Networking is a critical enabler for guaranteeing ultra-low latency and reliability (URLLC), which are essential for mission-critical applications like autonomous transport, industrial automation, and remote healthcare. Deterministic networks use precise scheduling and path control to deliver predictable performance.

Edge-Cloud Continuum concerns the seamless orchestration of computing, storage, and networking resources across edge and core clouds, and is seen as a driver for real-time processing and data sovereignty. The capacity to procure sovereign cloud services at the edge ensures compliance and responsive service delivery, particularly for industrial and public sector use cases. The edge-cloud-continuum is a necessary precondition for collaborative communication and computing.

Photonics has emerged as the transparent backbone of next-generation connectivity. As digital infrastructures evolve, the sheer scale of data traffic demands interconnects that can deliver massive capacity with uncompromising efficiency. High-capacity optical links have become the fundamental nervous system of backhaul and core networks. At the metro aggregation level, photonic technologies enable the seamless consolidation of traffic from diverse access networks, able to handle the exponential traffic growth. Moving into long-haul transport, photonics provides the ultra-reliable, energy-efficient conduits that stitch together continents, research infrastructures, and global enterprises. Equally important is the energy efficiency of photonics. As sustainability becomes a defining principle of digital transformation, optical interconnects offer a path to drastically reduce the environmental impact of data transmission. By minimising electrical-to-optical conversions and leveraging advanced modulation techniques, photonics ensures that scaling capacity does not come at the expense of environmental responsibility.

Digital Twins: By creating virtual replicas of physical digital infrastructures, digital twins allow operators and stakeholders to see, understand, and anticipate how complex systems behave in real time. These replicas are living, dynamic environments fed by continuous telemetry from sensors, devices, and applications. Through the integration of AI and machine learning, digital twins can analyse live data to detect anomalies, predict failures, and recommend corrective actions before disruptions occur. This makes them indispensable for predictive maintenance, reducing downtime and increasing resilience. Beyond maintenance, digital twins serve as testbeds for innovation. They allow rapid experimentation with new protocols, configurations, or service deployments without risking disruption to live networks. This capability accelerates the pace of innovation, enabling operators to trial advanced orchestration strategies, energy-saving techniques, or security enhancements in a safe, controlled environment. At the strategic level, digital twins act as a catalyst for autonomous network management by simulating and optimising traffic flows, resource allocation, and service performance, thereby providing the intelligence for self-organising, self-healing networks. Ultimately, digital twins transform networks from reactive infrastructures into proactive, intelligent ecosystems.

Non-Terrestrial Networks (NTNs): The role of NTNs is growing, including beyond satellites also high-altitude platforms. The concepts are currently used for patching connectivity gaps and expanding service reach. However, NTNs should no longer be seen merely as backup solutions for underserved areas. In the vision for future mobile communications, NTNs become native components of the connectivity fabric, enabling direct, high-quality links between devices, vehicles, and infrastructures regardless of geography. NTNs extend the edge-cloud continuum into the sky, providing direct connectivity that complements terrestrial networks. This integration allows applications to dynamically select the most efficient path based on latency, resilience, and sovereignty requirements. With advances in antenna design, spectrum harmonisation, and multi-RAT integration, NTNs enable direct-to-device communication without relying on ground gateways. This unlocks new possibilities for end-user devices and autonomous systems to connect directly to satellites or high-altitude platforms, ensuring service continuity even in mobility-intensive or remote scenarios.

Cognitive Networks: Next-generation networks will be self-organising and self-learning, able to intelligently adapt to changing conditions; dynamically adjusting routing, spectrum allocation, and power management. This cognitive ability, powered by AI and advanced analytics, boosts efficiency and reliability, creating networks that continuously tune themselves for optimal performance. Efficiency is increased as resources are allocated precisely where they are needed, and reliability is enhanced through proactive fault detection and self-healing mechanisms. In practice, this means that whether facing sudden surges in demand, interference in spectrum, or energy constraints, the network can reconfigure itself autonomously to maintain optimal performance.

Semantic Communications represent a paradigm shift in communications. Instead of treating data as a stream of raw bits, networks begin to interpret and prioritize the meaning behind the information being transmitted. This approach leverages advances in artificial intelligence, natural language processing, and contextual awareness to ensure that only information relevant to the user or application intent is conveyed. At the application level, semantic communications can transform user experience. A connected vehicle does not need every byte of traffic data; it needs the meaningful alerts about congestion or hazards. A healthcare monitoring system does not need to transmit every heartbeat; it needs to flag anomalies that matter for diagnosis. By focusing on contextually significant information, semantic communications ensure that networks deliver what is needed, not just what is available. By embedding semantic awareness into communication protocols, networks can anticipate user needs, adapt dynamically to changing contexts, and support collaborative applications across domains. In this way, semantic communications become a cornerstone of sustainable, human-centric digital infrastructures, aligning technical efficiency with societal impact.

3.8. ICT Infrastructure resilience

Resilience in European ICT infrastructures is about ensuring that digital systems remain secure, reliable, and adaptive under stress. Current research focuses on cybersecurity, critical infrastructure protection, resilience of wireless protocols against malicious interference, supply chain dependencies, cyber-attacks, and regulatory compliance. Resilience has become a **strategic priority for Europe's digital infrastructures**, as networks and services are increasingly critical to economic stability, public safety, and sovereignty. The EU emphasises resilience in policy frameworks such as the NIS2 Directive (cybersecurity of networks and information systems) and the CER Directive (protection of critical entities), alongside coordinated risk assessments of future ICT infrastructures, in particular in the context of 5G and 6G.

At the forefront lies **cybersecurity and trust**, where advanced defence mechanisms must evolve to counter increasingly sophisticated threats, including AI-driven attacks. Protecting critical infrastructures, from telecom networks and data centres to submarine cables and cloud platforms, is equally essential, ensuring continuity of services that underpin society and the economy.

To achieve this, research is focusing on designing **resilient architectures** that are distributed, fault-tolerant, and capable of self-healing, so networks can adapt dynamically and maintain service even under stress. Yet resilience must also align with Europe's climate ambitions, making **energy efficiency**

and sustainability central to the equation. Digital infrastructures, from data centres to 5G/6G networks, consume vast amounts of power, making them vulnerable to energy price shocks and supply disruptions. By increasing efficiency or the introduction of local renewable energy sources, infrastructures become more resilient and less dependent on external sources. This ensures continuity of critical services for society, strengthens economic competitiveness, and aligns resilience with Europe's climate goals.

Another cornerstone is interoperability and standardisation, enabling diverse ICT systems to work seamlessly across borders and sectors. This ensures that **resilience is not fragmented but coordinated at European scale**. Finally, governance and regulation provide the framework to embed resilience strategies within EU values of sovereignty, privacy, and trust, ensuring that technological strength is matched by ethical and societal responsibility.

3.9. Security and Trust

Network and service security is a foundational pillar for future communication networks, services and applications. The vision is that security is integrated holistically across all domains of the network and service infrastructure providing easy to use security and trust services for the applications, hiding the increasingly complex and distributed network environment. Network and service security are key strategic enablers for European digital sovereignty and resilience, focusing on securing critical supply chains, safeguarding citizen data, and protecting the functioning of essential services.

Distributed and Multi-Layered Security Architectures: Security strategies focus on distributed architectures, recognising that centralised security models are insufficient for the scale and complexity of smart, federated networks. Security functions must be embedded at every layer ensuring comprehensive defensive coverage and resilience against threats. This distributed approach enables rapid detection and mitigation of attacks localised to specific domains without compromising the whole network. The need for robust authentication schemes that support diverse device types, user profiles, and tenant models (including MNOs, non-public networks, and OTT players) is highlighted. Trusted identity management underpins network access and service provisioning, enabling secure multi-tenancy and resource sharing in a highly programmable and virtualised environment.

Continuous Security Assessment and Adaptive Defence: Future networks are expected to implement continuous, dynamic security assessment. Leveraging multi-agent AI-based learning and analytics, networks will autonomously monitor behaviour patterns, detect anomalies, and predict emerging risks. This real-time intelligence supports adaptive defences that reconfigure network policies, isolate threats, and maintain service integrity without human intervention. At the same time, compliance to evolving European and international standards and certification frameworks is required. This includes alignment with regulations such as the EU Cybersecurity Act, the Cyber Resilience Act, and the NIS2 Directive, as well as proactive engagement with certification schemes tailored for ICT infrastructure and services.

Integration Across Software, Hardware, and Operations: Security is integrated throughout software development lifecycles, hardware design (including secure silicon and trusted execution environments), and operational workflows. This end-to-end secure lifecycle approach minimises vulnerabilities arising from component supply chains, software bugs, or configuration errors.

Quantum-safe cryptography is becoming a critical focus as quantum computing advances threaten the security of traditional encryption methods. Future networks are preparing by researching and implementing quantum-resistant algorithms that can safeguard confidential communication against potential quantum attacks. **Privacy-preserving AI techniques**, such as split learning, enable collaborative machine learning without exposing raw user data. This approach partitions AI model training between clients and servers, balancing computational loads while ensuring sensitive data remains protected. Such methods are key for secure AI deployment in distributed networks. **Trust architectures** emphasise multilateral frameworks that manage trust relationships across diverse network operators and regulatory domains. These frameworks ensure interoperability, accountability, and security assurances in cross-border contexts, underpinning secure multi-stakeholder network ecosystems. Additionally, **Integrated Sensing and Communication (ISAC)** technologies bring new security and privacy implications by combining communication and environmental sensing functions. The dual-use nature of ISAC necessitates advanced safeguards to prevent unauthorised data access or misuse, preserving user privacy while enabling innovative applications.

3.10. Private Networks and Non-Public Networks:

Private networks span a wide spectrum of technologies, each tailored to the needs of specific sectors, environments, and applications. When utilising cellular technology deployments like 5G or the emerging 6G the notion of **non-public networks (NPNs)** has been established.

In the enterprise world, **Wi-Fi–based private networks** provide cost-effective, flexible connectivity across campuses, offices, and factories. However, they can struggle with interference and predictable latency, which is why industries often complement them with more deterministic solutions. For manufacturing plants, energy grids, and transport systems, wired private networks such as Industrial Ethernet are the gold standard. These networks deliver high reliability and deterministic performance, ensuring that robotic arms, conveyor belts, or power distribution systems operate with precision. However, their limitation lies in the lack of mobility support.

Meanwhile, the rise of the Internet of Things has given prominence to **low-power wide-area networks** (LPWANs) such as LoRaWAN. These private networks are designed for scale and efficiency, connecting thousands of sensors across farms, cities, or utility grids. They don't carry heavy data loads, but they excel at transmitting small packets over long distances with minimal energy use. In more dynamic or **mission-critical contexts, mesh networks provide resilience** by allowing devices to connect directly to one another, forming a self-healing web of connectivity. Defence operations, emergency response teams, and smart city deployments often rely on these networks to ensure communication persists even if parts of the infrastructure fail. For industries operating in remote or global environments, maritime shipping, aviation, or mining, satellite-based private networks provide dedicated coverage where terrestrial infrastructure cannot reach. Though they face challenges with latency and cost, they ensure that connectivity is borderless.

Cellular non-public networks (NPNs) stand out as a **new generation of enterprise infrastructure**. Unlike Wi-Fi or other local private networks, cellular NPNs are designed to deliver mission-critical performance: ultra-low latency, high reliability, and secure, sovereign control over data flows. They scale seamlessly across large sites, support mobility without interruption, and integrate directly with public mobile networks when needed. This makes them particularly suited for industries such as manufacturing, logistics, healthcare, and energy, where downtime or interference can have serious consequences.

Cellular NPNs face several global challenges. **Spectrum availability and harmonisation** remain critical, as enterprises need predictable access to frequencies across regions. **Interoperability and standardisation** are also pressing issues, ensuring that cellular and non-cellular private networks can coexist and complement one another. At the same time, **security and trust frameworks** must evolve to protect sensitive industrial and public sector data in multi-stakeholder environments. Finally, the **cost**

and complexity of deployment can be a barrier, especially for SMEs, while **regulatory compliance and sovereignty concerns** add layers of responsibility in cross-border contexts.

3.11. Conclusion

The key technological trends shaping ICT are **AI-native design, sustainability, spectrum innovation, enabling technologies, core network evolution, infrastructure resilience, as well as security and trust.** Europe's leadership depends on aligning research, standardisation, and deployment in these areas. By doing so, Europe can ensure that future digital infrastructures are a technological leap as well as a **societal and environmental milestone.** More details can be found in the three annexes of this document:

- Annex 1 - Enabling Technologies to be mastered,
- Annex 2 - Main technical areas of Research,
- Annex 3 - High Level Fields of Applications.

Grand Challenges

4. Grand Challenges

4.1. Introduction

Europe faces profound and interconnected challenges that go well beyond the technical performance of any single technology. While advancing network capabilities is critical, it is equally essential to ensure economic, social, and environmental sustainability. At the same time, Europe is increasingly losing strategic ground in key technology domains: consumer devices, cloud platforms, and advanced semiconductor manufacturing remain dominated by American and Asian companies. This technological dependence poses risks for Europe's digital sovereignty, economic resilience, and ability to set global standards.

In this context, the transition from 5G to 6G is not merely about achieving higher data rates, lower latency, or enhanced connectivity. It represents a paradigm shift in the role that networks play within society, the economy, and the environment. 6G has the potential to integrate digital infrastructures with smart environments, energy-efficient systems, and AI-driven services, creating networks that are not only faster but also more intelligent, sustainable, and human-centric. Achieving this vision requires Europe to address multiple, interlinked priorities: embedding sustainability at the core of network design, empowering citizens through trustworthy digital services, enabling advanced smart cities and industries, and safeguarding technological and industrial competitiveness in a rapidly evolving global landscape.

These strategic imperatives are recognised across multiple European initiatives and foresight documents. They are reflected in the CELTIC-NEXT holistic vision, which emphasizes collaborative, cross-sector innovation; in the 6G-IA European White Paper, which outlines Europe's ambitions for next-generation networks; in the SNS-JU Strategic Research and Innovation Agenda, which maps the path for societal, economic, and environmental impact; and in vendor perspectives gathered in 2025, which highlight industry expectations, market trends, and the need for Europe to maintain leadership in critical technology areas. Taken together, these insights underscore that the evolution to 6G is not just a technological upgrade, but a strategic opportunity to align Europe's digital infrastructure with societal goals and global competitiveness.

4.2. Resilient, Ubiquitous, and Energy Aware Infrastructure

This challenge focuses on designing and deploying the next generation of digital networks that are not only high-performing but also robust, secure, and ubiquitously available, serving dense urban environments, suburban areas, and the most remote regions alike. The ambition is to create a foundational digital infrastructure capable of supporting the rapidly growing demands of society, industry, and public services, while ensuring resilience in the face of an increasingly complex threat landscape. Modern networks must withstand disruptions from a variety of sources, including cyberattacks, natural disasters, equipment failures, or unanticipated system overloads, all while maintaining seamless service for citizens, businesses, and critical societal functions.

Ubiquity and inclusion are central to this challenge. Reliable connectivity should be a universal enabler, allowing every individual and organisation, regardless of geographic location, socio-economic status, or digital literacy, to access essential services, educational resources, healthcare platforms, and economic opportunities. Ensuring broad coverage requires innovative combinations of terrestrial networks (fibre, 5G, and emerging 6G), non-terrestrial networks (satellite-based links), and localised micro-network solutions, particularly in rural, underserved, or critical areas.

Energy efficiency and environmental sustainability are embedded at the infrastructure level. Network components (from radio access networks to edge computing nodes and large-scale data centers) must consume drastically less energy, targeting reductions up to 100× compared to current 5G deployments. AI-driven energy management, dynamic sleep modes, and low-power radio designs will optimise energy use, while circular design principles for hardware lifecycles (modularity, component reuse, and end-of-life traceability) will minimise material waste and carbon footprint. Real-time infrastructure-level carbon monitoring, enabled by integrated sensors and telemetry, will provide detailed insights into energy consumption and emissions, supporting continuous improvement and evidence-based environmental policies.

Beyond technical performance, this resilient, energy-efficient, and ubiquitous infrastructure will act as a foundation for a wide range of critical digital services. It will enable industrial automation, advanced mobility solutions, autonomous systems, large-scale IoT deployments, and smart city applications, all while ensuring reliability, safety, and accessibility. Key objectives include:

- **Multi-layer resilience** achieved via redundancy, self-healing capabilities, automatic rerouting, and rapid recovery protocols, ensuring continuous service during failures, cyberattacks, or environmental disruptions.
- **Comprehensive coverage** without gaps, integrating terrestrial, non-terrestrial, and localized micro-network technologies to guarantee connectivity in rural and remote areas, critical infrastructure sites, and underserved communities.
- **Circular infrastructure approach**, emphasizing modular hardware design, component reuse, sustainable manufacturing, and traceability of ICT equipment across its full lifecycle.
- **Infrastructure-level carbon monitoring**, incorporating sensors and telemetry to provide real-time insights into energy consumption, emissions, and overall environmental impact, enabling data-driven sustainability strategies.

4.3. Trustworthy, Secure, and Human-Centric Digital Ecosystems

Modern digital networks are no longer mere technical infrastructures; instead, they have evolved towards increasingly social infrastructures that underpin human activities, economic interactions, and societal trust. As digital services become central to everyday life, networks must ensure that citizens, businesses, and institutions can rely on them to operate securely, transparently, and inclusively. This specific challenge focuses on developing AI-driven and digital services that are explainable, privacy-preserving, and fully aligned with European ethical, legal, and regulatory frameworks, including the EU AI Act and the Data Act. Security and trustworthiness are embedded from the ground up, protecting users and critical infrastructures against evolving cyber threats while safeguarding sensitive data in a future-proof manner.

A human-centric approach is essential. Digital inclusion, accessibility, and societal trust are not optional features: they are core design principles. Citizens must be able to engage confidently with digital services, regardless of location, age, socioeconomic status, or digital literacy. This requires accessible and affordable connectivity, intuitive multilingual interfaces, and protective measures against misinformation, harassment, and other forms of digital exclusion. Furthermore, the design of AI and data-driven services must prioritise transparency and accountability, ensuring that users understand how decisions are made and can control their personal data.

Security and privacy must be guaranteed at multiple layers of the network. Emerging threats, including quantum computing attacks, require the integration of post-quantum cryptography and advanced threat detection mechanisms from the architectural level upwards. At the same time, privacy-preserving technologies such as federated learning, secure multi-party computation, and differential privacy enable the secure and ethical use of data for AI applications, allowing insights to be gained without compromising individual privacy. Key objectives include:

- **Zero-trust and post-quantum security**: Integration of a zero-trust framework and post-quantum cryptography at the architecture level to protect critical infrastructures, ensure future-proof confidentiality, and maintain trust in the network.
- **AI transparency and user control:** Development of explainable AI models, user-accessible data provenance logs, and mechanisms that allow individuals to understand and control automated decisions, in full compliance with the EU AI Act and Data Act.
- **Privacy-preserving data sharing:** Implementation of advanced techniques such as federated learning, secure multi-party computation, and differential privacy to enable collaborative data use while safeguarding personal information.
- **Digital inclusion and accessibility:** Ensuring affordable and reliable connectivity, designing multilingual and inclusive interfaces, and providing accessibility-by-design features for vulnerable groups, reducing digital divides across society.
- **Societal trust and safety mechanisms:** Deployment of tools for misinformation detection, content authenticity verification, and harassment protection to promote safe, trustworthy digital spaces and increase public confidence in digital services.

4.4. Smart Environments enabled by Convergent Platforms

Smart environments are increasingly central to Europe's vision of a digital, sustainable, and inclusive society. They represent a convergence of physical and digital systems, where connected devices, intelligent platforms, and advanced analytics collaborate seamlessly to enhance quality of life, economic productivity, and environmental sustainability. This challenge focuses on integrating heterogeneous technologies, such as Internet of Things (IoT) devices, edge and cloud computing, artificial intelligence, and industrial platforms, into cohesive, interoperable ecosystems that support diverse applications across cities, regions, and sectors.

The objective is to transform scattered digital infrastructures into unified smart environments that are not only efficient and intelligent but also accessible and resilient. Applications range from smart urban areas and autonomous transport systems to renewable energy grids, precision agriculture, and advanced manufacturing. Achieving this vision requires bridging sectoral silos, ensuring rural and remote regions are not left behind, and harmonising standards to promote interoperability and scalability. Open interfaces, cross-sector collaboration, and adherence to European standardisation efforts will foster innovation, strengthen digital value chains, and enable sustainable resource management across all environments. Key objectives include:

- **Unified data layer and open interfaces:** Establishing a common data framework that enables seamless interoperability between IoT devices, digital twins, edge/cloud orchestration, and vertical platforms, ensuring that data can flow securely and efficiently across sectors and regions.

- **Cross-sector convergence:** Breaking down traditional silos between energy, manufacturing, mobility, smart buildings, and agriculture, enabling multi-domain applications, improved resource utilisation, and holistic environmental management.
- **Edge-native orchestration:** Deploying compute and intelligence close to data sources to enable real-time processing for latency-critical applications, such as industrial automation, autonomous vehicles, and local environmental monitoring.
- **Rural and regional cohesion:** Developing plug-and-play, cost-effective solutions that can operate in low-connectivity or resource-constrained environments, ensuring that both urban and rural communities benefit from smart environments without leaving regions behind.
- **Aligned standardization roadmap:** Accelerating the adoption of European open standards to facilitate interoperability, scalability, and vendor neutrality while supporting European leadership in digital platforms and ecosystems.

4.5. Sustainability and Climate Responsibility

The evolution toward 6G networks represents a paradigm shift in digital services, moving beyond traditional communication to deliver fully integrated sensing, positioning, and computing capabilities as native network functions. This challenge focuses on enabling immersive, intelligent, and proactive digital experiences that combine ultra-high-speed communication, distributed computing, and real-time environmental awareness. Emerging applications, including extended reality (XR), holographic telepresence, multi-sensory interfaces, autonomous mobility, and telemedicine, will demand unprecedented data rates, ultra-low latency, and seamless orchestration of network and computational resources.

6G networks will act as more than a communication medium: they will function as distributed computational platforms, providing real-time AI inference and predictive analytics at the edge. Integrated sensing and communication (ISAC) capabilities will enable networks to perceive and respond to the physical environment, offering contextualised, proactive services. At the same time, user-centric considerations such as privacy, data sovereignty, interoperability, and personalisation will be deeply embedded into network design, ensuring that the benefits of next-generation digital services are accessible, secure, and adaptable to diverse user needs.

Key objectives include:

- **Integrated Sensing and Communication (ISAC) for environment awareness:** Enabling networks to perform real-time object detection, localisation, gesture recognition, and situational monitoring without relying solely on external sensors. This capability will support applications in autonomous vehicles, smart factories, and interactive telepresence.
- **100× energy reduction in network operations** through AI-driven energy management, dynamic sleep modes, and low-power radio designs for base stations, data centres, and edge nodes.
- **Networks as distributed computing platforms:** Deploying AI inference and analytics at the edge to enable autonomous decision-making in robotics, industrial automation, telemedicine, and other latency-critical applications, reducing reliance on centralised cloud computing.
- **Real-time immersive experiences:** Supporting multi-sensory XR, holographic telepresence, and other next-generation applications requiring terabit-per-second communication, sub-millisecond latency, and ultra-reliable connectivity, unlocking new forms of digital interaction and collaboration.

- **Quality of Experience (QoE) personalisation:** Dynamically adapting network resources, computational power, and rendering based on user context, device capabilities, and application requirements, ensuring optimal performance and user satisfaction.
- **Privacy-preserving context awareness:** Implementing local data processing and secure analytics to protect sensitive information, such as gestures, biometric signals, or medical data, while still enabling highly responsive and intelligent network services.

4.6. Sustainable and Resource-Efficient Digital Transformation

This challenge addresses the critical role of digital technologies in driving Europe's transition toward sustainability and climate neutrality across multiple economic sectors and societal domains. Unlike approaches that focus solely on the efficiency of ICT infrastructure, this challenge emphasises the systemic integration of digital tools to actively enable energy savings, emission reductions, circular resource management, and broader societal and environmental benefits. Embedding sustainability into the design, deployment, and operation of digital systems allows Europe to accelerate its transition toward climate-neutral and resilient societies while ensuring that technological advances deliver measurable environmental and social values.

The challenge spans multiple sectors: just to name a few, energy, manufacturing, mobility, agriculture, buildings, and urban environments. In these domains, digital technologies such as AI, machine learning, digital twins, edge/cloud orchestration, and predictive analytics can enable actionable insights, real-time optimisation, and proactive resource management. For instance, smart energy management systems can balance supply and demand across grids, reduce peak loads, and integrate renewable energy sources efficiently. In industrial settings, AI-driven process optimisation can minimise waste, reduce emissions, and improve productivity. Urban mobility and transport networks can be optimised through predictive traffic management and electrification strategies, decreasing congestion and pollution while maintaining accessibility and economic performance.

Beyond operational efficiency, this challenge focuses on measuring tangible sustainability outcomes through Key Value Indicators (KVIs) that extend beyond traditional technical KPIs. KVIs capture among others, environmental, societal, and economic impacts, including carbon reduction, water and energy savings, biodiversity preservation, and equitable access to sustainable services.

Circularity is a core principle: digital systems should be designed for reuse, upgradability, and recyclability, ensuring that hardware and software components minimise their environmental footprint throughout their lifecycle. Multi-layer strategies like software-defined lifecycle extension, modular device architectures, and end-of-life traceability, ensure that digital systems support a regenerative economy. Additionally, green procurement models can incentivise data centres, IoT devices, and infrastructure providers to adopt renewable energy sources, transparent carbon accounting, and sustainable manufacturing practices.

Key objectives and impact pathways include:

- **Digital technologies as enablers of emission reduction:** AI-driven energy management for smart grids, factories, and buildings can achieve significant reductions in energy consumption (>20%) while integrating distributed renewable energy sources and demand-response mechanisms.
- **Digital twins for resource optimisation: High-fidelity simulations of industrial processes, urban systems, transport networks, or agricultural operations enable predictive**

optimisation, minimising waste, emissions, and resource overuse while supporting scenario planning for climate-resilient operations.

- **Key Value Indicators (KVIs) for holistic impact assessment:** Introducing KVIs that capture environmental and social outcomes such as CO_2 avoided, water conserved, biodiversity preserved, and improved quality of life, ensures that digital interventions are evaluated for real-world sustainability impact rather than technical performance alone.
- **Multi-layer circularity strategies:** Circular design principles are applied across devices, infrastructure, and software ecosystems, promoting component reuse, recyclability, software-defined lifecycle extension, and reduction of electronic waste.
- **Green procurement and sustainable supply chains:** Procurement models incentivise low-carbon, renewable-powered ICT infrastructure and services, fostering transparency in carbon accounting, lifecycle emissions, and environmental impact while supporting market uptake of sustainable digital solutions.

4.7. European Competitiveness, Standardisation Leadership and Technological Sovereignty

Europe is facing intensifying global competition in the ICT domain, where control over cloud platforms, semiconductor supply chains, device ecosystems, and advanced digital services is increasingly concentrated outside Europe. American and Asian actors dominate hyperscale cloud, consumer electronics, and chip manufacturing, creating strategic dependencies that expose Europe to supply-chain vulnerabilities, escalating costs, and risks to data sovereignty. As 6G technologies evolve from connectivity solutions into the backbone of digital economies, maintaining a passive role in the value chain would threaten Europe's ability to ensure secure, resilient, and climate-conscious digital infrastructures.

This challenge, therefore, focuses on achieving technological sovereignty through strengthened European capabilities across research, innovation, standardisation, and industrial production. A key objective is to reduce dependency on foreign platforms and technologies, particularly in strategic layers such as cloud, edge computing, semiconductors, secure hardware, operating systems, and network equipment, while enabling European industry to compete globally. Leadership in standardisation bodies such as 3GPP, ETSI, ITU, and IETF is essential to ensure that emerging 6G architectures reflect European principles of openness, trust, privacy, and sustainability.

A strong innovation ecosystem must underpin this ambition. Europe's leadership will only materialize if SMEs, deep-tech startups, universities, and major industrial players co-innovate and access shared testbeds, large-scale pilots, and investment mechanisms that accelerate market uptake. With coordinated action across research and industry, Europe can shift from being a consumer of digital technologies to becoming a global exporter of trusted, sovereign, and sustainable digital solutions.

Key objectives include:

- **European design and manufacturing autonomy:** Developing and scaling European alternatives in hyperscale cloud, edge platforms, secure hardware, semiconductors, and open RAN ecosystems to reduce dependence on external providers and retain value within Europe.
- **Strategic influence in global standards:** Increasing European leadership positions in 3GPP, ITU, ETSI, IETF, and ISO through coordinated industry–research alliances, ensuring that 6G standards reflect EU priorities such as privacy-by-design, openness, and sustainability.

- **Acceleration path for SMEs and deep-tech:** Providing access to validation environments, cross-border testbeds, regulatory sandboxes, and dedicated investment instruments to support scale-up and global commercialisation.
- **Open innovation and IP valorisation:** Encouraging shared intellectual property strategies such as FAIR data models, open API frameworks, transparent licensing, and European technology transfer mechanisms, to strengthen European digital value chains.
- **Ethical and value-based technology leadership:** Positioning Europe as a global benchmark for AI governance, digital rights, security, and environmental responsibility, ensuring that future networks embody European values of trust, inclusiveness, and sustainability.

4.8. Conclusion

The grand challenges of the coming years are multidimensional and deeply interconnected. Europe must simultaneously address the resilience of digital infrastructures, strengthen societal trust in digital systems, enable convergent and intelligent smart environments, unlock new classes of immersive digital services, accelerate the sustainability transition, and secure global competitiveness and technological sovereignty. These dimensions span well beyond technological innovation, reaching societal, environmental, and geopolitical imperatives.

To succeed, Europe needs a coordinated and mission-driven strategy that aligns research excellence with regulatory innovation, market adoption, and cross-sector collaboration. This approach must be grounded in real-world needs, ranging from climate neutrality and resource efficiency, to trust and digital sovereignty, to inclusion and territorial cohesion. 6G and future digital ecosystems will be foundational infrastructures, shaping how people live, work, move, consume resources, and participate in society. Europe must ensure these infrastructures reflect European values: openness, sustainability, equity, privacy, and human-centricity.

Addressing these challenges through a coordinated research and innovation program will ensure that future networks are not merely faster or more capable, but strategic enablers of European prosperity and resilience. 6G and beyond should become the backbone of a digital society that is inclusive, sustainable, trusted, and globally competitive.

Europe has the opportunity not only to shape the next technology generation, but to define a new model for digital transformation, putting people, the planet, and economic sovereignty at its core.

5. Implementation approach Roadmap

5.1. Introduction

The commonly understood role of a SRIA **Implementation Roadmap** is to translate the SRIA's strategic objectives into concrete actions, milestones, and timelines. It shall provide a clearly structured pathway to implementation.

In the case of CELTIC-NEXT, which is based on a substantial technical ICT basis and numerous fields of applications (so-called verticals), there is no unique road-mappable path to implementation.

It is important to understand that CELTIC-NEXT is based on the fundamental nature of innovation: the bottom-up, unconstrained character of innovation. It is translated in the principle of the bottom-up calls: proposers are free to define their project proposal according to their own research interests.

But it is also important to understand that CELTIC-NEXT is focused on innovation that is close to the market; so far projects have led to more than 1600 new or improved products and services.

CELTIC-NEXT also provides a strong flexibility during projects' execution: projects' focus can be adjusted to new technological developments in the field.

Those three characteristics of the CELTIC-NEXT programme lead us to the following: a cascaded/parallel implementation approach; each time a technology or part of it becomes available (at lower TRL 3-4), it can be developed further and integrated into a CELTIC-NEXT project (targeting TRL 5-7).

This is an extremely important advantage considering that new technologies' research and development are becoming more and more agile, abandoning the classical waterfall approach, therefore enabling incremental development and commercialisation of products and services. No need any more to wait for the full technology to be developed, to be able, at least, to integrate some parts (low-hanging fruits) into innovative demonstrators and early field trials with early adopters (who are also participants in the CELTIC-NEXT projects).

The implementation roadmap is divided into **short-term**, **medium-term**, and **long-term priorities.**

5.2. Readiness Levels definitions and interdependencies

TRL (Technology Readiness Level) assesses a technology's technical maturity, while MRL (Market Readiness Level) or Market Readiness Level (MRL) assesses a product's or service's readiness for commercialization.

	Technology Readiness Level (TRL)	Market Readiness Level (MRL)
What it measures:	The maturity and stability of the technology itself.	The commercial viability and readiness of a product or service for the market.
Focus:	Core functionality, scientific validation, and technical feasibility.	Customer requirements, manufacturing processes, supply chain, quality, and economic viability.
Scale:	Typically, a 1-9 scale, from basic research to a fully tested and proven technology ready for production.	MRL frameworks often have their own scales, sometimes correlated with TRLs, to assess manufacturing and market readiness.

Goal:	To determine the technical risk and progress of a technology development program.	To ensure a product can be consistently manufactured to meet customer needs and is ready for commercial production.

TRL focuses on the core functionality and feasibility of the technology itself, from initial research to a proven prototype, while MRL considers factors like customer needs, manufacturing scalability, supply chains, and market acceptance to determine if it's ready for commercial use.

Key difference TRL and MRL are complementary frameworks. A technology can have a high TRL (meaning it works well technically) but a low MRL (meaning it's not yet ready for mass production or market entry). Conversely, a product could have a strong market case but rely on a technology that is not yet mature enough (low TRL). To bring a product to market, both TRL and MRL must be advanced to a suitable level.

This is exactly why CELTIC-NEXT requires projects to target a commercialisation plan, looking at pushing products and/or services based on full or partial efforts realised in the project. The targeted time to market is three years after project's end. This means that CELTIC-NEXT does not only target an increase of TRL, but also a fair and realistic analysis of MRL, with as well a targeted increase. One of the reasons for this is to have the full technological and business value chains represented in the projects' consortia.

5.3. Short-Term Priorities

The immediate focus is on **laying the foundations** for next-generation ICT (incl.6G) and strengthening EUREKA Countries' sovereignty in ICT itself and where ICT is fundamental as an enabler for other sectors of the Economy and Society.

Key Actions:

- **Flagship Projects**: Launch CELTIC-NEXT flagship initiatives on AI-native networks, FR3 spectrum pilots, and sustainability metrics (Key Value Indicators).
- **SME Integration**: Help SMEs to get targeted funding and support to participate in early advanced ICT and 6G R&D.
- **Interoperable/interconnected Testbeds and Pilots**: Establish EUREKA testbeds for enabling collaboration on this SRIA (with the ability to cover pan-European pilots). This would enable projects to focus on their innovations (requiring higher investment) without having to invest from scratch into new testbeds. The National 6G Sovereign Platforms are already envisaging their collaborations within the framework of CELTIC-NEXT.
- **Standardisation Engagement**: Ensure strong Eureka contributions to relevant standardisation bodies like 3GPP Release 20 and ITU IMT-2030 processes. CELTIC-NEXT will support this by asking the EUREKA Network to consider standardisation efforts as eligible costs on all countries.
- **Sustainability Metrics**: Define and validate KVIs for energy efficiency, carbon footprint, and societal impact.

Example Milestone: By 2027, EUREKA should have at least **three operational cross-border 6G testbeds** demonstrating AI-native capabilities and sustainability metrics.

5.4. Medium-Term Priorities

This phase focuses on **scaling innovations** and aligning with global standardisation milestones.

Key Actions:

- **Standardisation Alignment**: Contribute to 3GPP Release 21, which will define normative 6G standards.
- **Interoperable Testbeds**: Expand pilots into interoperable platforms across Europe, integrating vertical industries.
- **Vertical Integration**: Deploy real field pilots in healthcare, energy, transport, and manufacturing.
- **Spectrum Deployment**: Begin commercial use of FR3 spectrum (7–24 GHz) with multi-RAT spectrum sharing.
- **AI Frameworks**: Establish standardised AI/ML frameworks for RAN, core, and service orchestration.

Example Milestone: By 2030, EUREKA should demonstrate **pre-commercial 6G networks** with integrated sensing, AI-native cores, and FR3 spectrum deployment.

5.5. Long-Term Priorities

The final phase focuses on commercial rollout and global leadership.

Key Actions:

- **Commercial 6G Deployment**: Launch 6G services across Europe, ensuring interoperability and sustainability. This could be coordinated with IPCEIs.
- **Quantum Integration**: Incorporate quantum-safe cryptography and explore quantum communication pilots.
- **Global Leadership**: Position Europe as a leader in sustainable ICT, influencing global standards and markets.
- **Societal Impact Monitoring**: Implement continuous monitoring of KVIs to ensure networks deliver societal and environmental benefits.
- **Innovation Ecosystem**: Strengthen Europe's role in global value chains, ensuring SMEs and academia remain integral.

Example Milestone: By 2032, EUREKA should achieve **full commercial 6G rollout**, with networks that are AI-native, energy-efficient, and globally interoperable.

5.6. Conclusion

It provides a structured pathway for EUREKA to maintain leadership in ICT while addressing societal, environmental, and economic challenges. The roadmap is informed by **CELTIC-NEXT's operational model**, the **6G-IA European Vision**, the **SNS-JU SRIA**, and **vendor perspectives** that stress simplification, energy efficiency, and early AI integration.

Governance and Ecosystem

6. Governance and Ecosystem

6.1. Introduction

In the ICT and telecommunication sector, the evolution of service delivery models has been driven by two major technology trends: (i) the need to overcome poor cost efficiencies and limited flexibility in meeting diverse requirements, and (ii) the paradigm shift toward full softwarisation and cloud-native architectures. These developments have transformed linear value chains into complex value networks, where enterprises must navigate interdependent relationships to deliver value propositions across provisioning and vertical ecosystems.

At the same time, Europe's digital infrastructures, spanning networks, cloud platforms, edge computing, and data centres, are increasingly recognised as a **multi-stakeholder endeavour**. Their resilience and innovation depend on coordinated governance involving industry, academia, SMEs, public authorities, and international partners. Initiatives such as CELTIC-NEXT, the 6G-IA European Vision, and the SNS-JU SRIA highlight the need for stronger integration, simplification, and global engagement.

Together, these trends open opportunities but also pose challenges: enterprises must define their role within evolving ecosystems, while EUREKA countries must ensure that governance mechanisms, stakeholder collaboration, and digital infrastructure strategies reinforce their leadership in the next era of ICT innovation.

6.2. The Digital Infrastructure Ecosystem

As the backbone of digital infrastructures, the 5G and beyond 5G ecosystems can be defined as complex networks of interacting cross-industry actors who work together and depend on each other to define, build, and deliver value-creating customer solutions[6]. The depth and breadth of potential collaborations among actors characterise the ecosystem, with each actor delivering a piece of the solution and thus contributing to the strength of the overall ecosystem. The power of the ecosystem comes from the fact that each actor can derive profitable returns without the need to own or operate all components of a solution. Accordingly, it can be assumed that no stakeholder operating in the 5G and beyond 5G ecosystems could individually deliver on the full value proposition to the customer.

Previous business models in the telecommunications and telco industry tended to be linear, which is in contrast with today's cooperation tends to be more circular and cooperative, building upon multilateral cooperation based on the skills and capacities of each interacting stakeholder in the ecosystem. Therefore, it is necessary to align understanding with other stakeholders within the ecosystem, where involved stakeholders / enterprises must acknowledge dependency on each other and rule out the possibility of serving the customer alone.

In spite of the strong collaboration needed in the 5G / beyond 5G arena, the ecosystems can suffer uncertainties and tensions as the business models mature because cooperating enterprises compete for market share and continually refine their business strategies. This can also impact the business models and overall positioning of others involved in the ecosystem. This can be caused by potentially more dominant enterprises that expand investments within the roles they assume or that invest to position themselves in new, competing roles within the ecosystem. Nevertheless, operating in an interdependent

[6] Hallingby, Hanne Kristine, Fletcher, Simon, Frascolla, Valerio, Gavras, Anastasius, Mesogiti, Ioanna, & Parzysz, Fanny. (2021). 5G Ecosystems. Zenodo. https://doi.org/10.5281/zenodo.5094340

ecosystem is still in the best interests of all 5G / beyond 5G stakeholders for maximising value creation and associated revenues and thus promoting innovation and market growth.

6.3. Stakeholder Roles in the Innovation Ecosystem

To address the complexity of the digital infrastructure ecosystem, it can be partitioned into a provisioning ecosystem and a vertical ecosystem, which are complementary to each other. The provisioning ecosystem caters to developing, delivering, and providing communications services while the vertical ecosystem applies these services in combination with other technologies and offers them to vertical customers and users. The roles in the provisioning ecosystem include, among others, Service Providers, Network Operators, Hardware and Software Suppliers, Cloud providers, Datacentre Providers and Solution integrators. The roles in the vertical ecosystem include, among others, Software Providers, Data Processing and Hosting Providers, Service integrators, Computer Consultancy, as well as vertical sector-specific roles from sectors such as industrial automation, healthcare, or automotive. One actor can have multiple roles in an ecosystem and can be part of several related and parallel ecosystems.

CELTIC-NEXT's operational model is a bottom-up and industry-driven innovation concept, fostering collaboration among SMEs, academia, and large industry. The Innovation Ecosystem, taken at its broadest sense, encompasses the following stakeholders and roles:

- Industry: Lead technology development, standardisation, and commercialisation; invest in R&D and pilot deployments. Large vendors and operators provide the scale, infrastructure, and global reach needed to shape standards and deploy networks. They drive flagship projects and contribute to 3GPP and ITU.
- SMEs are the innovation engines, bringing agility, niche expertise, and disruptive ideas. CELTIC-NEXT's bottom-up model ensures strong SME participation, which is vital for sovereignty and competitiveness.
- Academia and Research Institutes: Advance fundamental research, train the next generation of experts, and facilitate knowledge transfer. Universities and research centres provide the scientific foundation for breakthroughs in AI, photonics, quantum, and cybersecurity. They also train the next generation of ICT experts.
- Public Authorities / Governments: Provide strategic funding, align national priorities, and create enabling policy frameworks. The European Commission, national governments, and regulators ensure that innovation aligns with societal goals, ethical standards, and sustainability targets. They provide funding, regulatory frameworks, and policy direction.
- Standardisation Bodies: Harmonise global standards, facilitate interoperability, and ensure fair competition. CELTIC-NEXT promotes the Eureka voice in global standardisation by asking label awarded projects to disseminate their work into relevant standards.
- End Users and Civil Society: Provide feedback on societal needs, ethical considerations, and user acceptance. CELTIC-NEXT encourages involvement of representatives of end users and civil society, already in early stages of research and innovation activities.

From the perspective of industry, governance in ICT innovation must be guided by clarity, simplification, and a strong focus on practical outcomes. Experience from the rollout of 5G has demonstrated that excessive optional features and fragmented development efforts can introduce unnecessary complexity, slow down adoption, and dilute the impact of technological advances. Industry, therefore, emphasises the need for learner specifications that avoid over-engineering and concentrate on the essential functionalities required for widespread deployment. Equally important is the early standardisation of emerging frameworks, particularly in the areas of artificial intelligence and machine learning. Establishing common approaches at the outset ensures interoperability, reduces duplication of effort, and accelerates the integration of AI/ML into network operations and services. Without such early alignment, innovation risks being locked into proprietary silos, undermining both efficiency and competitiveness.

6.4. Multi-Stakeholder Collaboration and Governance Models

Europe's governance model for ICT innovation is based on public funding (from various levels, e.g. EU, Member States), public-private partnerships, and intergovernmental collaboration. The main sources of funding related to 5G / beyond 5G / 6G arena are listed below:

- CELTIC-NEXT: Operates under the EUREKA framework, mobilising industry, SMEs, and academia in collaborative projects. Its governance is flexible, bottom-up, and industry-driven.
- 6G-IA as a private initiative represents the voice of European industry and research in global standardisation, ensuring Europe's priorities are reflected in IMT-2030.
- EC driven research and innovation programmes
  - Horizon Europe program - a wide research and innovation program tackling 5G / beyond 5G aspects.
  - SNS-JU: A formal public-private partnership between the European Commission and the 6G-IA, providing strategic direction, funding, and alignment with EU policy goals.
- ESA: The European Space Agency, a 23-member international organisation devoted to space exploration. The ESA human spaceflight programme includes participation in the International Space Station (ISS) and collaboration with NASA.
- National programmes and initiatives: Complementary funding schemes and strategic initiatives at country level, supporting ICT innovation, 5G/beyond 5G deployment, and alignment with European priorities. These programmes often provide targeted support for SMEs, universities, and industry, and play a critical role in ensuring national contributions are integrated into the broader European R&I ecosystem.

CELTIC-NEXT has established Memorandums of Understanding with both 6G-IA and ESA, ensuring their integration within the broader innovation ecosystem. Collaboration between CELTIC-NEXT projects and these organisations, as well as with other relevant programmes and initiatives, is strongly encouraged. Accordingly, projects should actively engage in, or pursue cooperation with, other sectors involved in public-private partnerships, such as those focused on Virtual Worlds, Robotics, and Big Data, where appropriate. To ensure efficient and seamless collaboration among projects, programmes, and initiatives, projects are encouraged to adopt appropriate collaboration models and establish governance models suited to these collaborations.

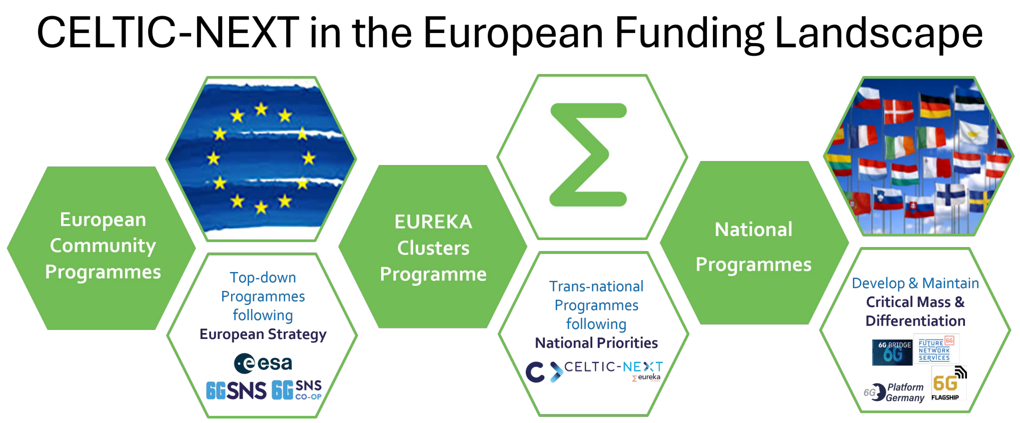
6.5. International Engagement

Europe's governance model for ICT innovation is built on a layered approach that combines EU-level programmes, national initiatives, and intergovernmental collaboration under frameworks such as EUREKA. Within this ecosystem, CELTIC-NEXT plays a pivotal role by stimulating interactions and synergies across stakeholders, ensuring that resources are used in a complementary way and that Europe's ICT domain remains a global leader and a cornerstone of the European economy.

At the same time, Europe's governance must be outward-looking. ICT is a global industry, and Europe's influence depends on **active engagement in international fora**. A strong European presence in **standardisation** bodies such as 3GPP, ITU-R, and ITU-T is essential to shape IMT-2030 and future generations of networks. **Bilateral cooperation** with like-minded regions, including Canada, Japan, and South Korea, strengthens Europe's position and ensures alignment of research roadmaps. Finally, Europe can differentiate itself globally by championing **human-centric, sustainable, and trustworthy networks**, fully aligned with the UN Sustainable Development Goals.

CELTIC-NEXT is very proactive in stimulating interactions and collaborations that ensure good coverage of the ICT technological domain in the Eureka and European R&I context. The approach of finding synergies and maximising the complementary use of resources helps ensure that the different Eureka and European programs can all contribute to making the European ICT domain a global leader and a keystone of the European economy.

Links to Regional & National Programs within European Nations: CELTIC-NEXT offers a way for innovative ICT and service ideas, developed and tested locally, to be exposed internationally. By growing projects internationally, both the quality of the results and the potential market for the results can be enhanced. National initiatives, IPCEIs and others could use the CELTIC-NEXT working structures to organise and support collaborative projects building on national results.



Links to Horizon Europe and the Smart Networks and Services Joint Undertaking: The major ICT investment program under Horizon Europe is the Smart Networks and Services Joint Undertaking (SNS-JU). CELTIC-NEXT has established close working links with the SNS JU. The close relationship is guaranteed through overlap between the CELTIC-NEXT Core Group and the SNS JU Governance. The Chairman of the CELTIC-NEXT Cluster is also a board member of the 6G-IA and on the SNS JU Governing Board. This gives CELTIC-NEXT a strategic position to facilitate liaison & cooperation between CELTIC-NEXT and the SNS JU. This relationship has been formalised through a joint MoU committing both parties to long-term collaborations.

Links to key other Initiatives: (i) CELTIC-NEXT provides inputs and comments to the NetWorld-Europe European Technology Platform to help develop their Strategic Research & Innovation Agenda. This document is a key road-mapping reference for both CELTIC-NEXT and the SNS-JU. (ii) Work is ongoing between CELTIC-NEXT and the European Space Agency (ESA) to have synchronised activities around how satellites can become a core part of a European communications service offering.

EUREKA: CELTIC-NEXT currently supports two other Eureka clusters with either tools or personnel and proactively addresses objectives common to all EUREKA Clusters. CELTIC-NEXT took the lead in introducing cross-cluster thematic calls, providing tools to support peer clusters, and demonstrating the flexibility and adaptability of the cluster instrument and processes. CELTIC-NEXT will continue to contribute actively to the inter-cluster activities to ensure, together with the other Clusters, that the Eureka Clusters Program is an efficient and effective instrument for collaboration in the technological ICT and digital society areas that will strengthen the industries involved and the EUREKA Nations' national competitiveness going forward.

6.6. Mechanisms for Collaboration

Collaboration is enabled through a variety of mechanisms that ensure broad engagement, knowledge exchange, and impact across the ICT domain:

- **Flagship Projects**: Large, multi-partner initiatives designed to tackle grand challenges such as AI-native networks, sustainable ICT infrastructures, and next-generation communication systems. These projects mobilise diverse stakeholders, pool resources, and deliver high-visibility outcomes that strengthen Europe's leadership in ICT innovation.
- **Testbeds and Living Labs**: Shared infrastructures where industry, academia, and SMEs co-develop, experiment, and validate emerging technologies under real-world conditions. These environments accelerate technology readiness and provide critical feedback loops between research and deployment.
- **Standardisation Bodies**: Active participation in international organisations such as 3GPP, ITU, and ETSI ensures that European priorities and values are embedded in global standards. Engagement in these bodies not only shapes technical specifications but also strengthens Europe's influence in setting the direction of global ICT ecosystems.
- **Cross-Sector Platforms**: Mechanisms that integrate vertical industries into ICT R&I programmes. This cross-sectoral collaboration enables co-creation of solutions, ensures relevance to societal needs, and maximises the economic and social impact of ICT innovation.

6.7. Conclusion

The governance and ecosystem of Europe's ICT innovation are multi-layered, inclusive, and globally engaged. It is essential to involve all relevant actors and stakeholders of the European digital infrastructure ecosystem and to apply appropriate collaboration and governance models. Within this framework, **CELTIC-NEXT provides the bottom-up foundation**, mobilising industry, SMEs, and academia in collaborative projects; **SNS-JU ensures strategic alignment** with EU policy goals and investment priorities; and **6G-IA represents the European voice in global standardisation**, safeguarding Europe's voice in shaping IMT-2030 and beyond. By integrating industry, SMEs, academia, and public authorities, and by engaging internationally, Europe can ensure that 6G and future generations of networks are developed in line with European values of trust, sustainability, and sovereignty.

7. Impact and Societal Responsibility

7.1. Introduction

The impact of Europe's ICT strategy extends far beyond technical performance. Networks are now **critical infrastructures** that shape economies, societies, and the environment. This section explores the expected **economic, societal, and environmental impacts** of the Strategic Research and Innovation Agenda (SRIA) 2025–2032, and how it aligns with broader European and global policy frameworks such as the **UN Sustainable Development Goals (SDGs)**, the **European Green Deal**, the **AI Act**, and the **Cybersecurity Act**.

At the heart of this transformation lies the recognition that human-digital innovation must deliver tangible value to society. The sovereign digital ecosystem empowers European industry and citizens alike by ensuring that data, connectivity, and intelligence remain secure, interoperable, and governed by shared value with the ability to innovate and compete globally without compromising transparency, trust, or inclusion. This agenda sets a unified direction for the 6G and broader ICT ecosystem, aiming to unlock new potential for industrial transformation, economic growth, and societal advancement, while reinforcing technological leadership on the global stage.

CELTIC-NEXT acts as a facilitator and thus key enabler of green digitalization, fostering research in the development of technologies promoting optimized energy use through intelligent network management and promoting circular economy principles in the ICT sector.

7.2. Economic Impact

7.2.1. Growth and Competitiveness

The vision is to enhance Europe's competitiveness by driving data-driven research and innovation, thereby fostering sustainable industrial growth. Through the promotion of open science, innovation, and public–private collaboration, it aims to build resilient value chains that meet the demands of a digital and green economy. ICT is projected to be a **trillion-euro driver of economic growth**. According to SNS-JU[7] estimates, smart networks and services could enable **€3.6 trillion in global economic output and 22 million jobs by 2035**. Europe's leadership in digital infrastructures will ensure that a significant share of this value is captured within Europe.

7.2.2. Industrial Transformation

Future digital infrastructures will transform connectivity across sectors such as manufacturing, healthcare, mobility, energy, and agriculture. They will enable real-time data exchange, autonomous decision-making, and ultra-reliable communication. Industries will benefit from AI-driven automation, AI-native networks, digital twins, and near-zero latency control, driving innovation in smart factories, precision medicine, intelligent transport, and sustainable resource management. SMEs, through CELTIC-NEXT projects, can gain access to advanced infrastructures and new markets, empowering them to engage fully in digital and AI transformation. This democratisation of technology fosters entrepreneurship, strengthens regional competitiveness, and supports new business models built on digital trust, ensuring leadership in global value chains.

[7] https://ezywureyi7i.exactdn.com/wp-content/uploads/2023/12/sns-ju-sria-2020-2027-first-edition-2021.pdf

Standardisation is the backbone of digital infrastructure roll-out, ensuring interoperability, trust, and global competitiveness. CELTIC-NEXT is firmly anchored in this ambition by acting as a **bottom-up, industry-driven complement** to Europe's coordinated standardisation roadmap. While initiatives such as the **SNS JU** drive pre-standardisation R&D under Horizon Europe, CELTIC-NEXT translates these research outcomes into **industry-validated pilots and demonstrators**, accelerating their path toward standardisation.

By engaging SMEs, large enterprises, and research institutions, CELTIC-NEXT feeds practical insights into **European Standardisation Organizations (ETSI, CEN, CENELEC)**, aligning technical progress with policy frameworks such as the **European Green Deal, Cybersecurity Act, and AI Act.** Moreover, CELTIC-NEXT projects contribute to resilience and security-by-design principles promoted by the **European Cybersecurity Competence Centre (ECCC)**, including trust frameworks for AI-based network management and post-quantum cryptography.

In this way, CELTIC-NEXT operates as a strategic bridge: it grounds Europe's high-level standardisation ambitions in real-world deployments, ensuring that innovations in 5G, 6G, and broader digital infrastructures are interoperable, secure, and aligned with Europe's values.

7.3. Societal Impact

7.3.1. Inclusion and Accessibility

Digital inclusion is a **core European value** aimed at empowering people and fostering social cohesion. Networks should be designed to provide **ubiquitous coverage**, bridging the divide between urban and rural areas and supporting vulnerable groups. By promoting affordable access, localised services, and community-driven networks, underserved regions and populations can be empowered. This approach reflects Europe's commitment to **trust, sustainability, solidarity, and sovereignty**, while aligning with the UN Sustainable Development Goals (SDG 10: Reduced Inequalities and SDG 4: Quality Education).

7.3.2. Trust and Ethics

As AI becomes integral to decision-making and communication systems, CELTIC-NEXT supports the operationalisation of ethical AI principles, ensuring fairness, accountability, and explainability in its programme. This will strengthen societal trust and support informed citizen engagement in a technology-driven future.

- The **AI Act** advances Europe's strategic priorities by promoting innovation within a clear governance framework rather than restricting it. It emphasises the need for trustworthy and explainable AI, ensuring that technological progress aligns with ethical and societal values. Future networks must embed these principles by design, integrating transparency, accountability, and security as core elements.
- The **Data Act** guarantees fair access to and use of data, reinforcing user control. It ensures that data generated by connected products and services—such as IoT devices, smart machines, or industrial sensors—can be accessed and reused by both individuals and businesses, rather than being limited to manufacturers or service providers.
- The **Cybersecurity Act** underpins Europe's digital transformation—from AI and IIoT to 6G networks—on a foundation of trust, resilience, and accountability. It establishes certification frameworks to secure infrastructures and supports the creation of a trusted Digital Single Market.

7.3.3. Health, Education, and Skills

- **Telemedicine and bio-digital integration**: Advances in telemedicine and bio-digital technologies will expand healthcare access. Reliable, low-latency networks will enable remote diagnostics, surgical procedures, and real-time health monitoring, ensuring personalised healthcare is available across both urban and remote regions.
- **Immersive education platforms**: 6G-powered immersive platforms will support lifelong learning and reskilling. Holographic classrooms, extended reality (XR) environments, and AI-driven tutoring systems will foster interactive learning, global collaboration, and personalised educational experiences.
- **Digital literacy programmes**: Comprehensive digital literacy initiatives will equip citizens to engage confidently with emerging technologies. These programmes will help build a future workforce with the technical, ethical, and AI governance skills required to thrive in a 6G-enabled society.

7.4. Environmental Impact

7.4.1. Sustainable 6G

CELTIC-NEXT acts as a facilitator and thus key enabler of green digitalisation, supporting research in the development of technologies promoting optimised energy use through intelligent network management and promoting circular economy principles in the ICT sector. Networks themselves must be radically more efficient. Operators and the 6G-IA call for **100× energy efficiency improvements over 5G**.

7.4.2. 6G for Sustainability

The sectors expected to benefit most from 6G in the context of sustainability are healthcare, education, manufacturing/industry, energy, transport, agriculture, and smart cities. These areas stand out because 6G's ultra-low latency, energy efficiency, and pervasive connectivity can directly support greener operations, digital inclusion, and reduced resource consumption.

Healthcare & Telemedicine: Advances in 6G-enabled healthcare will transform the way medical services are delivered. Reliable, low-latency networks will make remote diagnostics, surgical procedures, and real-time health monitoring possible, ensuring that patients receive timely and personalised care regardless of location. By reducing the need for travel for both patients and doctors, these technologies contribute to lower emissions and a more sustainable healthcare system. Importantly, they also support equitable access to medical expertise, extending high-quality healthcare to rural and underserved regions that have traditionally faced barriers to advanced services. In this way, telemedicine and bio-digital integration improve efficiency and sustainability as well as strengthen inclusivity within Europe's healthcare landscape.

Inclusive Education & Lifelong Learning: The advent of 6G will revolutionise education by enabling immersive and interactive learning environments. XR classrooms, holographic teaching, and AI-driven tutoring systems will provide learners with personalised, adaptive experiences that go beyond traditional methods. These technologies support global collaboration, allowing students and educators to connect seamlessly across borders, share knowledge, and participate in collective problem-solving. By expanding access to high-quality education, they will help reduce inequalities between regions and communities, ensuring that lifelong learning and reskilling opportunities are available to all. In doing so, 6G-powered education aligns directly with the UN Sustainable Development Goals, particularly SDG 4 (Quality Education) and SDG 10 (Reduced Inequalities), reinforcing Europe's commitment to inclusive and equitable growth.

Manufacturing & Industry (Industry 4.0/IIoT): The integration of 6G into manufacturing and industrial processes will accelerate the transition to Industry 4.0. Smart factories equipped with real-time monitoring and predictive maintenance capabilities will optimise production efficiency, reduce downtime, and extend the lifespan of machinery. By enabling energy-efficient operations and minimizing waste, 6G connectivity supports greener production models that align with Europe's sustainability goals. Furthermore, these advances will strengthen circular economy practices and support resilient, transparent, and sustainable supply chains. In this way, 6G enhances industrial competitiveness and embeds sustainability at the core of Europe's manufacturing ecosystem.

Energy & Utilities: The deployment of 6G will play a transformative role in modernising Europe's energy and utility systems. Smart grids and demand-response mechanisms, powered by ultra-reliable connectivity, will enable real-time monitoring and dynamic adjustment of energy flows. This will allow utilities to balance supply and demand more efficiently, reducing waste and improving resilience. At the same time, seamless integration of renewable energy sources, is supported through real-time balancing, ensuring that clean energy can be distributed reliably across diverse regions. By embedding intelligence and automation into energy infrastructures, 6G will enable efficient distribution, lower carbon footprints, and accelerate the transition toward a sustainable, climate-neutral economy.

Transport & Mobility: The evolution of 6G will reshape transport and mobility by enabling seamless connectivity for autonomous vehicles and intelligent traffic management systems. Ultra-low latency and high-reliability networks will allow vehicles to communicate with each other and with infrastructure in real time, improving safety and efficiency. Optimised logistics and traffic flows will reduce congestion and emissions, contributing to cleaner urban environments. At the same time, 6G will support the electrification of transport and the development of sustainable urban mobility strategies, ensuring that cities can transition toward greener, more resilient, and inclusive mobility systems.

Agriculture & Food Systems: The integration of 6G into agriculture will enable precision farming practices that transform how food is produced and managed. IoT sensors and drones connected via ultra-reliable networks will provide real-time data on soil conditions, crop health, and weather patterns, allowing farmers to make informed decisions with unprecedented accuracy. These capabilities will optimise water use, reduce reliance on pesticides, and improve overall yields, thereby strengthening food security and contributing to resilient food systems that can meet the needs of a growing population.

Smart Cities & Infrastructure: 6G will be an integrative platform for cities, connecting energy, transport, waste management, and public services into a seamless ecosystem. Ultra-reliable connectivity will allow real-time monitoring of air quality, water systems, and resource flows, providing city authorities and citizens with actionable insights to improve sustainability and resilience. Embedded intelligence in urban infrastructures, will promote efficient resource use, reduce environmental impact, and support climate-neutral strategies. These capabilities will support sustainable urban living, enhance quality of life, and strengthen resilience against the challenges of climate change.

7.4.3. Circular ICT

From the earliest stages of equipment and device design through to end-of-life treatment, the ICT sector must fully embrace **circular economy principles**. This means reducing e-waste, optimising resource use, and ensuring that materials are kept in productive circulation for as long as possible. By embedding intelligence into infrastructures, real-time monitoring, AI-driven optimisation, and predictive management can ensure that networks, data centres, and edge devices operate with maximum efficiency and extend hardware lifecycles.

When sustainability and circularity are integrated by design, ICT systems become enablers of transformation across all sectors they support, whether in industry, energy, mobility, or public services. They provide the foundation for a digital economy that is resilient, low-carbon, and resource-efficient, aligning technological progress with Europe's broader environmental and societal goals. In this way, ICT drives innovation and becomes a catalyst for systemic change towards a sustainable future.

7.4.4. Monitoring and Metrics

The introduction of **Key Value Indicators (KVIs)** marks a decisive step in ensuring that sustainability is measured with the same rigour as technical performance. While traditional KPIs capture efficiency, speed, and reliability, KVIs translate broader ambitions into quantifiable metrics. This dual approach empowers decision-makers to assess progress, justify investments, and steer future actions with a balanced view of both technological and societal impact. Policymakers, in turn, gain the tools to identify gaps, prioritize interventions, and allocate resources more effectively, embedding sustainability into the very fabric of digital transformation.

For example, carbon footprint monitoring could evolve into a standard network function, making environmental impact as visible and actionable as latency or throughput. KVIs for 6G sustainability and circular ICT encompass a wide range of dimensions: energy efficiency, measured by reductions in network and data centre consumption per unit of data transmitted; resource lifecycle extension, reflected in the average operational lifespan of ICT equipment and connected devices; and material efficiency, achieved through reductions in e-waste and raw material use per service or device. They capture emission reductions across verticals, such as energy, transport, and industry, with precision agriculture service as one example, through reduced water and chemical use. Finally, circular ICT adoption is tracked through the percentage of systems implementing repair, reuse, and recycling practices.

Together, these indicators provide a comprehensive framework that ensures sustainability is not treated as an aspiration but as a measurable, actionable outcome. By embedding KVIs into the design and governance of 6G systems, Europe can align technological progress with environmental responsibility, driving a resilient, low-carbon, and resource-efficient digital economy.

7.5. Policy Alignment

The impact of future digital infrastructures must be understood in terms of technological innovation as well as in their alignment with overarching policy frameworks. The present CELTIC-NEXT SRIA is designed to reinforce this alignment, ensuring that advances in connectivity, cloud, edge, and AI-enabled systems contribute directly to economic competitiveness, social cohesion, and environmental sustainability, as outlined in some of the most crucial policy frameworks:

- **UN Sustainable Development Goals (SDGs)**: Digital infrastructures support global objectives on climate action[8], industry innovation[9], and reduced inequalities[10] by enabling greener operations, resilient services, and inclusive access.
- **European Green Deal**: By driving energy-efficient infrastructures and low-carbon digital services, CELTIC-NEXT contributes to emission reductions of at least 50% by 2030 and supports the legally binding goal of climate neutrality by 2050 under the European Climate Law[11]. This positions digital infrastructures as enablers of a clean, fair, and economically sound transition.
- **AI Act**: As AI becomes embedded in networks and services, CELTIC-NEXT aligns with Europe's first comprehensive legal framework on AI[12], ensuring that digital infrastructures foster trustworthy, transparent, and human-centric AI.
- **Cybersecurity Act**: Resilient infrastructures must also be secure. CELTIC-NEXT supports certified ICT products, services, and processes, embedding security-by-design[13] principles to protect Europe's digital economy and society.

7.6. Conclusion

The impact of CELTIC-NEXT is **multidimensional** and spans economic, societal and environmental dimensions:

- **Economic**: By fostering innovation, improving industrial efficiency, and enabling new business models, digital infrastructures will drive sustainable growth, strengthen competitiveness, and create opportunities for SMEs and startups in a data-driven, connected ecosystem, supporting jobs, prosperity, and market leadership.
- **Societal**: Enhanced healthcare, inclusive and immersive education, and widespread digital literacy are only a few examples of areas that will empower citizens, ensure equitable access to services, and build resilience in a rapidly evolving digital landscape, anchoring inclusion, trust, and empowerment.
- **Environmental**: With a focus on efficient resource use, emission reduction, extended hardware lifecycles, and circular economy principles, CELTIC-NEXT contributes to a low-carbon, resource-efficient, and climate-resilient future, fully aligned with the European Green Deal and the UN Sustainable Development Goals.

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[8] https://sdgs.un.org/goals/goal13

[9] https://sdgs.un.org/goals/goal9

[10] https://sdgs.un.org/goals/goal10

[11] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

[12] https://digital-strategy.ec.europa.eu/en/policies/regulatory-framework-ai

[13] https://digital-strategy.ec.europa.eu/en/policies/cybersecurity-act

8. Recommendations

8.1. Introduction

The CELTIC-NEXT Strategic Research and Innovation Agenda (SRIA) 2026–2032 provides a **comprehensive framework for developing ICT leadership** within the EUREKA members' network.

As we navigate the global uncertainties from 2026-2032, it is crucial for industries operating in a smart, connected world to remain resilient, even amid unprecedented restrictions. In light of ongoing global turbulence, Europe's economy and especially the connectivity sector serving several vertical markets must discover innovative flexible strategies to foster business growth whilst bridging the gap between essential regulations and the needs of the industry serving a global market. The long-standing spirit of CELTIC-NEXT with its bottom-up, industry-driven innovation is a perfect envelop to generate and assess economic, environmental and societal impact that plays a vital role in CELTIC-NEXT. The CELTIC-NEXT community aims to leverage its influence through strong collaborative efforts that support various emerging ecosystems in a flexible, industry-led, bottom-up manner, capable of responding quickly to unprecedented restrictions.

CELTIC-NEXT's foundation is enriched by the 6G-IA European Vision, the SNS-JU SRIA, and vendor perspectives that highlight lessons from 5G and priorities for 6G. This conclusion synthesises the key insights, reinforces Europe's and the wider EUREKA member's network leadership goals, and outlines the next steps for implementation and stakeholder engagement.

8.2. Strategic Synthesis

The SRIA has articulated a **holistic vision** for EUREKA's ICT future:

AI-native Networks and ICT for AI, with its design principle, maximises the value through responsible AI methodology, enabling the mobile operators to fully realise the economic potential of their AI initiatives, keeping consumer trust, operational efficiency and products compliant with regulations and standards. It can be split into visionary approaches, operational model, technical controls and third-party ecosystems embracing the required change management. Coordinative efforts are required to feed as well as to align with different national sandbox systems to provide the opportunity to showcase AI maturity progress. Well-aligned industry standards will be established to serve vertical industries whilst effectively equipping them with trusted AI development and monitoring systems. This approach aims at supporting industries in managing evolving risks effectively.

Sustainability is both a system property and a societal enabler measured through Key Value Indicators (KVIs). Future ICT (incl. 6G) and their ecosystems are expected to address outstanding economic, societal, and environmental challenges. The UN Sustainability Development Goals and the Green Deal are seen as basis to serve a healthy connected digital society with the ambitions to empower all citizens equally and to protect the planet. CELTIC-NEXT has already demonstrated excellence in green networks through award-winning projects, such as AI4Green, which was honoured with the EUREKA Innovation Award in 2024.

Beyond communication services, such as collecting, positioning and processing data in the sphere of a smart connected world, the focus is on reducing the current over-complex mechanisms in the current cloud and AI environments. Utilising cost-effective sensing methods, like fibre networks, and implementing green, purpose-built, flexible sensor networks to leverage data effectively is one aspect.

Moving beyond large language models and rule-based gaming models to address emerging governance challenges in Europe and beyond will be the engine to address future markets. By embracing security by design principles into the new emerging sensor and processing networks, the overall complexity of distributed data management can be leveraged by lightweight computing systems that are closely integrated with intelligently managed communication infrastructures, enabling the web 4.0 vision of fostering the quality of life in several dimensions.

Ensuring the sovereignty of EUREKA countries in critical technologies requires operators and manufacturers to maintain a leadership role. In the communications domain, 6G is expected to deliver enhanced resilience by integrating non-terrestrial networks (NTN) and addressing gaps in emerging continuous computing paradigms, thereby reinforcing Europe’s strategic autonomy.

Societal responsibility is achieved by adhering to established European guidelines. The AI Act embeds ethical principles into AI technologies, while privacy in 6G networks is safeguarded EU-wide through security-by-design approaches integrated into new architectures. These measures facilitate compliance with the NIS-2 Directive, which strengthens cybersecurity and requires close coordination with the GDPR. Together, they demand strict security measures and risk assessments for IT systems and personal data, with the GDPR continuing to govern all aspects of personal data processing.

This synthesis reflects a **convergence of perspectives**: CELTIC-NEXT’s bottom-up innovation, the 6G-IA’s global vision, the SNS-JU’s policy alignment, and vendors’ pragmatic focus on simplification, resilience and sustainability.

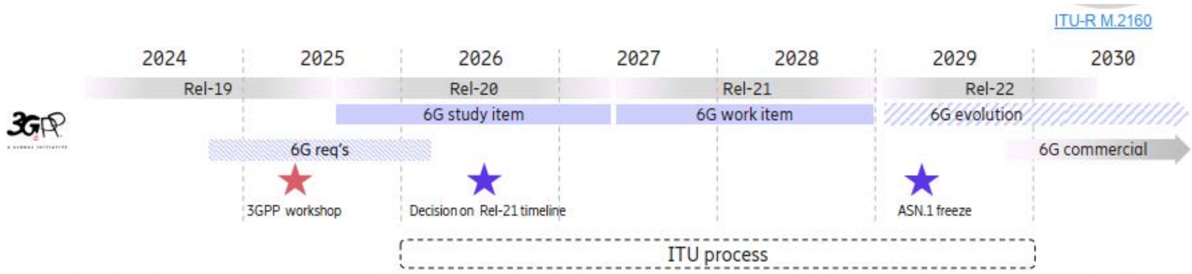
8.3. Strategic Implementation Measures for Reinforcing EUREKA Countries’ ICT Leadership

CELTIC-NEXT projects and Flagship initiatives contribute to and follow, among others, ITU, 3GPP, ETSI and GSMA guidelines, while remaining aligned with the United Nations’ Sustainable Development Goals. The following implementation plan is designed to reinforce the programme’s strategic strength:

1. **Launch Flagship Projects**: To reinforce EUREKA Countries’ digital leadership, flagship initiatives will be launched that can flexibly adapt to emerging national strategies. These initiatives will be driven by strong industry groups and guided by leading experts, ensuring that they generate measurable impact across evolving ecosystems. By combining strategic responsiveness with deep technical expertise, they will accelerate innovation, foster collaboration, and strengthen the programme’s position in the global digital landscape.
2. **Establish Testbeds**: A central priority will be the creation of interconnected testbeds. These testbeds will act as living laboratories where new concepts can be validated, demonstrated, and scaled. Positioned at the forefront of innovation, they will drive economic growth by opening new markets and fostering industrial competitiveness. At the same time, they will contribute directly to internationally aligned standards and generate measurable value, ensuring that CELTIC-NEXT’s advances are globally interoperable and strategically impactful.
3. **Build on Proven Excellence**: Building on the legacy of previous achievements, CELTIC-NEXT will continue to showcase excellence in research and innovation. These successes provide a strong foundation for reinforcing leadership in the global ICT market. At the same time, the programme remains committed to upholding core values, such as trust, inclusiveness, and sustainability.

4. **Strengthen International Collaboration**: CELTIC-NEXT projects will actively engage in global partnerships to ensure alignment with and contribution to international standards. The flagship approach will focus on scaling interoperable pilots efficiently, integrating emerging ecosystems in a resilient and sustainable manner. This dual strategy, global alignment and local resilience, will guarantee that future digital infrastructure developments are internationally recognised and firmly anchored in sustainable growth.

Support 6G Deployment: CELTIC-NEXT will play a pivotal role in contributing to the deployment of 6G technologies in full alignment with 3GPP specifications. By leveraging its flexible, adaptive, and bottom-up approach, these efforts will ensure that European stakeholders remain central to the successful rollout of commercial 6G networks from 2030 onwards, considering the 3GPP timeline (see figure below).



These steps demand strong leadership from the CELTIC-NEXT Core Group Members, who are active across various governance bodies, and require robust support from national authorities to enable effective collaboration towards a successful rollout of future digital infrastructures. The success of the CELTIC-NEXT SRIA relies on the active involvement of all stakeholders, with the CELTIC-NEXT Office and Management Team serving as key instruments to facilitate and coordinate this engagement:

- **Industry** must invest in R&D, drive standardisation, and deploy digital infrastructure and applications.
- **SMEs** must be empowered to innovate and scale.
- **Academia** must provide scientific breakthroughs and train talent.
- **Public authorities** must align funding, policy and regulation.
- **Citizens** must be engaged through transparency, inclusion, and trust.

8.4. Conclusion and Call to Action

The SRIA 2026–2032 is a **call to action**. The CELTIC-NEXT community now has the chance to lead globally in building networks that are **trustworthy, sustainable, and human-centric**. By aligning research, industry, and policy, the CELTIC-NEXT programme can ensure that 6G and future digital infrastructure technologies become **pillars of a resilient, inclusive, and sustainable digital society.**

The next decade will be decisive, and with vision, unity, and determination, the CELTIC-NEXT can help the EUREKA Countries and their industries to position themselves as ICT leaders, shaping a digital future that embodies values and delivers benefits to all citizens.

Annex 1 - Enabling Technologies to be mastered

5G , B5G, 6G

- Enhanced overall architectures to support needed enablers
- End-to-end Horizontal and Vertical Network Convergence
- AI/ML for Digital Infrastructures
- End-to-end Network Automation
- Autonomous Systems and Networks
- Connectivity as a Shared Critical Utility
- Wireless and Wired Tera-Broadband technology:
  - Wireless (electromagnetic and visual light waves):
    - Larger massive MIMO systems
    - No "Cell" Radio Networks with distributed smart mMIMO systems
    - TeraHertz Communications
  - Wired optical:
    - Photonics
    - Optical smart networks
    - Optical spectrum: Sliceable Optics, shared lambdas
    - Increasing Bandwidth in Optical Network: use of additional bands, Higher modulation schemas
  - Quantum-based communications
    - Advanced QKD Networking
    - Entanglement
  - Integrated Sensing and Communications (ISAC)
  - Native integration of diverse ICT resources, including AI/ML capabilities, at both infrastructure and platform levels
  - Service function chaining
  - Intent-based orchestration frameworks allow tenants to specify high-level intents (e.g., performance, security, sustainability goals)
  - Core Network Evolution

Wired and Wireless Industrial ICT

- Industrial features of 5G and beyond
  - Time Sensitive Networks
  - Precision Positioning incl. ISAC
- Private Networks
- More Indoor techs like Terahertz, Visible Light Coms,
- Non-3GPP convergence (like Wi - Fi, Industrial Networks Standards...)
- Tera scale Internet of Things (IoT)

ICT Critical Infrastructure as a Utility, The Critical Connectivity Grid

- Macro/Micro Grids' concepts related technologies adapted to ICT as it exists for Energy
- Full end-to-end Slicing of physical networks and infrastructures (see Smarter Networks)
- Cyber-security
  - Quantum QKD
  - AI/ML & Big Data Real Time Analytics based Security
  - Reinforcement of Sovereignty
  - Cyber-attack-based Disaster recovery
- Trust enablers
  - Security
  - Auditability
  - Transparency

Space dimension enabled 5G/B5G/6G

- SAT enabled 5G/B5G/6G
  - Moving ICT to SAT
    - RAN in SAT (D2D/Space-RAN)
    - CORE in SAT (Space-CORE?)
    - MEC in SAT (Space-Edge Dc?)
    - MBH in SAT (Space-Mobile Backhaul?)
    - Value Added Services in SAT
  - Earth Meshed Network (including Oceans)
    - SAT to Ground
    - SAT to Sea
    - SAT to Air Objects & IOTs
    - SAT to SAT
    - => SAT to All
  - Multimodal SATs
    - Combining GPS info with Network info
    - Combining Observation modalities with Network info
- Avionics communications
  - Air to Ground
  - Air to Air
  - Drones / HAPS
  - Balloons?

Distributed & Smarter Networks

- Deeper "edge-ification" for Distributed, collaborative and hierarchical AI/ML
- AI-native Networks
  - Distributed AI/ML
    - Consuming
    - Producing
    - Supporting
- More Multi-Purpose Adaptable Networks:
  - Universal adaptive core
  - Programmable network Operating System
- Advanced very large-scale monitoring (for AI, ML, DL...)
- Intelligent and Automated Dynamic Spectrum Management :
  - Electro-magnetic Spectrum: Horizontal & Vertical Flexible Sharing CBRS, DSS, LSA, LAA, MultiFire, new enablers...
  - Optical spectrum: Sliceable Optics, shared lambdas
- Full Slicing
  - Real End-to-End leading to:
    - Multi-layered multi-tenancy
    - Full neutral hosting
    - Multi-Dimensions sliceable (incl. Spectrum and Time)
  - Thanks to: Deeper Network Programmability

Annex 2 - Main technical areas of Research

Ubiquity / Pervasiveness	Dynamic capacity following people seamless mobility	Automation, Reliability, Transparency: Cognitive operations	Sustainability, Protection and Trust	Holographic "transportation" & Real-time Synchronous Digital Twin
• Urban, sub-urban down to rural • Into the home for education and remote working • Stationary and in move • One Identity for seamless experience • Smart Regions/Cities/Buildings/Homes • Dynamic, Composable, and Multi-Tenant Infrastructures • Integration of All Network Domains	• In "normality" • In "crisis" (pandemics, major climate events) • Highly Precise Positioning • Edge Computing • Open-RAN / vRAN • Slicing • Deep virtualization • Integration of All Network Domains	• AI-native Networks, incl. AI-RAN • ICT supporting large and intense AI/ML deployment for verticals (connectivity, processing, data storage…) • Extensive Monitoring • Big Data Analytics • Artificial Intelligence • Transparency or the Imperceptible latency • Deterministic Networking • Programmability and Controllability • Advanced Governance and Service Customisation • Integration of All Network Domains	• Cyber-security (incl. Post-Quantum) • Identity management • System Sustainability and Efficiency	• Holographic media teleport • Multi-sense networks • Time engineered applications • Integrated Sensing and Communications (ISAC)

Annex 3 - High Level Fields of Applications

Human Centred Technologies and Services, for an Augmented Life Experience	Full industrial digitization and support of vertical industries	Sustainable, Sovereign, Secure Futuristic use cases
• Digital divide elimination • Digital support for Inclusive Education (incl. Remote) • Smart Regions/Cities/Buildings/Homes • Smart Transportation • Smart Tourism • Sustainability & Efficiency of Smart Energy Grids • Public Safety & Crowd Control • E-Health & Care • Users in Control and Trust of offered services • Digital (Media, Gaming, Sports, Culture and Entertainment) • Remote and Nomadic Working (Digital Nomads)	• Digital Enterprises • Private Networks for Smart Manufacturing (Indus.5.0) • Smart Logistics (geolocation IOT networks) • Smart Agriculture • Future Financial and Fin-Tech • ICT support to third party AI based applications • Connectivity Grid / Telecom Infra as 4th Utility, like Energy	• Holographic "Teleportation" • "World" Real-time Synchronous Digital Twin

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