Smart Networks and Services International and European Cooperation Ecosystem

D3.4 Vertical Position Paper

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Abbreviations List

Abbreviation / Term	Description
3GPP	3rd Generation Partnership Project
5GAA	5G Automotive Association
5G MAG	5G Media Action Group
5G PPP	5G Public Private Partnership
6G-IA	6G Smart Networks and Services – Industry Association
AI	Artificial Intelligence
AIOTI	Alliance for Internet of Things Innovation
CPE	Customer-Premises Equipment
DMR	Digital Mobile Radio
ESA	European Space Agency
EIM	European Rail Infrastructure Managers
eMBB	Enhanced Mobile Broadband
ERTICO	European Road Transport Telematics Implementation Coordination Organisation
IoT	Internet of Things
MCPTT	Mission-Critical Push-To-Talk
ML	Machine Learning
MoU	Memorandum of Understanding
mMTC	Massive Machine-Type Communications
NTN	Non-Terrestrial Networks
PSCE	Public Safety Communication Europe
RAN	Radio Access Network
R&D	Research and Development
R&I	Research and Innovation
RIS	Reconfigurable Internet Surfaces
SLAs	Service-Level Agreements
SNS	Smart Networks and Services
ThZ	Terahertz
UC	Use case
UPF	User Plane Functionality
URLLC	Ultra Reliable and Low Latency Communications
US	United States
VET	Vertical Engagement Tracker
xR	Extended Reality

Executive Summary

The telecommunications industry has undergone deep changes in the last decades while further disruptions may lie ahead, driven by new technologies such as AI or LEO (low earth orbit satellites). The rise of big tech companies providing telco services outside the traditional mobile industry (triggering heavy traffic and huge network investment), heavy competition and low level of returns on network technologies have raised concerns about the economic sustainability of the European telecom industry and its capability to invest in new generations of network technologies such as 6G.

The Mobile sector is paramount for economic growth. In Europe the direct, indirect and induced economic benefit - the 'Mobile Economy' - is evaluated at 1,1Trillion € representing 5% of EU GDP. The benefit for the mobile ecosystem (mobile operators, vendors, services to the mobile industry, consultancies etc.) is only one third of the total economic benefit, while productivity gains for consumers and verticals account for two thirds (700 B€) of the total value (1060 B€). In 2030 the global economic impact of the mobile industry in Europe is evaluated at 1,2Trillion €, 160 B€ will be produced by 5G in key European industrial sectors.

The telecom sector is pivotal to the digitalization of the European economy since advanced connectivity is a prerequisite for the adoption of key digital technologies such as Cloud or AI that all together drive competitiveness of European industries. 2030 Digital Decade targets monitoring digital infrastructure and digital transformation targets show gaps to reach end of decade targets.

Understanding trends, challenges, and emerging use cases across vertical industry domains is critical for shaping the future of connectivity technologies such as 6G. As industries undergo rapid transformation driven by digitalisation, automation, and sustainability goals, their expectations for connectivity are evolving. The analysis of vertical sector trends, challenges, and use cases highlights the potential of advanced connectivity technologies in reshaping several industrial sectors. Vertical sectors such as Public Safety, Automotive, Transportation, Smart Manufacturing, Media, Agriculture, and Healthcare are poised for evolution through enhanced connectivity, data-driven capabilities, and innovative solutions. However, these transformations also face barriers such as technological maturity, interoperability, regulatory hurdles and infrastructure demands.

Beyond traditional vertical sectors, a survey circulated between relevant vertical associations between July and December 2024 framed the state of the art regarding the current implementation and adoption of 5G-based solutions and the expectations for 6G connectivity systems. The results are summarized in this document. Alignment of R&D trends within the SNS JU Programme with observed industry trends is vital to bridging the gaps between experimental research and market needs.

The Vertical Engagement Tracker (VET), an online platform developed under the SNS JU Programme, plays a pivotal role in mapping and monitoring these use cases across sectors.

To reap the full economic impact of 6G, policy measures must be taken both at sectorial and cross sectorial level. Europe suffers from lower competitiveness with respect to competing economies such as USA and China. The reason stands in lower productivity of the European economy, less empowered by key digital technologies such as 5G, Cloud and AI**.** Europe urgently needs to accelerate on innovation to maintain its industrial leadership, but Europe is lagging behind in digital technologies. Innovative digital companies are generally failing to scale up in Europe, with a huge gap in later-stage financing between the EU and the US. Once companies reach the growth stage, regulatory and bureaucratic hurdles prevent them from scaling-up into mature, profitable companies.

Drivers and barriers of economic growth are finally summarized, and a set of recommendations and position statements are listed. Acceleration on digitalization to boost productivity, reinforce the EU ICT market and reform the telecom sector are the main recommendations to maximize the economic impact of 6G and the telecom sector on European economy.

1 Introduction

This document is the final deliverable of the Work Package on Vertical Engagement part of SNS ICE Project. Its purpose is to recap main outcomes on vertical engagement activities produced by SNS ICE project and provide recommendations to maximize socio economic impact of 6G for Europe.

Vertical Engagement is a key activity within SNS JU. Established by 6G-IA Board years ago (then as 5G-IA), the Task Force on Vertical Engagement is now running under 6GIA Board to engage with verticals and gather industrial trends & needs to help shape SNS JU work programs and project calls. 11 partnership agreements (Figure 1) were signed with key European associations providing a framework of collaboration with vertical industries.

Figure 1: List of Partnerships with Vertical Associations

The portfolio of vertical partnerships has been key to the success of the activities performed under SNS ICE, such as the vertical trends analysis and the survey presented in deliverables D3.2 [1] and D3.3 [2]. In D3.2 result from SNS JU funded projects were gathered and made available online thanks to a Vertical Engagement Tracker ("VET") with detailed information on vertical use cases tackled by projects (see deliverable D3.1 [3]). In D3.3 results of a survey engaging vertical partners and their memberships on 5G experience and 6G expectations were analysed and hereafter summarized.

2 Background

2.1 State of the Industry in Europe

The Telecommunications industry has undergone deep changes in the last decades while further disruptions may be ahead of us driven by new technologies such as Artificial Intelligence (AI) or Low Earth Orbit (LEO) satellites. The rise of big tech companies providing telco services outside the traditional mobile industry (triggering heavy traffic and huge network investment), heavy competition and low level of returns on network technologies have triggered concerns about the economic sustainability of the European telecom industry and its capability to invest in new generation of network technologies such as 6G [4].

Figure 2 depicts the Return on Capital Expenditure (ROCE) of key EU Operators, which notably presents a declining trend over the past years. Moreover, as indicated in the Connect Europe Report (based on Analysis from Mason data) on the State of Digital Communications 2025, the **total telecom investment** in Europe has declined by 2%, going from 59.1 B€ in 2022 to 57.9 B€ in 2023, as indicated in Figure 3. Additionally, as depicted in Figure 4 **Network investments** will sum up 195 B€ in the 2023-2030 period triggered by 5G expansion and evolution to 5GSA and 5G Advanced. **Capital intensity** (CAPEX/return) will remain high putting operators and investors under severe financial pressure.

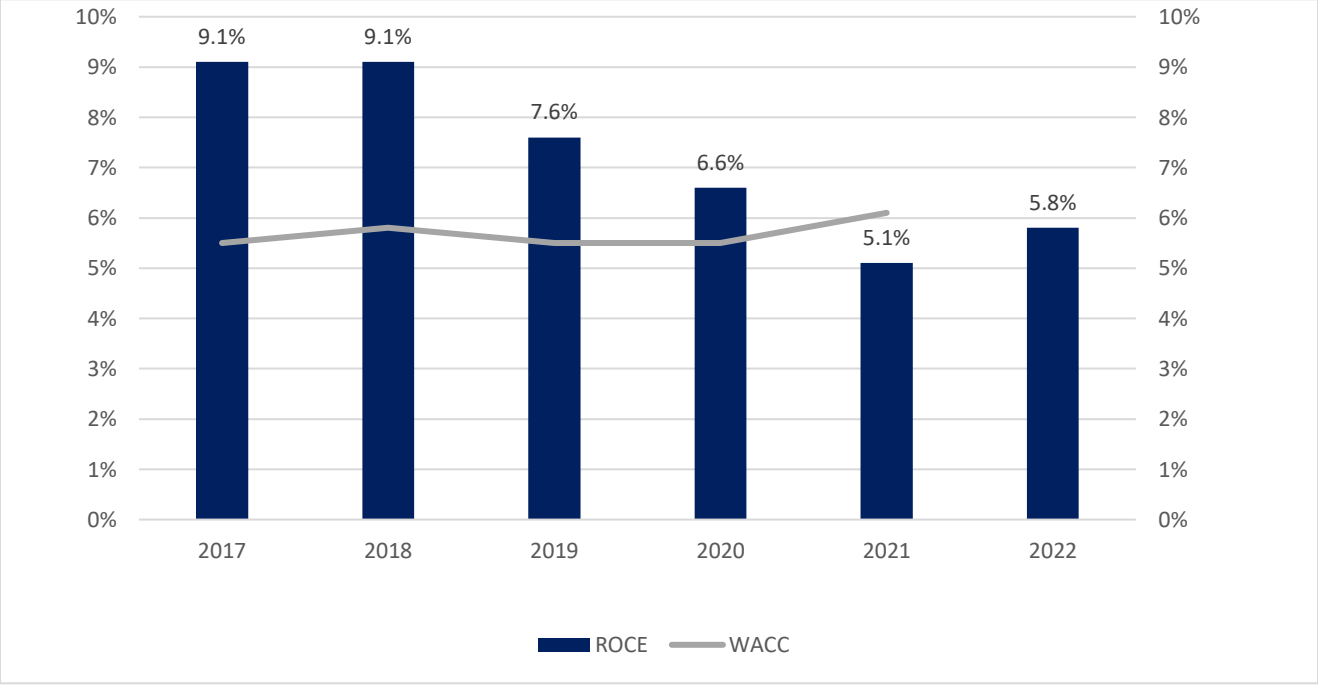

Figure 2: Return on Capital Expenditure (ROCE) of key EU Operators

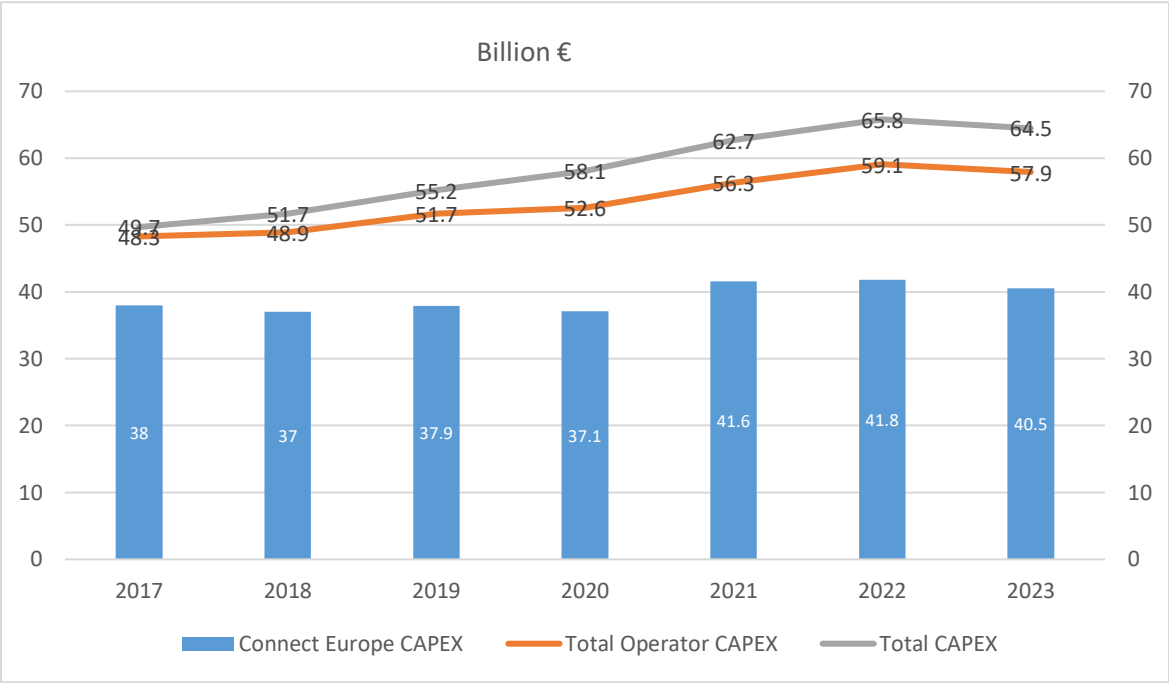

Figure 3: Total capex in Europe, excluding spectrum costs (2017-2023) [4]

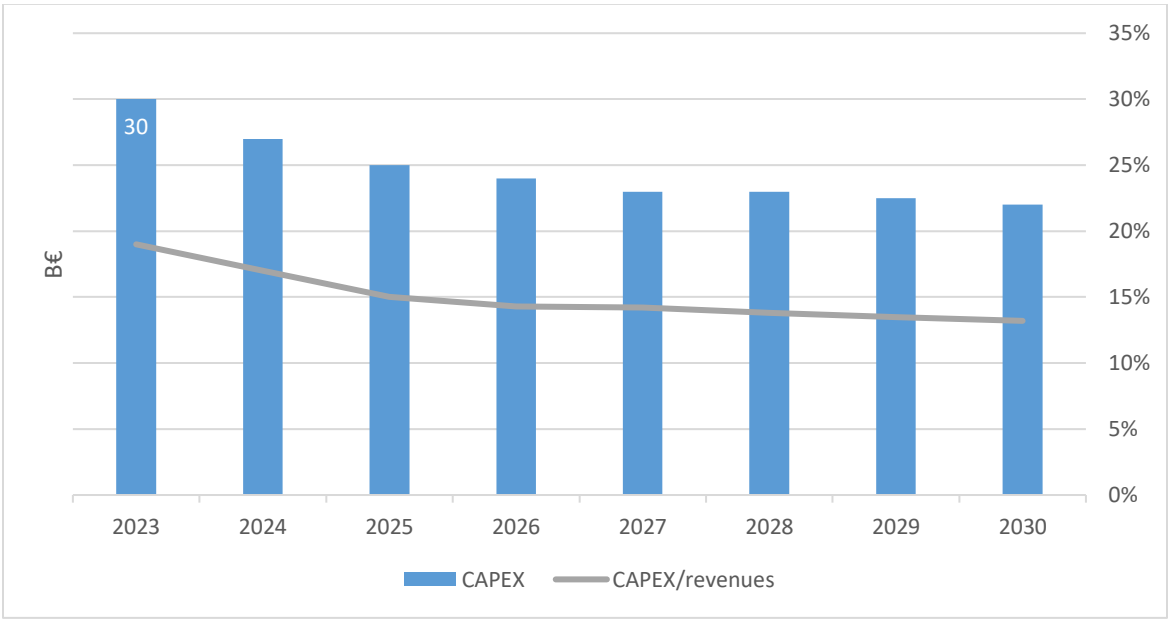

Figure 4: EU CAPEX / CAPEX intensity 2023-2030 [4]

2.2 Mobile Economy in Europe

Mobile networks are of paramount importance for European economic growth, as several other sectors depend on their proper functionality and continuous growth. In Europe the *Mobile Economy* is evaluated at 1,1Trillion € representing 5% of EU GDP according to the latest GSMA report [5]. Figure 5 depicts the economic contribution of the mobile industry for Europe, showcasing the tremendous importance of the networks, especially for productivity. The direct and indirect economic benefit for the mobile industry (mobile operators, vendors, services to the mobile industry, consultancies etc.) accounts only for 1/3 of the total economic effect, while productivity gains for consumers and **verticals** account for 2/3 (700 B€) of the total value.

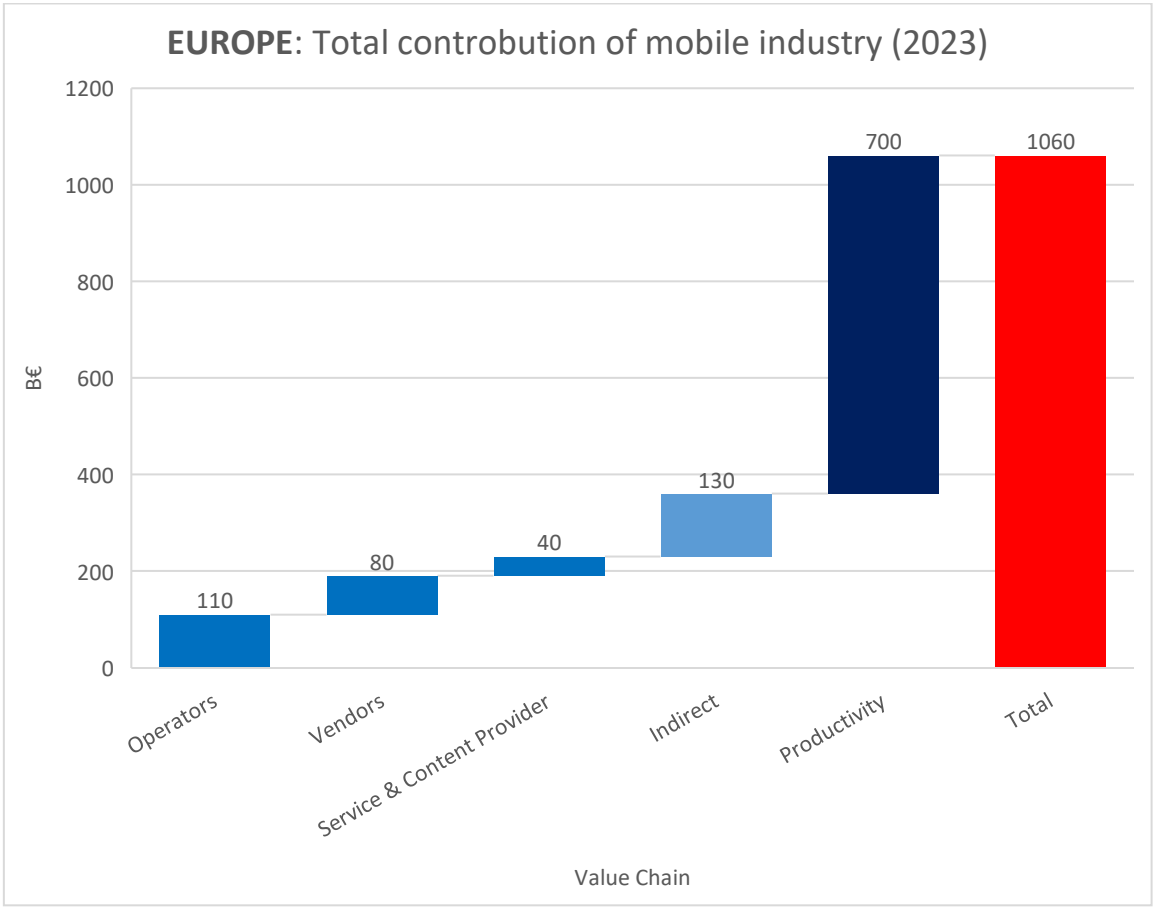

Figure 5: EUROPE: The economic contribution of the mobile industry (2023)

For 2030 the global economic impact of the mobile industry in Europe is evaluated at 1,2Trillion €, of which 160 B€ will be the economic impact of **5G** in key European industrial sectors, as depicted in Figure 6. The European mobile industry also accounted for 3,3M jobs in Europe in 2023 (Figure 7), showcasing the integrated impact of the telecoms industry to the industrial bedrock of Europe.

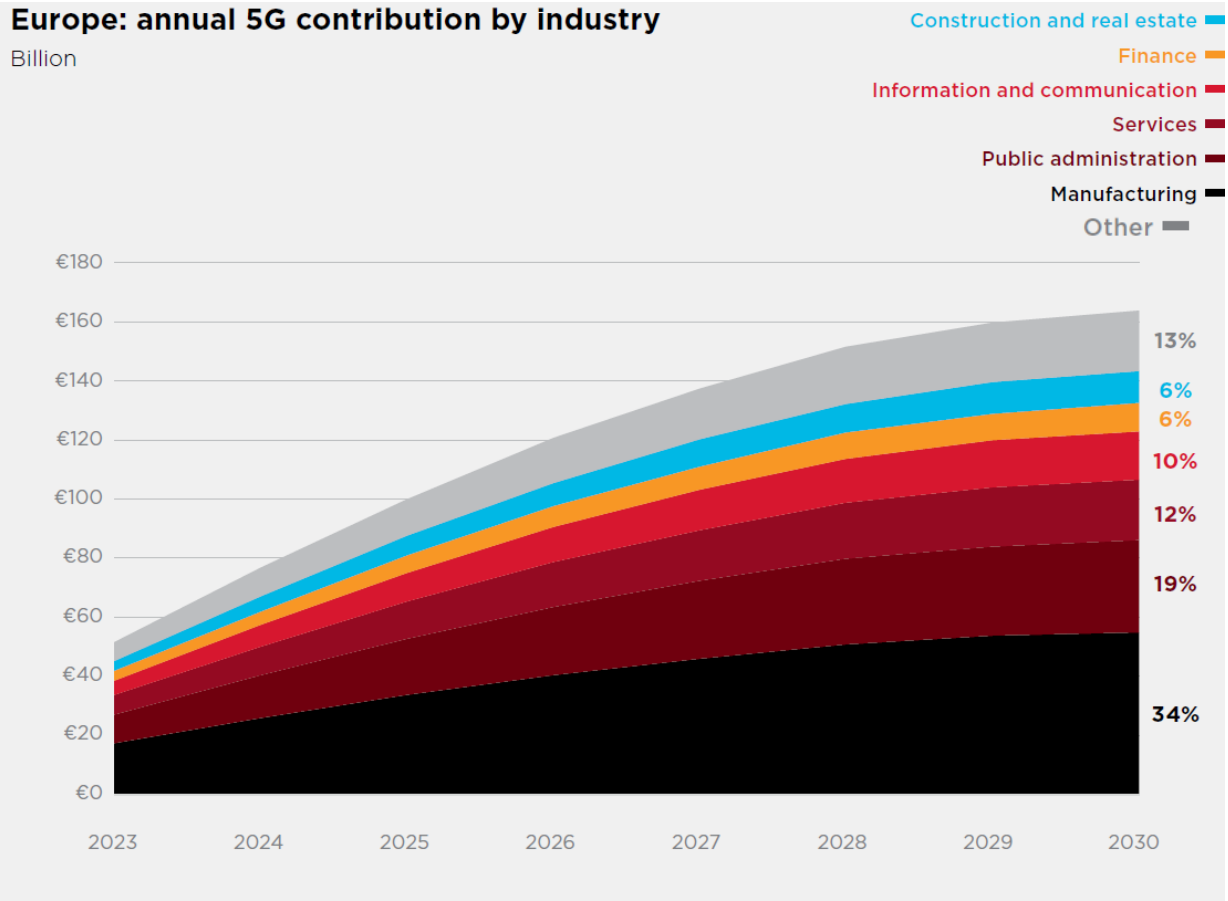

Figure 6: 5G economic contribution by industry (2030) [5].

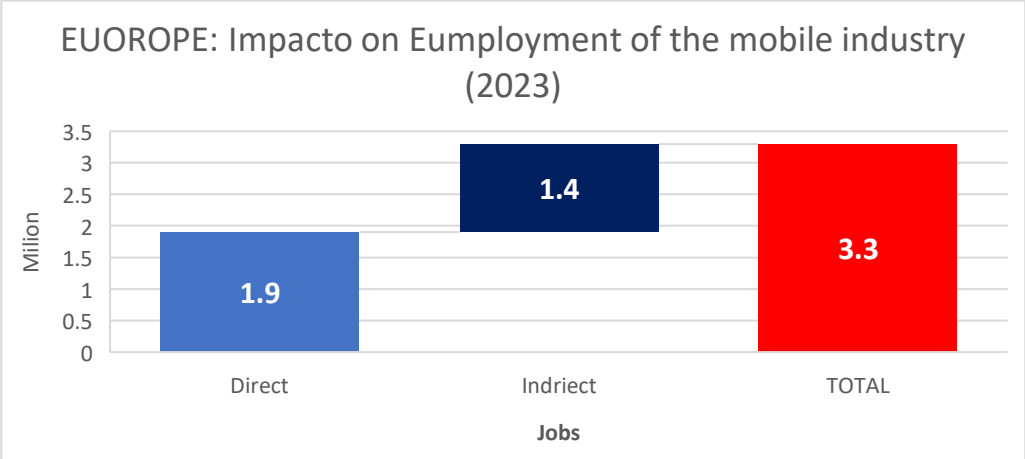

Figure 7: Impact of mobile economy in EU jobs.

2.3 State of the EU Economy Digitalization

The Telecom sector is also pivotal to the digitalization of the European economy since advanced connectivity is a prerequisite for the adoption of key digital technologies such as Cloud or AI that all together drive the competitiveness of European industries. European Commission's 2030 the state of Digital Decade report [6] targets the monitoring of **digital infrastructure** targets (Figure 8) and **digital transformation** targets (Figure 9) for 2030, as well as their delta compared to the current status.

While 5G coverage looks largely on track, 5G in mid band (3,4-3,8 GHz) considered as an indicator of "high quality 5G" falls behind. 'Stand-alone' 5G, which ensures high reliability and low latency use case, is still not deployed at scale, except in a few cases of private networks. Accelerating **5G** deployment is crucial for EU competitiveness and sets the basis for future **6G** deployment, which will reuse large parts of the 5G infrastructure. According to estimates, the increasing softwarisation and cloudification of digital broadband networks require an additional 80 B € of investment up to 2027. This is additional to the amount needed to bridge the over 200 B € investment gap required to achieve the Digital Decade connectivity targets as indicated in the 2023 WIK Consult study commissioned by the EC on investment and funding needs for the Digital Decade connectivity targets and in the first Report on the State of the Digital Decade [6].

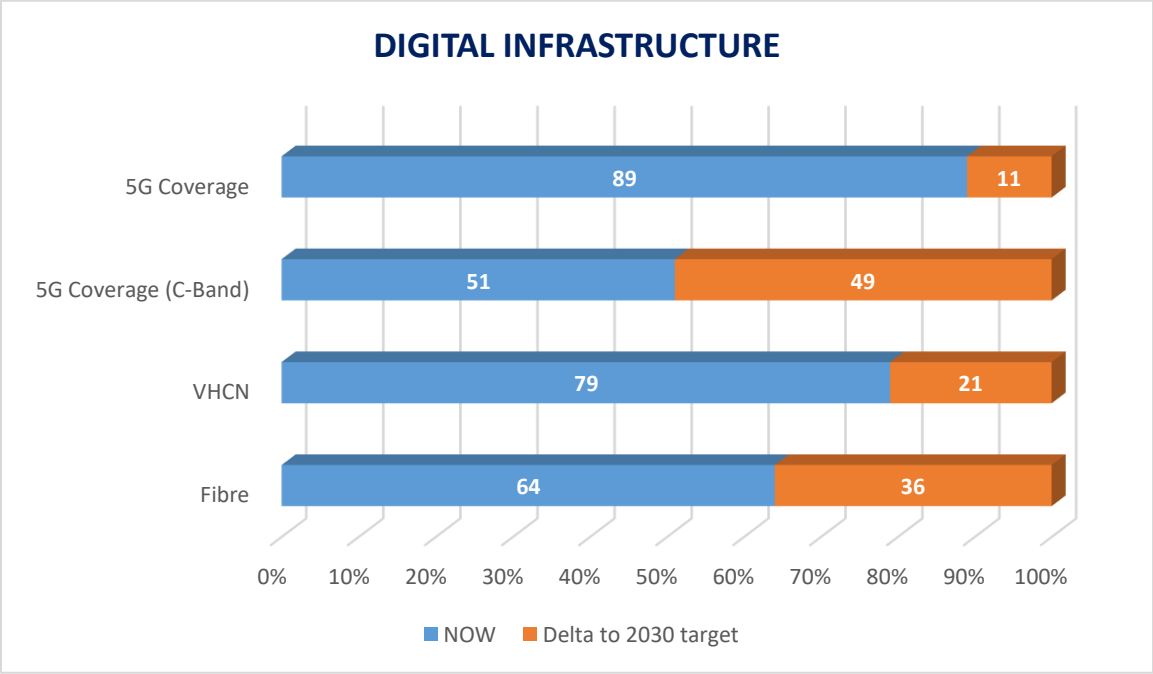

Figure 8: Digital Infrastructure KPIs [6].

Businesses' uptake of digital technologies remains a key challenge, as indicated in Figure 9. Cloud adoption increased by only 7% in 20024, falling short of the 9% needed to meet the target. There has been no noticeable improvement in AI take-up, and merely 32% of European companies have adopted data analytics. The digitalization of SMEs also progresses slowly and unevenly across the EU, with an annual increase of only 2,5%, which is half of the growth rate required to achieve the target. At the current rate of Member State's intervention, the remaining time projected to meet the targets is sometimes well beyond the agreed 2030 timeframe, as depicted in Figure 10.

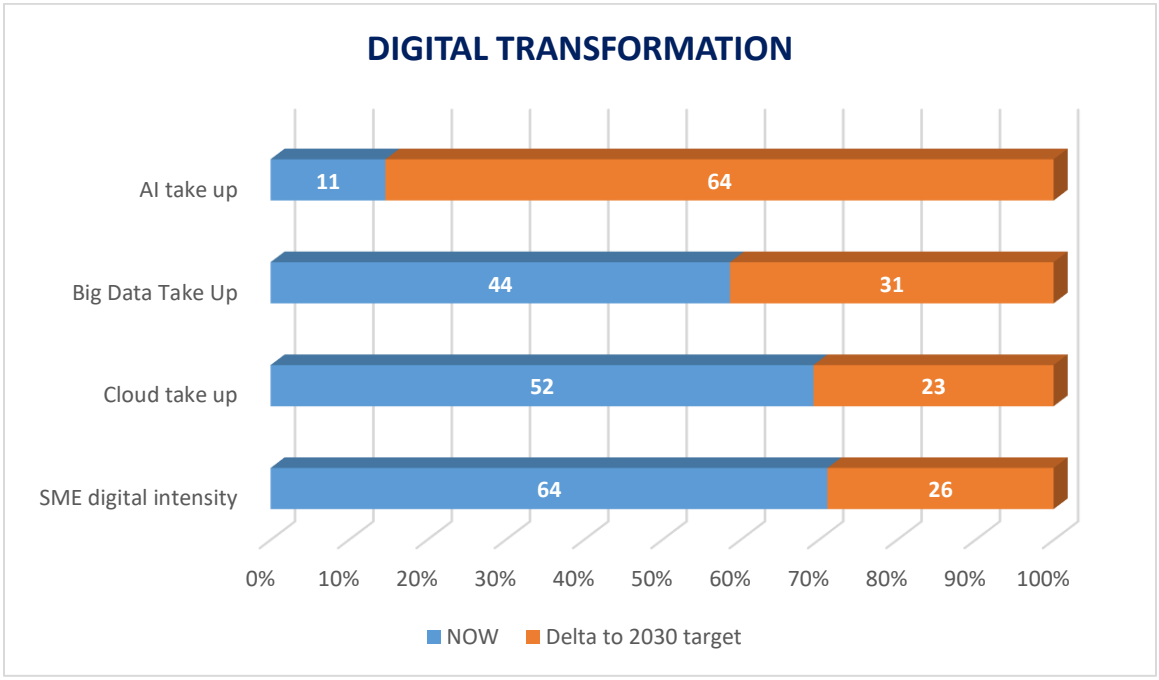

Figure 9: Digital Transformation of Businesses [6].

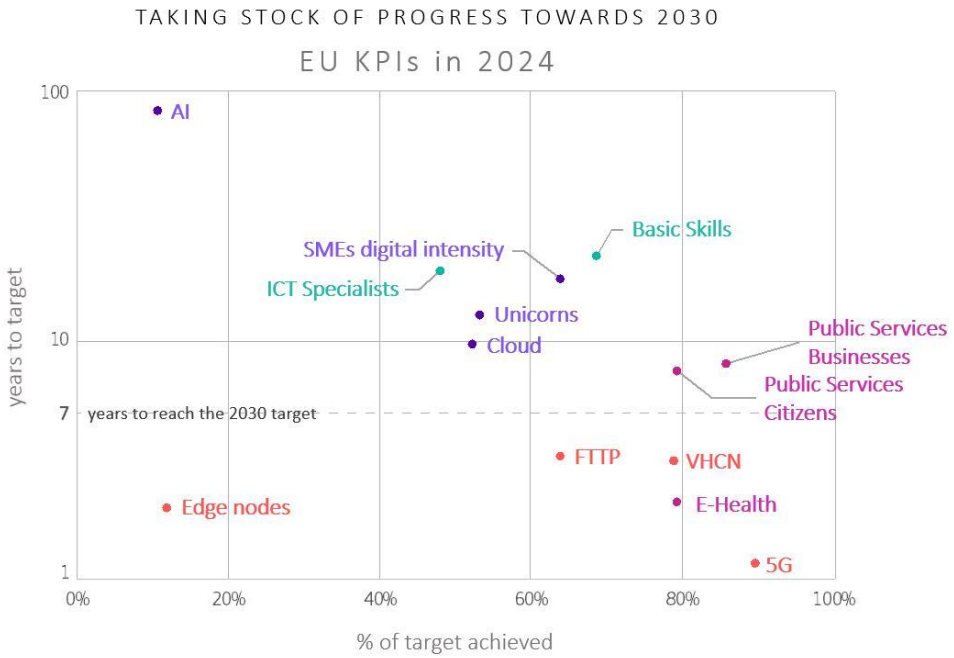

Figure 10: Projected time to target based on last annual average progress for each KPI [6].

3 Vertical Trends analysis

This section combines insights from the trends analysis carried out for the SNS ICE project. The detailed results of the trend analysis and the analysis based on the input provided by the SNS JU projects to the VET, can be found in deliverables D3.2[1] and D3.3 [2] of SNS ICE.

3.1 Trends and challenges across vertical industry domains

Understanding trends, challenges, and emerging use cases across vertical industry domains is critical for shaping the future of connectivity technologies such as 6G. As industries undergo rapid transformation driven by digitalisation, automation, and sustainability goals, their expectations for connectivity are evolving. This creates a dynamic interplay between industrial needs and ongoing R&D efforts in SNS JU, emphasising the necessity of continuous monitoring and alignment. By identifying sector-specific demands and technological gaps, R&D efforts can be directed to address pressing challenges, enable transformative use cases, and meet industrial expectations effectively. As part of the analyses across vertical industry domains carried out by the SNS ICE project, a thorough mapping of emerging trends, challenges, and main use cases was carried out Table 1.

Table 1 below provides insights into how these dynamics shape across key verticals mapped in D3.2 [1] through direct consultation with representatives of key vertical associations, highlighting the strategic importance of aligning connectivity innovation with industrial progress. Moreover, it provides a structured snapshot of the transformative trends, existing challenges, and practical applications in each vertical sector, offering a clear pathway to align connectivity solutions with sectoral demands for 5G, 6G and beyond.

Table 1: Vertical trends across multiple industry domains

Vertical Sector	Trends	Challenges	Main Use Cases
Public Safety	Transition to data-centric MCC, real-time situational awareness, and vertical location tracking for emergencies	Network robustness, interoperability, accuracy in varied environments, ruggedised devices	Real-time emergency response coordination, disaster management with drones, smart surveillance, enhanced location services
Automotive	Cooperative Connected and Automated Mobility (CCAM), proliferation of C-V2X, digital roads, diverse mobility services	Spectrum allocation and use for direct communications, regulatory frameworks, cross-border interoperability, integration of vehicle-to-everything (V2X) services	Autonomous driving, traffic hazard information sharing, pre-emptive traffic lights, teleoperated driving
Transportation	Urban Mobility integration, multimodality, sustainable logistics, predictive traffic management	High infrastructure costs, interoperability of systems, regulatory diversity across regions	Mobility-as-a-Service (MaaS), predictive traffic management, integrated multimodal transportation solutions
Smart Manufacturing	Industry 4.0 advancements, servitisation, real-time supply chain management,	Interoperability, system integration, skilled workforce shortage, delays	Digital twins, autonomous machines, mass sensorisation for real-time operations

	adoption of AI, IoT, and robotics	in device commercialization	
Media	Real-time high-definition content delivery, immersive AR/VR experiences, AI-driven content personalisation	Infrastructure costs, data privacy concerns, technological expertise for AR/VR, accessibility of immersive technology	High-definition live broadcasting, personalised interactive streaming, remote collaborative media production
Agriculture	Smart farming with IoT, precision agriculture, predictive analytics, end-to-end farm management	IoT standardization, rural network coverage, cybersecurity for interconnected systems	Climate monitoring, automated irrigation, agricultural drones for surveillance, cattle monitoring, precision farming
Healthcare	Virtualisation of care, IoT integration for patient monitoring, AI-driven diagnostics, telemedicine	Cybersecurity and data privacy, digital divide, integration of smart pharmaceuticals, scalability of network slicing	Remote patient monitoring, AR/VR for medical training, real-time emergency services, smart pharmaceuticals for chronic disease management

The analysis of vertical sector trends, challenges, and use cases highlights the potential of advanced connectivity technologies in reshaping several industrial sectors. Vertical sectors such as Public Safety, Automotive, Transportation, Smart Manufacturing, Media, Agriculture, and Healthcare are poised for evolution through enhanced connectivity, data-driven capabilities, and innovative solutions. However, these transformations also face barriers such as technological maturity, interoperability, regulatory hurdles and infrastructure demands.

3.2 Current 5G trends and 6G expectations

Beyond traditional vertical sectors, a survey circulated between relevant vertical associations between July and December 2024 framed the state of the art regarding the current implementation and adoption of 5G-based solutions and the expectations for 6G connectivity systems. The results, thoroughly described in D3.3 [2], are summarised in Table 2 below.

Table 2: 5G trends and 6G expectations comparison

5G trends	6G expectations
Adoption and Impact: 5G adoption varies significantly across industries (0%-100% by 2030), with moderate estimates highlighting transitional adoption. High costs and licensing barriers pose challenges, particularly for SMEs. Advanced connectivity technologies (eMBB, URLLC, mMTC) enable diverse applications	**Simplicity & Maintainability:** Simplified network management with automated configuration tools will increase accessibility to advanced connectivity solutions for various industries, particularly in automotive use cases like teleoperated driving and high-bandwidth video streaming. Delays in standardisation and global interoperability pose challenges, but terahertz communications promise ultra-high-speed data transfer to improve safety and monitoring systems.

Multi-domain 5G Applications: Use cases like autonomous machines, IoT devices, and connected vehicles leverage 5G for real-time data exchange. Infrastructure gaps, especially in underserved areas, slow adoption. AI drives predictive analytics, automation, and decision-making	**Global Coverage:** Connectivity in underserved and remote areas for critical applications like telemedicine and smart agriculture. Despite immature low-energy networking technologies and high infrastructure costs, satellite connectivity can provide ubiquitous coverage in areas previously unreachable by terrestrial networks.
Low-Latency Solutions: Demand for low-latency solutions such as telepresence, holoportation, and XR experiences is growing. Standardisation delays (e.g., Open RAN, 5G-V2X) hinder implementation. Edge cloud and IoT support real-time analytics and distributed monitoring	**Very Low Latency:** Real-time capabilities crucial for applications like remote surgery, autonomous vehicles, and industrial automation. Economic barriers, such as high development costs and limited edge device suppliers, present challenges. Reconfigurable Intelligent Surfaces (RIS) provide a promising solution to enhance signal quality and connectivity in dense environments, paving the way for these advanced use cases.
Smart Integrations: Applications include healthcare monitoring, automated parking, and smart grids. Integration of satellite communications remains limited, reducing coverage in remote areas. Digital twins aid simulation, predictive maintenance, and resource optimisation	**AI-Powered Services:** Intelligent automation, cognitive radio, and predictive analytics integrated into network operations can revolutionise public safety and emergency response. Challenges include infrastructure complexity, requiring a high number of base stations, and operational hurdles in managing large-scale deployments. Network APIs, offering customisable and scalable functionalities, can address these challenges effectively.
Enhanced Infrastructure: Improved networks like 5G hybrid slices enable seamless connectivity for critical applications. However, uplink performance and latency still fall short in high-demand areas. XR technologies enhance immersive experiences across sectors	**Sufficient Bandwidth:** Support for data-intensive applications and dense device networks. Limited network availability and spectrum allocation issues currently hinder such advancements. Integrated sensing and communication technologies offer game-changing potential by enabling real-time data acquisition necessary for these applications.
Collaboration and growth: Cross-sector collaboration in automotive, healthcare, and energy drives innovation but faces financial barriers, regulatory hurdles and limited SME access. NTNs complement terrestrial 5G for global connectivity	**Security and Resilience:** Enhanced security and resilience are vital for mission-critical use cases. These applications face challenges due to their reliance on complementary technologies such as satellite communication. Cloud-native networks offer seamless scalability and flexibility, ensuring robust and secure operations in enterprise and critical sectors.
Economic Contribution: 5G is projected to make significant GDP contributions, but deployment complexity (e.g., base station requirements) slows scaling. Network slicing and APIs enable scalable, customisable solutions for diverse applications	**Economic Sustainability:** reduced deployment and operational costs are necessary to make connectivity solutions viable for SMEs and emerging markets. Solutions, are currently hindered by limited funding for early-stage technologies. Low-energy communications provide a sustainable and cost-effective approach, supporting energy-efficient IoT devices and broader adoption in developing regions.

From the analysis of Table 2 it can be observed that while 5G adoption faces gaps across industries due to infrastructure limitations, high costs, and regulatory hurdles, 6G aims to address these barriers, accelerating industry trends across various verticals with technologies like terahertz communications, reconfigurable intelligent surfaces (RIS), and satellite-based global coverage. For example, where 5G struggles to deliver seamless connectivity in underserved areas, 6G promises ubiquitous coverage and very low latency for mission-critical applications such as telemedicine and autonomous vehicles. Although 5G adoption has been uneven, its ongoing integration has laid the groundwork for advanced use cases in automation, IoT, and immersive applications, 6G applications could help bridge technological and financial gaps, significantly accelerating these trends—if barriers like economic constraints, spectrum allocation issues, and operational complexities are effectively overcome. Potential 6G-enabled game-changing technologies include cloud-native networks, AI-powered services, and energy-efficient IoT solutions, 6G has the potential to drive innovation, ensure economic sustainability, and deliver transformative impact across industries. A crucial factor would be ensuring that these advancements are not held back by existing limitations but thrive on the foundational progress made by 5G.

3.3 Current R&D trends across the SNS JU Programme

Alignment of R&D trends within the SNS JU Programme with observed industry trends is vital to bridging the gaps between experimental research and market needs. This section highlights how R&D efforts under SNS JU projects from Call 1 and Call 2 complement industry trends, providing insights into the missing steps required for adoption and implementation across verticals. This synergy allows researchers and industry stakeholders to refine their focus and ensure that technological developments meet real-world demands. The analysis draws on a robust dataset of 247 use cases from 52 projects, reflecting the diverse applications of advanced connectivity technologies across multiple domains.

The Vertical Engagement Tracker (VET)[1], an online platform developed under the SNS JU Programme, plays a pivotal role in mapping and monitoring these use cases across sectors. By cataloguing R&D outcomes and linking them to relevant vertical industry associations, the VET provides a comprehensive view of technological progress and its alignment with industry needs. The detailed mapping of use cases—spanning transportation, manufacturing, smart cities, and more—highlights both the breadth of applications and the challenges in scaling these solutions. This approach ensures that the SNS JU Programme remains focused on addressing the critical gaps in technology adoption, fostering innovation, bridging the gap between research initiatives and industrial expectations, and paving the way for more impactful and targeted innovation.

Table 3 below highlights a broad spectrum of transformative technologies being deployed across various vertical sectors, including XR, AI, IoT, Edge Computing, and 5G/6G connectivity. These technologies demonstrate significant potential to drive innovation, enhance efficiency, and support real-time decision-making across industries such as healthcare, manufacturing, smart cities, and public safety. However, several adoption challenges are evident. Issues such as uneven technology readiness, limited scalability, and inconsistent integration hinder the broader implementation of these solutions. Challenges are particularly pronounced in underdeveloped areas, where infrastructure gaps, high costs, and lack of accessibility pose significant barriers. While technological advancements are progressing, their integration into real-world applications often remains limited due to operational complexities, resource constraints, and the need for further standardisation.

Addressing these challenges at the R&D level allows to bridge the gap between experimental research and market adoption, aligning R&D efforts with the specific needs of vertical industries. This could help mitigate current 5G adoption issues, such as infrastructure and integration bottlenecks, while simultaneously laying the groundwork for meeting some of the ambitious expectations linked to 6G innovations. This would not only accelerate the deployment of transformative technologies but also enable widespread innovation across multiple vertical sectors.

[1] More info at https://sns-trackers.sns-ju.eu/vertical-engagement-tracker.

Table 3: R&D trends in vertical applications

Vertical sector	Main Technologies		
Media / Entertainment	**Type**	**Adoption trends**	**Adoption challenges**
	XR (AR/VR)	Immersive user experiences in live events and gaming with 360-degree views	Limited adoption in enhancing accessibility for differently-abled users
	5G/6G	Enables low-latency, high-bandwidth connectivity for real-time VR streaming	Scalability issues for high-quality XR experiences in large-scale live events
	AI	Personalised content delivery based on user preferences	Inconsistent integration for dynamic user engagement during live events
Education	**Type**	**Adoption trends**	**Adoption challenges**
	XR (AR/VR)	Interactive learning environments (e.g., holographic teaching)	Sparse adoption for STEM education to visualise complex concepts
	AI	Assess student progress and recommend tailored learning paths	Limited applications for personalised learning in remote education settings
	Edge	Support real-time, high-resolution video and interactive collaboration	Underutilised for enabling real-time collaboration in low-connectivity areas
Manufacturing	**Type**	**Adoption trends**	**Adoption challenges**
	XR (AR/VR)	Virtual prototyping and immersive worker training	Edge computing inconsistently implemented for latency-sensitive processes in manufacturing
	IoT	Real-time monitoring and optimisation of production lines	Cybersecurity concerns for IoT devices
	Digital Twins	Simulating machinery for predictive maintenance and resource efficiency	DT adoption limited to large enterprises, with smaller businesses lacking resources
Healthcare	**Type**	**Adoption trends**	**Adoption challenges**
	AI	Diagnostics for decision-making in patient care	Insufficient use in rehabilitation therapies and surgical planning.
	IoT	Wearables support real-time patient monitoring.	Adoption in rural healthcare facilities remains low
	5G/6G	Connectivity for remote surgeries and advanced prosthetics.	Limited integration for real-time analysis, leading to delays in decision-making
	XR (AR/VR)	Remote medical diagnostic and operation	High reliability and confidence, low latency, high security are needed

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Automotive / Transport / Logistics	**Type**	**Adoption trends**	**Adoption challenges**
	IoT	Sensors enable predictive maintenance and fleet optimisation	Inconsistent deployment for predictive maintenance in public transportation
	AI	Algorithms power autonomous driving and real-time traffic management	Limited use for immediate decision-making in autonomous vehicle systems.
	Blockchain	Secured over-the-air updates for connected vehicles	Low adoption for secure transaction records in fleet operations
Public Safety (PPDR)	**Type**	**Adoption trends**	**Adoption challenges**
	AI	Optimised emergency resource allocation and disaster response	Underutilised for real-time overlays of evacuation routes during emergencies
	IoT	Sensors enable real-time situational awareness	Minimal edge computing adoption for drone-based rescue missions
	5G/6G	Critical communication for first responders	Limited edge computing use for immediate decision-making
Smart Cities	**Type**	**Adoption trends**	**Adoption challenges**
	IoT	Sensors monitor infrastructure health (e.g., water systems, power grids)	Limited integration for adaptive lighting and air quality monitoring
	AI	Real-time data for traffic flow optimisation and energy efficiency	Inconsistent adoption for crowd management and urban planning
	5G/6G	Latency reduction in smart utility management	Underutilised for real-time insights into managing urban infrastructure
Tourism & Culture	**Type**	**Adoption trends**	**Adoption challenges**
	AI	Personalised visitor experiences and predicts crowd flow in popular destinations	Limited integration for real-time recommendations and dynamic itinerary planning for visitors
	IoT	Enabled guides for dynamic tours of historical sites	Sparse adoption for crowd control and infrastructure monitoring in heritage sites
	XR (AR/VR)	Virtual museum exhibits and cultural experiences	Underexplored applications for virtual tourism
Agriculture	**Type**	**Adoption trends**	**Adoption challenges**
	IoT	Sensors for real-time soil and crop health data	Inconsistent deployment for water and nutrient monitoring in developing regions
	AI	Optimised resource use and pest management	Underutilised AI-driven analytics for weather predictions and yield forecasting
	Edge	Low-latency decision-making for precision farming	Minimal adoption for real-time farm equipment management

3.4 Vertical-oriented insights from SNS ICE Final event

Vertical engagement activities performed under SNS ICE were presented during the project final event to an open audience including the SNS community and other stakeholders, i.e., EU Officials, SNS JU Office representatives, 6GIA Board Members, Industry leaders and the wider SNS Community including Researchers, Verticals, experts etc. Verticals are key to the success of 6G as most of the economic impact of new generation mobile technologies happens at industrial level[2]. Therefore, having engaged verticals from the day 1 in designing 6G is paramount and SNS ICE effort to "close the gap" with vertical industries was perceived very positively by public and private stakeholders.

During the final event both the vertical surveys performed under SNS ICE and the vertical engagement tracker were presented. The vertical survey objectives were double fold: gather lessons learned on 5G adoption by vertical industries and their expectations on 6G to fill the gap with unattended 5G hypes. Some relevant outcomes emerged, as the need for more simplicity and maintainability of 6G with respect to 5G, fill the coverage gap with NTNs integrated into 6G and consider from day 1 also sustainability aspect (e.g. low energy consumption by design to reduce carbon footprint and lower network OPEX) for 6G deployment. The survey was executed engaging 6GIA MoU partners and the general 6G membership.

The Vertical Engagement Tracker (VET) emerged as the golden nugget of the SNS ICE project, a well-designed and interactive web tool that gathered, organized and shared the key information about all vertical oriented projects running under SNS JU. 283 use cases were mapped from Open Calls 1 and 2, encompassing 11 key vertical sectors in 25 countries. Different projects, from basic research to trials were mapped. Relevant information can be filtered out in the VET[3], like vertical uses cases, location, type of project. The VET is left behind as an important legacy from the SNS ICE project, and its maintenance and update with new data from the next SNS projects has been taken over by the follow-up CSA project, SNS CO-OP.

Both tools can be considered as an attempt to complement the typical bottom up and technology driven approach for EU funded project with a more top-down driven approach in which final users' needs and concerns are taken into consideration from day 1. The usefulness of SNS ICE's work with vertical sectors and the impact created was explained during the final event[4] (which took place on April 28th, 2025), while a live tour of the VET was also given, to educate the audience in the use and advantages of the tool. Overall, the feedback of the vertical sectors' representatives to the efforts of SNS ICE received very positive feedback, while in the limited time for Q&A that remained in the event, no clarifications questions were asked regarding the project's vertical activities.

[2] See Section 2.2

[3] https://sns-trackers.sns-ju.eu/vertical-engagement-tracker/vertical-cartography/vertical-engagement-charts

[4] https://smart-networks.europa.eu/event/sns-ice-final-event-showcasing-key-achievements/

4 Recommendations and Position Statements

5G will drive economic growth empowering vertical industries. 6G will offer enhanced performances and new use cases with respect to 5G, triggering further economic uplift.

To reap the full economic impact of 6G on the European economy, policy measures must be envisaged both at sectorial and cross sectorial level. Recent Letta [7] and Draghi [8] reports provide a solid basis for policy reshuffling at both levels.

4.1 Drivers and barriers for economic growth

Europe suffers from lower economic competitiveness with respect to competing regions such as USA and China. The reason stands in lower productivity of the European economy, less empowered by key digital technologies such as 5G, Cloud and AI. Productivity will be key for the European economic growth since labour workforce will shrink. Present productivity growth would only guarantee the present level of GDP until 2040.

Moreover, Europe lacks digital champions and is poorly resilient with respect to digital technologies. Europe is a market of 440 million consumers and 23 million companies, accounting for around 17% of global GDP, as depicted in Figure 11. The European model combines an open economy, a high degree of market competition and a strong regulatory framework.

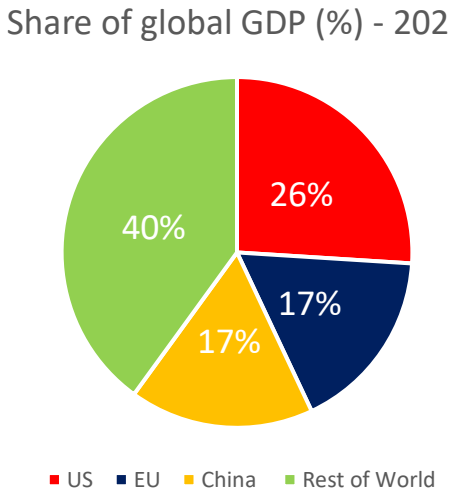

Figure 11: Share of World GDP

EU economic growth has underperformed with respect to US and China over the past two decades. The EU-US gap in the level of GDP 5 has gradually widened from 15% in 2002 to 30% in 2023, on a purchasing power parity (PPP) basis a gap of 12% has emerged. Around 70% of the gap is explained by lower productivity of EU economy. Europe's position in digital technologies (pivotal for future growth) is declining. Only four of the world's top 50 top companies are European and the EU's global position in tech is deteriorating: from 2013 to 2023, its share of global tech revenues dropped from 22% to 18%, while the US share rose from 30% to 38%.

Hence Europe urgently needs to accelerate on digital innovation to boost its productivity and maintain industrial leadership since Europe is lagging in breakthrough digital technologies.

70% of foundational AI models have been developed in the US while three US "hyper-scalers" account for over 65% of the global and the European cloud market. The largest European cloud operator accounts for just 2% of

[5] at 2015 prices

the EU market. Quantum computing is poised to be the next major innovation. In relation to investment in quantum, five of the top ten tech companies are based in the US and four in China, none in EU.

Barriers in Europe root in companies' creation and scale up with obstacles in the pipeline from innovation to commercialisation. Innovative digital companies are generally failing to scale up in Europe and attract finance, with a huge gap in later-stage financing between the EU and the US. Once companies reach the growth stage, regulatory and bureaucratic hurdles prevent them from scaling-up into mature, profitable companies and therefore many innovative companies end up seeking out financing from US venture capitalists (VCs) and consider expanding in the large US market as a more rewarding option than tackling fragmented EU markets.

In fact, there is no EU company with a market capitalisation over EUR 100 billion that has been set up from scratch in the last fifty years, while in the US all six companies with a valuation above EUR 1 trillion have been created over this period.

Fragmentation of the Single Market in national capital markets hinder innovative companies that reach the growth stage from scaling up in the EU. 147 "unicorns"6 were founded in Europe between 2008 and 2023 but 40 of these have relocated their headquarters abroad (mainly in the US). 61% of total global funding for AI start-ups goes to US companies, 17% to those in China and just 6% to those in the EU. For quantum computing, EU companies attract only 5% of global private funding.

Integrating AI into European economy will be another critical factor in unlock higher economic value:

- economic uplift of USD 60-110 billion per year is estimated from employing AI in the pharma and medical device industries;
- in the automotive sector, AI can enhance vehicle design by optimising structures and components, improve performance, reduce material use and optimise supply chains by predicting demand and streamlining logistics operations;
- in transports AI may increasingly automate functions to deliver safety and quality, navigation and route optimisation, predictive maintenance and fuel reduction,
- the energy sector is already heavily deploying AI, from grid maintenance to load forecasting and large gains are however still available: estimates of the market value for future AI applications in the sector reach USD 13 billion.

Europe's weak position in digital technologies comes from a static industrial structure which produces a vicious circle of low investment and low innovation. Over the last 2 decades, the top-three US companies for spending on R&I have shifted from the automotive and pharma industries in the 2000s, to software and hardware companies in the 2010s, and then to the digital sector in the 2020s. In contrast, Europe's automotive companies are still the top 3 R&I spenders. While US has shifted resources towards sectors with high potential for productivity growth, Europe investments have remained concentrated on mature technologies and in sectors where productivity growth rates of frontier companies are slowing.

In 2021, EU companies spent about half as much on R&I as share of GDP as US companies, a gap driven by much higher high tech investment rates.

This innovation gap translates into a gap in overall productive investment between the two economies, which is driven mainly by lower investment in ICT, software, data and IPR.

Regulatory burden is another handicap to EU digital companies' growth. EU counts with 100 tech-focused laws and over 270 regulators active in digital networks across all Member States. Often EU laws take an' ex ante approach' to avert potential risks often resulting in damaging overruling7 hindering investments. Digital companies trying to do business in EU face heterogeneous requirements, a proliferation of regulatory agencies and

[6] Startups valued over USD 1 billion

[7] For example, the AI Act imposes additional regulatory requirements on general purpose AI models that exceed a predefined threshold of computational power – a threshold which some state-of-the-art models already exceed

"gold plating" of EU legislation by national authorities. High compliance costs hinder investments, especially by small size companies.

This problem is further exacerbated by EU competition enforcement inhibiting intra-industry cooperation and consolidation. The net effect of EU regulatory burden is that only larger companies (often non-EU based) have the financial capacity and incentive to bear the costs of complying while innovative tech companies and SMEs may choose not to operate in the EU at all.

A fragmented Single Market often hinders companies from reaching sufficient size to accelerate adoption of advanced technologies. In EU barriers that lead companies in Europe to "stay small" prevent them to reap the opportunities of the Single Market. Barriers that hinder small companies to scale up include the high cost of adhering to heterogenous national regulations, the high cost of tax compliance, and the high cost of complying with regulations that apply once companies reach a particular size. Evidence from the US show that adoption rises with firm size for all advanced technologies like 5G, cloud and AI. Data show that in 2023, 30% of large businesses in the EU had adopted AI while only 7% of SMEs did8. A fragmented Single Market puts EU companies at a disadvantage in terms of the speed of adoption and diffusion of new AI applications.

Lack of computing power and lack of investment in connectivity may translate into digital bottlenecks. Training AI models and building vertically integrated AI applications requires massive increases in computing power, which is triggering an ongoing global AI chip race. Smaller and less well-funded EU companies may struggle to compete in the race to gather AI resources. Moreover, deploying AI will require faster, lower latency and more secure connections. The investment levels required to support EU networks are estimated at around EUR 200 billion to ensure full gigabit and 5G coverage across the EU. But Europe's per capita investment is lower than other major economies due to lower revenues for EU telco operators (Figure 12).

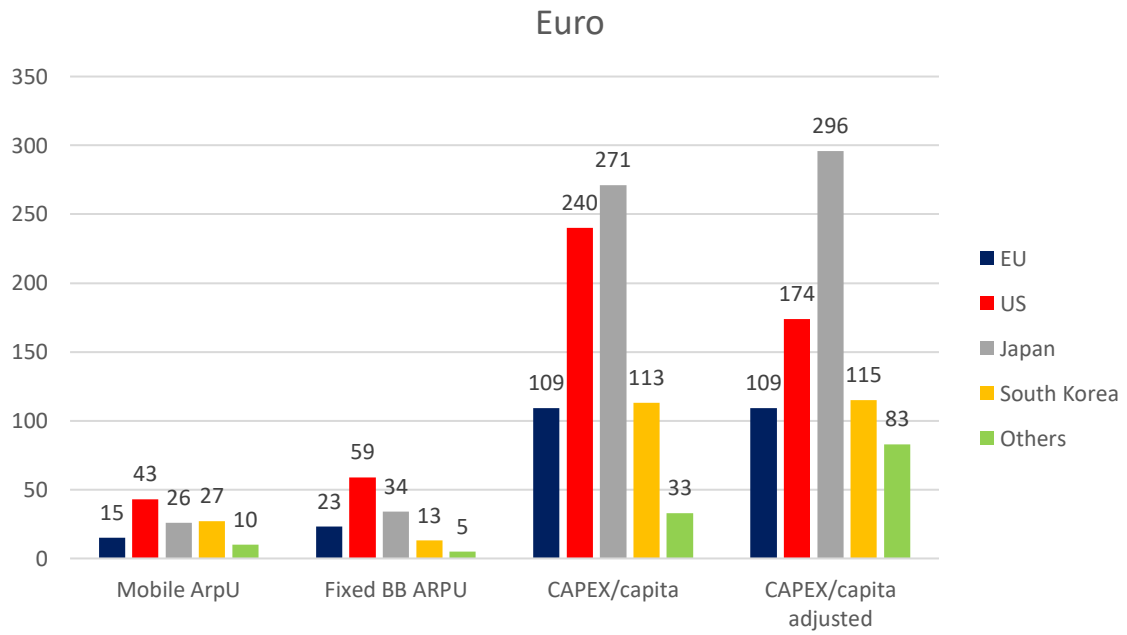

Figure 12: Human ARPU and CAPEX per capita comparison (ETNO 2023) [4]

A key reason for lower rates of investment is the fragmentation of the European telecommunications market. Europe accounts for 34 mobile network operator groups against a handful of operators in the US or China. This fragmentation makes the fixed costs of investing in networks more onerous for EU operators which are less incentivized to invest in next generation networks. Fragmentation hinders scale making it harder to capitalize on

[8] Size enables adoption because larger companies can spread the high fixed costs of AI investment over greater revenues, they can count on more skilled management to make the necessary organizational changes, they can deploy AI more productively owing larger data sets

new technologies. Europe currently has virtually no presence in edge computing as the Digital Economy and Society Index (DESI) figures indicate[9].

4.2 Recommendations to maximize economic impact of 6G and digital technologies

Based on the presented survey results, state of EU economy Digitalization and vertical trend analysis, a few recommendations can be made to maximize the economic impact of 6G for EU member states and to re-claim Europe's prominence in the Digital Technologies domains. Table 4 presents these recommendations.

Table 4: Recommendations to maximize economic impact of 6G

Recommendation	Suggested direction
Accelerate on digitalization	EU competitiveness will increasingly depend on the digitalization of all sectors improving productivity. To seize the benefits of digitalization and advanced technologies, EU requires state-of-the-art digital infrastructure including ubiquitous, high-speed mobile and fixed broadband networks, cloud computing and AI ready data centres.
Boost and protect EU data	Data generated in digital infrastructures will play a pivotal role. The 'data value loss' is today estimated at 90% with a long-term risk of loss of industrial know-how. This issue needs to be addressed along with digitization, considering the crucial role of data in the economy. Therefore, policies and initiatives to speed up digitalisation and boost advanced technologies should be prioritized - mobile and fixed broadband technologies (networks, services and devices), Cloud, AI, and semiconductors should be a strategic priority for EU policy makers.
Shift to a 'Digital Economy' industrial model	The EU's industrial model, so far based on imports of advanced technologies and exports from traditional sectors (e.g. the automotive, precision mechanics, chemical, materials and fashion industries), does not reflect the current pace of technological change. As 70% of the new value created in the world economy in the next ten years will be digitally enabled, the risk of value loss for the EU is huge. While the EU relies on third countries for over 80% of its digital products, services, infrastructures and intellectual property (IP), other economies (like US and China) have been shifting their economic model since the first internet revolution of the early 2000s, a trend which accelerated since the 2019 with the revolution. To shift to a digital industrial model Europe has to globally reinforce its ICT global market share.
Reform the telco sector and strengthen the Telecom Single Market	Pro consumer 'ex ante' driven regulation and stricter competition policy in the telecom sector have delayed consolidation, favoring a multiplicity of smaller players with poor financial leverage for new investments in novel network technologies. In other regions 'ex-post' regulation has allowed consolidation

[9] https://digital-decade-desi.digital-strategy.ec.europa.eu/datasets/desi/charts/desi-indicators?period=desi_2024&indicator=desi_bbspeed_1000&breakdown=total&unit=pc_lines&country=AT%2CBE%2CBG%2CHR%2CCY%2CCZ%2CDK%2CEE%2CEU%2CFI%2CFR%2CDE%2CEL%2CHU%2CIE%2CIT%2CLV%2CLT%2CLU%2CMT%2CNL%2CPL%2CPT%2CRO%2CSK%2CSI%2CES%2CSE

	to occur, with the result that e.g. in the US and China a few large operators serve hundreds of millions of citizens each, reaping the benefits of higher prices that allow financial wealth for further investment in a virtuous circle that bring to the aforementioned figures. In EU hard remedies were imposed upon attempts to consolidate the market into larger players leading to the creation of additional smaller players, reducing or eliminating the benefits of consolidation. EU providers have shrunk and become smaller compared to that of competing economic regions. *The total market capitalisation of the EU's telecom sector fell by 41% over from 2015 to -2023 to reach around EUR 270 billion, compared to over EUR 650 billion in market capitalisation for US telecom operators. Even more strikingly, the five largest US tech companies (Alphabet, Amazon, Apple, Meta and, Microsoft) capitalise around USD 8.7 trillion, while only four of the 50 largest tech providers by market capitalisation are EU companies*.[10] In Europe spectrum policies have been uncoordinated across Member States and mostly designed to maximize frequencies' pricing. In other regions, beauty contest mechanisms allowed operators to free resources for coverage and capacity enhancement. The multi-country (rather than pan-EU) set-up of the sector has also led to a costly proliferation of different obligations for EU telecom operators like local 'Lawful Interception' requirements and emergency public utility services all essentially set at Member State level. The new EU regulatory roadmap including a *Digital Network Act* (4Q2025) to reform the telecom sector and enhance incentives for network investments is urgently needed.
Reinforce public private partnerships	The European policy should promote collaboration among industry, society and institutions and support the dialogue between the stakeholders (both commercial and institutional) from different sectors. The different funding programs should be timely and effectively coordinated favoring collaboration and intersectoral synergies so that the opportunities arising from technology innovation and digital transformation can be seized in the different industrial sectors for the benefit of the entire European economy.
Europe will need to fully accomplish the Digital Single Market	The European Digital Market has still to be fully accomplished to unlock full economic benefit from the European scale. For instance, the lack of a European scale for digital companies has a very negative effect, since they tend to relocate elsewhere leaving Europe without big game changing project to be funded (e.g. IPCEI) which in turns hinders the creation of a solid capital market in Europe. Innovation in Europe has access to large public funding, comparable with US but it takes place mostly at national level. More coordinated effort across European countries and synergies with EU funding will create more impact of public funded innovation.

[10] ASML (391 B$), SAP (222 B$), Siemens (154 B$), and Schneider Electric (127 B$)

References

[1] SNS ICE Deliverable D3.2, 'Initial trends analysis in vertical sectors', January 2024, https://smart-networks.europa.eu/csa-s/#SNS-ICE

[2] SNS ICE Deliverable D3.3, 'Updated trends analysis in vertical sectors', December 2024, https://smart-networks.europa.eu/csa-s/#SNS-ICE

[3] SNS ICE Deliverable D3.1, 'Vertical Engagement Tracker', June 2023, https://smart-networks.europa.eu/csa-s/#SNS-ICE

[4] European Telecommunications Network Operators' Association (ETNO), 'State of Digital Communications', 2024, https://connecteurope.org/insights/reports/state-digital-communications-2024

[5] GSMA report, 'Mobile Economy Europe 2025, https://www.gsma.com/solutions-and-impact/connectivity-for-good/mobile-economy/europe/

[6] European Commission, 'Report on the state of the Digital Decade 2024 (EU), https://digital-strategy.ec.europa.eu/en/factpages/state-digital-decade-2024-report

[7] Enrico Letta, "Much more than a Market" April 2024, https://www.consilium.europa.eu/media/ny3j24sm/much-more-than-a-market-report-by-enrico-letta.pdf

[8] The Draghi report on EU competitiveness , "The Future of European competitiveness", September 2024, https://commission.europa.eu/topics/eu-competitiveness/draghi-report_en