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Lead editors	Kostas Trichias (6G-IA)
Authors	Kostas Trichias, Alex Kaloxylos, Pierre-Yves Danet, Alessandro Bedeschi (6G-IA); Colin Willcock (NSN); Didier Bourse (NNF); Uwe Herzog (Eurescom); Arda Gureller (Ericsson); Per H Lehne, Håkon Lønsethagen, Hanne-Stine Hallingby (Telenor); Rui Aguiar, José Cabaça (IT); Jessica Carneiro (Australo); James Clarke (SETU); Jose Almodovar Chico, Prachi Sachdeva (TNO); Carles Anton-Haro (CTTC); Raffaele de Peppe, Manuela Bargis (TIM); Veronica Vuotto (Trust-IT)
Reviewers	Kostas Trichias (6G-IA), Carles Anton Haro (CTTC)
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Abstract

This report assesses Europe's progress and strategic positioning in 6G through the 2025 SNS CO-OP Monitoring Framework and an updated global landscape review. SNS projects show strong research momentum, with extensive publications, standardization work, trials, and open-source outputs across Calls 1–3. Emerging priorities include AI-native architectures, RIS, advanced sensing, non-terrestrial networks, and energy-efficient system design. Vertical sectors - manufacturing, mobility, health, media, public safety, and smart cities - remain central to expected 6G impact. Projects increasingly integrate societal values, focusing on trustworthiness, sustainability, and user-centricity, with energy efficiency as a dominant theme. Global analysis shows Europe broadly aligned with international 6G directions but needing reinforced investment in AI, cloud-edge, semiconductors, and security. The updated SNS Vision emphasizes a smooth 5G-to-6G transition, sustainability-by-design, sovereignty in key technologies, and interoperable, human-centric networks. The strategic recommendations include strengthened competitiveness, collaboration, and innovation as we move towards SNS Phase 3 and FP10.

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Executive Summary

This report presents a comprehensive analysis of the progress, strategic direction, and emerging trends within the European Smart Networks and Services Joint Undertaking (SNS JU) ecosystem, as assessed through the 2025 SNS CO-OP Monitoring & Analysis Framework and an updated 6G global landscape review. It highlights Europe's positioning, priorities, and readiness for shaping the next generation of communication networks while identifying challenges and opportunities relevant for strategic decision-making.

SNS CO-OP continues the monitoring and assessment activities initiated under the previous SNS OPS CSA, refining the annual questionnaire to better capture project performance, technological orientation, and alignment with SNS JU priorities. Inputs from 35 Call 1 projects, 28 Call 2 projects, and all newly launched Call 3 projects form the analytical basis for this deliverable. The Framework consolidates data on dissemination, standardization, trial activities, intellectual property generation, and forward-looking technical ambitions.

Across SNS Calls 1 and 2, projects demonstrate strong momentum in research outputs, including a high volume of publications, standardization contributions, open-source engagement, PoCs, lab validations, and early trial activities. Standardization remains a central pillar, with significant contributions across major SDOs such as 3GPP, ETSI, and ITU-R. Call 3 projects, still early in their lifecycle, emphasize ambitious plans in key technical domains—AI/ML-driven architectures, Reconfigurable Intelligent Surfaces, advanced sensing, non-terrestrial networks, and energy-efficient system design. Vertical impact remains a strong focus, with projects addressing wide-ranging domains including manufacturing, mobility, health, media, public safety, and smart cities.

On the vision side, SNS projects place increasing importance on societal values, ethics, trustworthiness, sustainability, and user-centricity. Contributions to Key Value Indicators (KVIs) such as security, resilience, inclusiveness, and environmental sustainability are prominent. Energy efficiency continues to dominate sustainability efforts, though future work is expected to broaden toward lifecycle thinking and socio-economic dimensions. Market-wise, stakeholders expect significant disruption with the advent of 6G, particularly in cloud-edge integration, AI-driven network automation, and the expansion of private networks across industrial verticals.

The 6G landscape analysis confirms strong alignment between European efforts and global developments while revealing areas requiring strategic reinforcement. The report synthesizes the positions of major international associations (e.g., 6G-IA, NGMN, ATIS, B5PC), national initiatives, and industrial ecosystems. Core themes across regions include AI-native networks, spectrum evolution, microelectronics autonomy, secure cloud-edge infrastructures, and sustainable architectures. Europe maintains a competitive stance but must sustain investment and strengthen sovereignty in critical enablers such as AI, cloud, semiconductor technologies, and advanced security.

Finally, this deliverable provides an update to the SNS Vision, building on prior SNS-OPS work. The evolving vision highlights a smooth transition from 5G to 6G, a strong emphasis on sustainability-by-design, European technological leadership, and the creation of interoperable, trustworthy, and human-centric network infrastructures. The report concludes with strategic insights to guide decision-makers in steering SNS activities towards global competitiveness, reinforced collaboration, and impactful innovation as we move towards SNS Phase 3 and FP10.

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Abbreviations

Abbreviation	Explanation
3CN	3C Network – Connected, Collaborative Computing
3GPP	Third Generation Partnership Project
5G-ACIA	5G Alliance for Connected Industries and Automation
6G-IA	6G Industry Association
6GF	6G Forum
AI	Artificial Intelligence
AIaaS	AI as a Service
AIOTI	Alliance for IoT and Edge Computing Innovation
API	Application Programming Interface
AR	Augmented Reality
ATIS	Alliance for Telecommunications Industry Solutions
B2B	Business to Business
B5PC	Beyond 5G Promotion Consortium
B6GA	Bharat 6G Alliance
CAIRNE	Confederation of Laboratories for Artificial Intelligence Research in Europe
CAPEX	Capital Expenditure
CCAM	Cooperative Connected and Automated Mobility
CCSA	China Communications Standards Association
CFP	Call For Papers
CHIPS-JU	Chips Joint Understanding
CPE	Customer-Premises Equipment
CSA	Coordination and Support Action
CSO	Civil Society Organization
CT	Core Team
DG-CNECT	Directorate-General for Communications Networks, Content and Technology
DG-RTD	Directorate-General for Research and Innovation
DLT	Distributed Ledger Technology
DRO	Digital Rail Operations
EC	European Commission
ECCC	European Cybersecurity Competence Centre
ECF	European Competitiveness Fund
ECS	Edge Computing System
ECSO	European Cyber Security Organisation
EDIH	European Digital Innovation Hub
EE	Energy Efficiency
EFTA	European Free Trade Association
EGDC	European Green Digital Coalition

EIM	European Rail Infrastructure Managers
ELLIS	European Laboratory for Learning and Intelligent Systems
ENI	Experiential Networked Intelligence
ESA	European Space Agency
ESRA	European Semiconductor Regions Alliance
ETP	European Technology Platform
ETSI	European Telecommunication Standards Institute
EUCNC	European Conference on Networks and Communications
EuroHPC JU	Euro High Performance Computing Joint Undertaking
EV	Electric Vehicle
FEM	Front-End Module
FL	Federated Learning
FP10	Framework Programme 10
FRMCS	Future Railway Mobile Communication System
FSTP	Financial Support to Third Party
GaN	Gallium Nitride (semiconductors)
GSMA	Global System for Mobile Communications Association
HE	Horizon Europe
HPC	High Performance Computing
ICT	Information and Communication Technology
IDS	Intrusion Detection System
IETF	Internet Engineering Task Force
IMT-2030	International Mobile Telecommunications - 2030
IoT	Internet of Things
IP	Internet Protocol
IPCEI	Important Projects of Common European Interest
IPR	Intellectual Property Rights
ISAC	Integrated Sensing and Communications
ISG	Industry Specification Group
ITU-R	International Telecommunication Union – Radiocommunication Sector
KER	Key Exploitable Result
KPI	Key Performance Indicator
KSO	Key Strategic Orientation
KVI	Key Value Indicator
M&E	Media & Entertainment
MEC	Multi-access Edge Computing
MFF	Multi-year Financial Framework
MIMO	Multiple Input – Multiple Output
ML	Machine Learning
MLOps	Machine Learning Operations

MNO	Mobile Network Operator
MoU	Memorandum of Understanding
MR	Mixed Reality
NaaS	Network-as-a-Service
NESSI	Networked European Software and Services Initiative
NGA	Next G Alliance
NGMN	Next Generation Mobile Networks Alliance
NGO	Non-Governmental Organization
NTN	Non-Terrestrial Network
NWE	NetworldEurope
OAI	Open Air Interface
OPEX	Operational Expenditure
PoC	Proof of Concept
PPDR	Public Protection and Disaster relief
PQC	Post-Quantum Cryptography
PSCE	Public Safety Communications Europe
QIA	Quantum Internet Alliance
QKD	Quantum Key Distribution
QoE	Quality of Experience
QuIC	European Quantum Industry Consortium
R&I	Research and Innovation
RAN	Radio Access Network
RIS	Reconfigurable Intelligent Surface
RoI	Return on Investment
RT	Real Time
SB	Steering Board
SDG	Sustainable Development Goals
SDO	Standards Developing Organization
SME	Small or Medium sized Enterprise
SNO	Satellite Network Operator
SNS JU	Smart Network and Services Joint Undertaking
SoC	System on a Chip
SRIA	Strategic Research and Innovation Agenda
SRIDA	Strategic Research, Innovation, and Deployment Agenda
T&P	Trials & Pilots
TB	Technology Board
TF	Task Force
TN	Terrestrial Network
TRL	Technology Readiness Level
TSDSI	Telecommunications Standards Development Society

TSN	Time Sensitive Networking
UAV	Unmanned Aerial Vehicle
URLLC	Ultra Reliable Low Latency Communication
V2X	Vehicle to Anything
VET	Vertical Engagement Tracker
VFCS	Visions for Future Communications Summit
VR	Virtual Reality
VSC WG	Vision and Societal Challenges Working Group
VNF	Virtual Network Function
XR	Extended Reality
ZSM	Zero-touch network & Service Management

1 Introduction

Two main objectives of the SNS CO-OP CSA are (i) to support a continual monitoring and improvement process based on regular assessments of SNS KPIs; and (ii) to provide support for the identification of strategic R&I orientations at global, European Member State and vertical level. These objectives are mainly addressed by Work Package (WP) 1 "Strategic Perspectives" which has grouped its activities into three tasks: T1.1 "SNS Agenda & Vision", T1.2 "6G Trend monitoring Global & National, EU & Verticals", and T1.3 "SNS JU Data Collection & Progress Assessment". This document is the first Deliverable of WP1, prepared at the end of the first project year. As such it reports on all the activities, results and insights gained by the partners' work in the various WP1 Tasks.

One of the key items reported in this deliverable is the detailed analysis of the 2025 SNS CO-OP Questionnaire that all active SNS JU projects have been asked to complete, as part of the SNS CO-OP Monitoring and Analysis Framework activities. This framework has been taken over from the predecessor CSA SNS OPS, and re-examined by SNS CO-OP, based on the lessons learned from SNS OPS as well as based on projects' feedback. The two different versions of the questionnaire – one that is sent to newly started projects – and another one that is sent to all the other "ongoing" projects have been revised, and details on that process and the specific modifications are presented in Section 2 of this document.

A summary of the analysis of the project responses to the questionnaire is presented in Sections 3 and 4. Section 3 addresses the analysis of the responses from "ongoing" projects, which focuses on the project results achieved by projects from SNS Call 1 and 2 in 2024. This comprises the responses from 35 Call 1 projects and 28 Call 2 projects. It summarises the achievements in terms of dissemination activities, testing and trialling activities, contributions to SDOs and securing of IPR generated in these projects.

Section 4 then summarises the analysis of responses from the newly started Call 3 projects. These projects were asked about their plans and ambitions structured into three sections: a) Technical aspects, b) Vision aspects, and c) Market aspects. This activity is an important element of the monitoring and analysis framework. It enables a gap analysis and roadmap definition which constitute an important process within SNS as it allows for the comparison of the goals, the addressed technologies and verticals of the selected projects of each Call against the EU and SNS-JU high level goals. The results of the analysis were presented in a public webinar that was organised on 16 June 2025.

The 6G Landscape and Trends analysis performed by predecessor CSAs and which is now continued under SNS CO-OP examines the R&I activities that other regions, associations, verticals and stakeholders engaged in 6G are conducting. The insights gained from that provide a valuable view on the visions of these regions or organisations on the development of future 6G networks, and these insights are very useful for the SNS JU as they help in benchmarking the European and SNS vision and work against those of other relevant stakeholders. SNS CO-OP decided to go beyond yet another general trend analysis that had been performed previously, and instead to perform a targeted analysis on the work carried out and the vision of various stakeholders regarding key technologies, features and aspects of 6G networks, revealing commonalities and differences, as well as alignment or divergence of expectations regarding specific technologies and their expected impact in 6G. This included topics as e.g. Artificial Intelligence (AI), Cloud/edge - 3CN, Micro-electronics or Cyber-Security. The results of this landscape analysis are presented in Section 5 of this Deliverable.

Section 6 presents a first step towards an SNS Vision update which builds on the SNS Vision work done in the former SNS-OPS project. It provides a preliminary vision trend analysis and complements the trend analysis in Section 5 which emphasises stakeholder and industry vision perspectives. In this deliverable the emphasis is on identifying what has been published since March 2025 from European 6G stakeholders and relevant groups and fora, especially from the 6G-IA, and the SNS JU programme, in terms of e.g. a smooth migration from 5G to 6G, developing a sustainable 6G (and 6G for sustainability), or on strengthening the European competitiveness.

Finally, Section 7 completes the report with some conclusions.

2 SNS CO-OP Monitoring & Analysis Framework Evolution

The SNS JU Monitoring & Analysis Framework was established by the SNS OPS CSA during the first phase of the SNS JU [1], as a way to retrieve important information both from new as well as ongoing SNS JU projects, regarding their scope, ongoing work, technical approach, vision and market prospects. This framework, which is primarily based on an annual questionnaire issued to the projects, has since been established as one of the most critical SNS internal activities, allowing for up-to-date overview of the SNS JU status and providing useful information to be communicated to the rest of the world, regarding the SNS JU's work, vision and achievements.

This section outlines the handover of the Monitoring & Analysis Framework from SNS OPS to SNS CO-OP and its continuous operation to track project work as well as the updates applied per section for the 2025 edition of the questionnaire. The 2025 edition requested input from Call 3 projects that had just started, and from Call 1 and Call 2 projects regarding their accomplishments in the calendar year 2024.

2.1 Takeover from SNS OPS

SNS CO-OP took over the ownership of this framework from SNS OPS in 2025, making the project responsible for the maintenance and update of the questionnaire, as well as the annual request for input, collection, processing and presentation of the results. As all the partners that were engaged with the Framework in SNS OPS are also involved in SNS CO-OP, the transition was very smooth as no particular handover was necessary. All key personnel retained their respective roles (Questionnaire leader, section editors, online implementation, etc.), as well as the established way of working and communication that was deemed effective in SNS OPS continued in SNS CO-OP.

Still, SNS CO-OP partners took the opportunity to re-examine specific aspects of the way of operations regarding the framework and respective annual questionnaire, based on the lessons learned from the SNS OPS era as well as based on project feedback (through the collaborative SNS bodies i.e., SB and TB) and feedback from the SNS JU office. Before launching the 2025 edition of the annual questionnaire the following aspects were discussed and addressed:

1. Request from SNS JU projects to minimize the load (overhead) and requested information as much as possible
2. Request from SNS JU projects to eliminate duplication with other reporting mechanisms requesting similar or the same information (e.g., EC portal)
3. Request from SNS JU office to minimize ambiguity of results and offer targeted specific insights that may also assist in policy decisions
4. Request from SNS JU office to strengthen the KVIs section, offering more concrete insights that may be further used to understand and promote the projects' work.

To address points 1 and 2, the SNS CO-OP questionnaire team (project coordinator, WP leaders and questionnaire section leaders) had several meetings among them as well as with representatives of the SNS JU office trying to establish which questions remain important and which could be removed, which ones could be condensed/merged and streamlined and whether some of the questions could even be eliminated (to decrease the load towards the projects and minimize duplications) in case the same data could be retrieved from the EC portal. Especially the latter (alignment with the EC portal) took a considerable amount of time/effort as the DG-RTD IT services also had to be consulted to establish whether minor changes that would allow SNS CO-OP to use the portal data would be feasible. Unfortunately, such changes were not feasible, meaning that the data from the EC portal could not be used for the purposes of the Monitoring & Analysis Framework and all input had to be directly requested by the projects (even if it meant a small degree of duplication).

To alleviate this, SNS CO-OP partners adjusted the format of the annual questionnaire and the format of the expected answers to match the one used by the EC portal, meaning that projects were able to collect their input once and then report it both for the annual questionnaire and at the EC portal without changes, this minimizing the required effort form their side. Furthermore, SNS CO-OP partners performed a question-by-question review of the entire questionnaire, merging and streamlining questions where possible to minimize the required effort from the projects' side to provide the necessary information. During this review, the third point of the above list was also addressed, as open-ended questions were either completely discarded or modified to multiple-choice questions, offering a specific answer space to the projects, making it easier to extract concrete conclusions from the received responses, offering consolidated insights. The updates implemented per section of the questionnaire for its third edition (2025) are detailed in the following sub-sections.

To address the fourth point of the above list, SNS CO-OP representatives held several meetings and email exchanges with representatives of the 6G4Society CSA project, discussing the approach on KVIs and the exact wording that should be used in the questionnaire, to deliver concrete information on the use of KVIs by the projects. The expertise of 6G4Society dealing with Societal aspects and KVIs was used to update the KVI-related question in the Vision section of the questionnaire, attempting to deliver more concrete results that could offer specific insights regarding the use and usefulness of KVIs in SNS JU research. The details on the updated question are provided in Section 2.2.

2.2 Questionnaire for new projects - 3rd Edition (2025)

This section provides details on the questions that were altered or updated from the second edition of the questionnaire (2024) to the 3rd edition (2025), based on lessons learned and received feedback. The questionnaire addressed to new projects (addressed to Call 3 projects in 2025) remains structured in three distinct sections, namely Technical, Vision and Market. The updates are described below per section:

<u>Technical section updates (2025)</u>

The Technical section of the questionnaire is trying to determine the specific technological targets and focus of each new project and to set a basis for the expected technological output from each project. Based on these responses the overall SNS JU focus on technologies, KPIs and validation approach is determined. According to project and SNS JU office feedback as well as an internal review by SNS CO-OP partners on the effectiveness of the received responses and the ability to extract important insights, the following updates were performed to the technical section.

- **Q1 on Specific Objectives of the Work Programme (WP) was removed**: This question which was part of the first and second edition of the questionnaire (2023 and 2024 respectively) attempted to understand which of the specific objectives mentioned in the respective SNS JU WP were addressed by each project (either as primary or secondary). The received responses over the two first editions, indicated that the aggregated input was of low value, as projects tended to simply repeat the wording of the WP and their grant agreement, offering little to none additional information; while grouping and extracting of communal insights was also difficult due to the fact that different projects addressing different calls, were responding to different objectives. Based on the low value of the extracted information and the high load of attempting to analyse the responses, it was decided to completely remove this question.
- **Added one more multiple-choice option to the question on technological issues/aspects addressed**: One of the targets of the annual review of the questionnaire by SNS CO-OP project members is to adapt the questions to the specificities of the new SNS JU WPs and targeted calls. As such the option of "*Deterministic/Time Sensitive Networking (TSN)*" was added as one of the options under the question investigating the technological issues and aspects addressed by the projects, as a direct consequence of this technology being mentioned in the 2024 WP text.
- **Re-ordering questions to create thematic areas in the questionnaire**: To improve the "flow" of the questionnaire and to facilitate the provision of information from project representatives, several questions were re-ordered and questions addressing similar or related subjects were grouped together (i.e., one after the other) to create thematic areas within the questionnaire. As a result, the question on targeted SDOs was grouped with the question on targeted open-source bodies, the question regarding validation methodology was grouped with the question regarding the equipment used for validation; and the question on vertical stakeholder engagement in the project was grouped with the question on the vertical stakeholder's role.

After applying the above-mentioned updates, the 2025 Technical section of the annual questionnaire comprised a total of 10 questions and was addressed to Call 3 projects in Q1 2025.

Vision section updates (2025)

The Vision section aims to capture how the projects are emphasising some of the broader goals of the SNS programme. Therefore, it focuses on the societal aspects of technology in terms of challenges and values, and how 6G technology should meet the future needs. Sustainability is one of those pillars which is emphasized, not only in a single question, but reflected in several questions and options. The way sustainability has been addressed has changed through the questionnaire editions as explained below, but question V5 addressing the UN SDGs have remained unchanged and enables comparison across the whole programme. The following updates were applied to the Vision section.

- **Question V1 on societal challenges and question V2 on societal values** have undergone continuous revisions through the annual questionnaires for Call 1, 2 and 3. The changes reflect the evolution of the scope and objectives of the corresponding annual Work Programmes.
- **Sustainability and related aspects** (energy consumption and efficiency, carbon footprint etc.) was moved from being considered a societal value to the societal challenge question in the 2025 edition, based on the feedback of Sustainability experts from the 6G4Society CSA project and in accordance with the guidelines mentioned in the 6G-IA Vision White paper [2].
- **The European perspective** was introduced as an option in question V1 to reflect the increased attention to European technological sovereignty.
- **Question V3 on Key Value Indicators (KVIs)** KVIs have once again been addressed by focusing on assessment methods. The change in the 2025 edition is that it provides more detailed options, especially in distinguishing between different trial experiment methods.

The 2025 Vision section of the annual questionnaire comprised 5 questions in total.

Market section updates (2025)

The Market section of the questionnaire collects the SNS project views on the 6G market forecast. It examines the expected innovations driven by 6G and their impact on vertical sectors; it identifies main market trends, novel markets and main obstacles; and it investigates the methods used for validating business opportunities as well as for assessing commercial viability. This section also delves into the KERs to be delivered by the SNS projects and the targeted TRLs. Finally, it explores how the SNS projects stimulate the participation of SMEs.

Building on the richness of the responses, the feedback from the SNS CO-OP partners, and the developments in the SNS ecosystem, the questions are reviewed annually to optimise the value of the information collected and enhance the overall efficiency of the process. Nonetheless, it is important to note that there is a conscious effort to maintain the questions consistent in order to enable comparisons across years. A description of the latest updates is provided below.

- "*S*ecurity, privacy and trust" are now encompassed within the concept of "*Trustworthiness*". This change applies throughout the entire questionnaire.
- Question M1 was free text in in the first edition of the questionnaire (2023). A new pre-defined option i.e., "*Interoperability across system and standards"*, was introduced in 2025, while the answer "*Automation and lowered technological barriers*" was moved to Question M2, where it fits better as it tackles technologies and innovations. Moreover, some options were slightly rephrased to reflect the developments in the domain as follows: larger scale markets and market disrupters was split in two options: "*Larger scale markets*" and "*Market disrupters that generate new business opportunities and models*"; exploitation in vertical markets was changed to "*Intense exploitation in vertical markets*"; and, energy efficiency, increased openness of solutions and increased integration have been refined to offer more clarity as "*Sustainable 6G and 6G for sustainability, alternative models*", "*Increased market integration (i.e., merger of*

current big players such as MNOs vs market fragmentation)", and "*Increased openness and variety of solutions and integration with vertical markets*", respectively.

- In Question M2, *sustainability and energy efficiency* were removed as it was considered they do not convey technologies and innovations but refer to a vertical sector and/or domains. The option "*Automation for lowered technological barriers*" was moved from M1 and "*Automation for networks and cobots*" was added. The pre-defined answer TN-NTN-PN integration and interoperability was reformulated to "*Increased technical integration*" and cloudification was precise as "*Edge Continuum/MEC*"
- "Media/xR" was renamed as "*Media/Entertainment*" in Question M3, as it refers only to verticals and not technologies, and the option "Lack of business to business (B2B) and business to costumers (B2C) revenue streams" was included in Question M6.

2.3 Questionnaire for ongoing projects - 3rd Edition (2025)

The results of each annual edition of the questionnaire are set to be reported back to the SNS JU Office, providing essential insights into the progress, gaps and future direction of the R&I projects. Moreover, this data plays a central role in populating two online radars:

- The **Programme KPI Radar**[2]**,** which evaluates the overall impact and progress of SNS JU R&I projects, focusing on the maturity of use cases, SME involvement, scientific output, contributions to interoperability, sustainability efforts, and outreach activities. Programme Radar will display the programme KPIs with a visual overview of the SNS achievements and objectives at programme level.
- The **Technical KPI Radar**[3], which focuses on the technical KPIs targeted by the SNS JU R&I projects, giving stakeholders a clear view of the specific technical advancements and key metrics achieved by the SNS project R&I activities. This radar enhances the transparency and support strategic decision-making within the SNS JU ecosystem.

As the Call 1 projects are approaching their end, Call 2 projects are operational and Call 3 projects have recently started, it is important to be able to track their achievements and tangible outcomes, besides their vision and targeted end-results. To that end, questions targeted only at ongoing Call 1 & 2 projects (i.e., not Call 3 projects which started in January 2025) the SNS OPS ongoing projects questionnaire was updated accordingly. These updated questions were designed to help monitor programme-level KPIs, contribute to the SNS Programme KPIs radar, and simplify the collection of the KPI data. They also aim to provide a more in-depth understanding of each project concrete outcomes, impact, and contributions to the SNS programme.

The updated questions include inquiries about the number and scale of events or workshops organised or contributed to by the project, emphasising attendance figures. This includes various forms of academic and industry contributions, such as peer-reviewed journal articles, conference papers, book chapters, and white papers, where the main theme of each publication is explored. Contributions to standardisation organisations and IPR (patent) applications related to the project are also requested, reflecting direct engagement with broader industry and regulatory frameworks.

In order to better understand the updates implemented in 2025, Figure 1 illustrates how the fifteen questions in the 2024 questionnaire have been mapped onto the ten questions in the 2025 version. The essence of this change was to organize the events and publications questions into two main questions, and accordingly, the Excel template for reporting has been updated to make it easier to record responses

The questionnaire also delves into the practical application of project work, asking about the number of Proofs of Concept (PoCs), Lab Tests, Trials or Pilots executed, also matching them to the appropriate TRL level, including specifics like location, date, and focus area and the replicability of some use-cases.

[2] https://sns-trackers.sns-ju.eu/kpi-radars/programme-radar

[3] https://sns-trackers.sns-ju.eu/kpi-radars/technical-radar

This also encompasses queries about the usage and contributions to open-source communities, highlighting collaborative and open innovation. Energy efficiency is a focal point, with questions regarding its percentage of improvement as per the results of experiments or trials. The exact SNS JU metrics to be collected are provided and explained in Table 1 below.

This section of the questionnaire will be addressed to all active SNS projects on an annual basis, targeting the release of the questionnaire by mid-Q1 of each year, the collection of the project responses by the end of Q1 each year, and the availability of the processed results and gained insights before the end of Q2 each year. The processed results and insights will be used to populate the necessary progress and monitoring reports undertaken by the respective operational CSA project and required by the SNS JU office. Moreover, the results of the questionnaire will also be shared with the various working bodies of the SNS, e.g., the Steering Board (SB), the Technology Board (TB), the SNS Project Working Groups (WGs), etc., to facilitate their operation and to provide insights into the aggregate accomplishments of the SNS projects. The analysis regarding the achieved metrics of the SNS JU R&I 35 Call 1 projects and the 38 Call 2 projects was presented in a webinar on the16th of June 2025. All slide decks as well as the recording of the webinar itself can be found on the SNS JU website under the dedicated event page[4].

[4] https://smart-networks.europa.eu/event/sns-co-op-questionnaire-sns-call-1-2-projects-results-and-call-3-projects-ambitions/

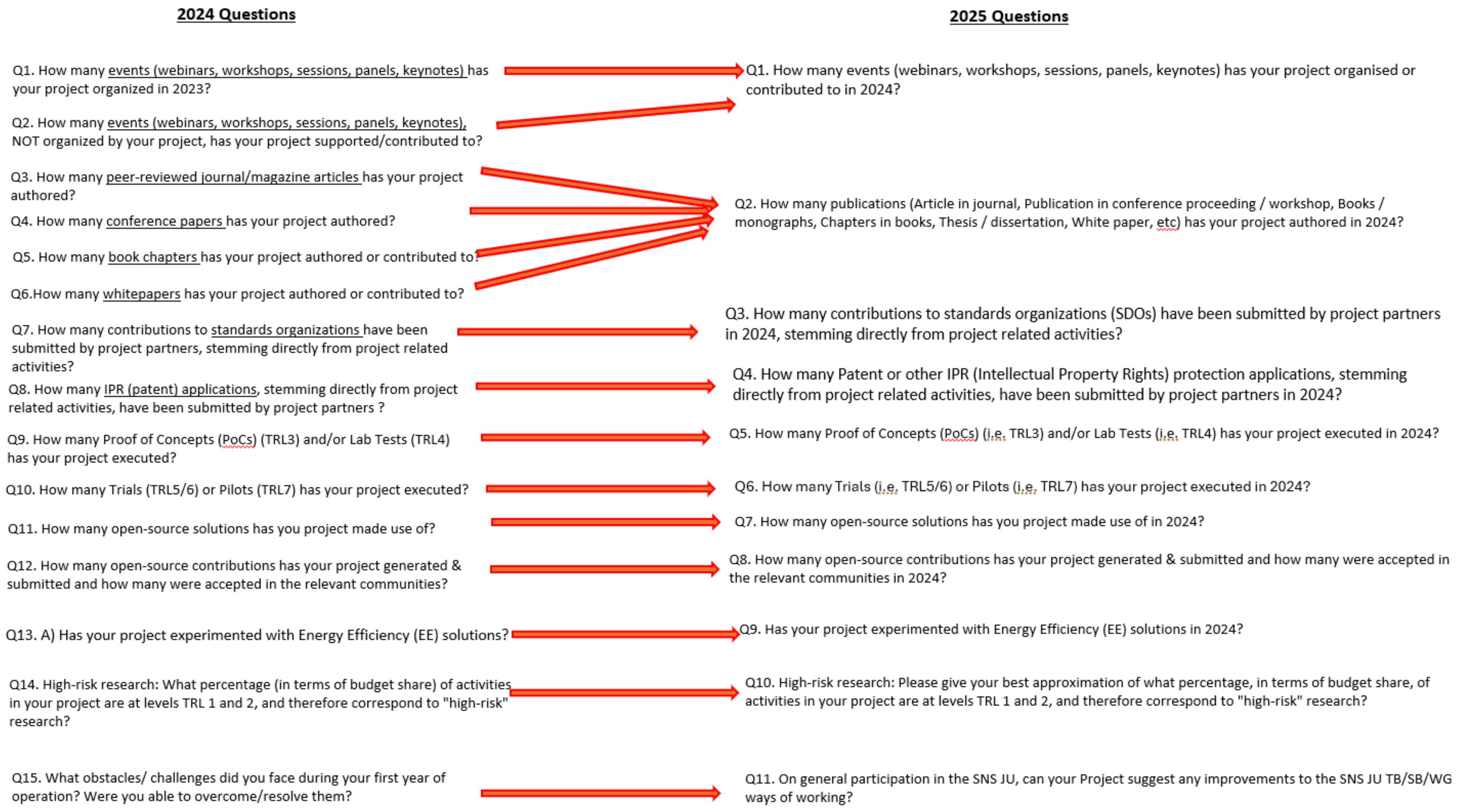


Figure 1: Questionnaire 2025 updates compared to Questionnaire 2024

Table 1: Questionnaire 2025 for Ongoing projects (incl. SNS JU metrics)

#	Question	Unit Of Measurement	Relevant KPI
1	How many **events** (webinars, workshops, sessions, panels, keynotes) has your project **organised** or **contributed** to in 2024?	# of events organized/contributed (webinars/workshops, sessions, panels, keynotes)	Outreach
2	How many **publications** (Article in journal, Publication in conference proceeding/workshop, Books/monographs, Chapters in books, Thesis//dissertation, White paper, etc) has your project **authored** in 2024?	# of published journal articles	Scientific Excellence I
3	How many **contributions to standards** organizations (SDOs) have been submitted by project partners in 2024, stemming directly from project related activities?	# of standards contributions with proper referencing	Impact
4	How many **Patent** or other **IPR** (Intellectual Property Rights) protection applications, stemming directly from project related activities, have been **submitted** by project partners in 2024?	# of IPR created (submitted to EPO or other body)	Impact
5	How many **Proofs of Concept** (PoCs) (i.e. TRL3) and/or **Lab Tests** (i.e. TRL4) has your project **executed** in 2024?	## of Tests/ Proofs of Concept (place-date)	Number of PoCs, Pilots, Trials
6	How many **Trials** (i.e. TRL5/6) or Pilots (i.e. TRL7) has your project **executed** in 2024?	# of large-scale trials (place-date)	Number of PoCs, Pilots, Trials
7	How many **open-source solutions** has you project **made use of** in 2024?	# and name of open sources used in the project	
8	How many **open-source contributions** has your project **generated & submitted** and how many were **accepted** in the relevant communities in 2024?	# open-source contributions	Number of Open-Source Contributions
9	Has your project experimented with **Energy Efficiency** (EE) solutions in 2024?	% increase	Energy efficiency of Telecom. Nets
10	**High-risk research**: Please give your best approximation of what percentage, in terms of budget share, of activities in your project are at levels TRL 1 and 2, and therefore correspond to "high-risk" research?	% of allocated funding budget to TRL 1 and 2 activities	General

3 SNS JU Outlook 2024 – Call 1 & 2 Ongoing Projects

The 2024 questionnaire was distributed to the ongoing SNS JU R&I projects: 35 Call 1 and 28 Call 2 projects, for a total of 63. It comprised 11 questions, supported by a dedicated Excel file to provide additional information. Section 3.1 presents an overview of the results achieved by the SNS projects, while Section 3.2 provides a more detailed analysis of the questionnaire responses.

3.1 Overview of SNS project achievements

SNS JU projects have delivered substantial measurable results during the first two years of their operation (Jan 2023 - Dec 2024), underscoring a successful commitment to both academic excellence and industrial relevance. Figure 2 provides an overview of the programmatic KPIs achieved by all 63 projects of Call 1 and Call 2 in the period January 2023 – December 2024 (aggregated). In terms of knowledge generation, the 63 projects collectively produced **1439 publications**, with strong emphasis on rapid dissemination via **890 conference /workshop** papers, and solid scientific contributions through **506 journal articles**. This is also reflected in terms of community engagement, with **1341 events** either organized or contributed to, ensuring maximum visibility and peer interaction. Crucially, the program is effectively translating research into practical readiness. This is evidenced by **269 Tests & Trials** executed, including **184 Proofs of Concept** and **85 Trials & Pilots**, indicating successful progression from laboratory validation to near-real-world demonstration.

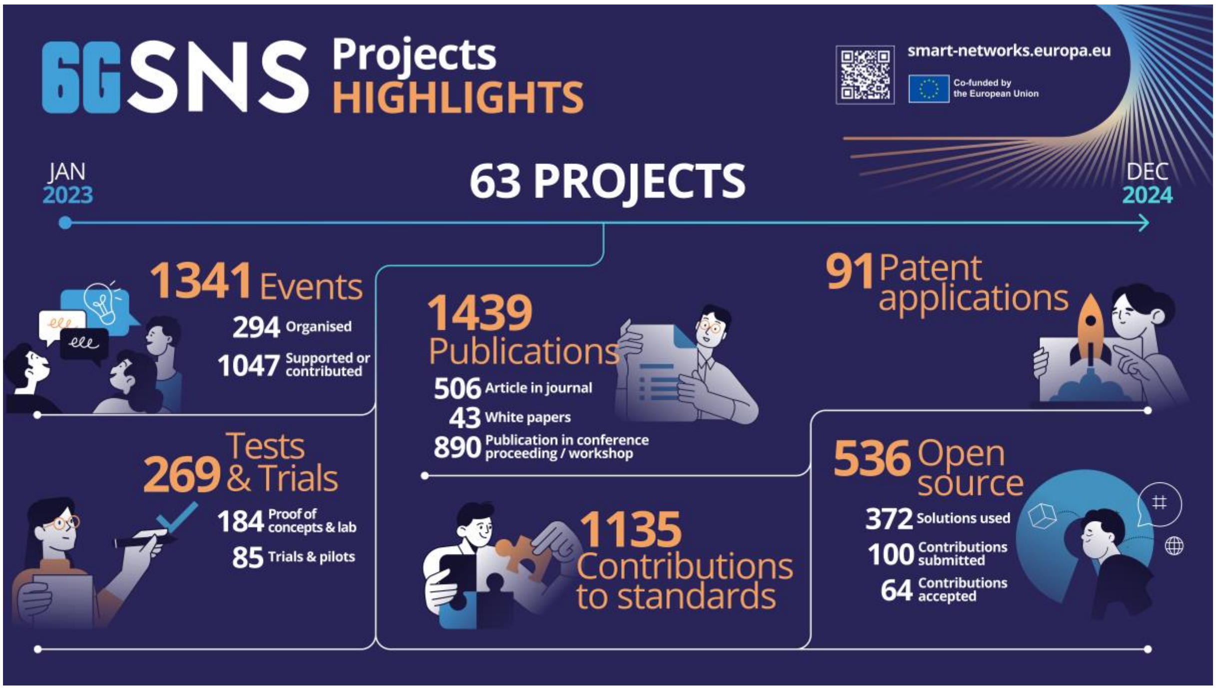


Figure 2: Infographic on SNS JU accomplishments (aggregated data for 2023 and 2024)

Long-term impact and commercial viability are being actively secured through robust Intellectual Property (IP) and standardization efforts. Collectively, SNS projects have filed **91 patent applications**, signalling a strong drive to protect core technological innovations for future market uptake. Furthermore, the focus on global interoperability is exemplified with **1135 contributions to standards**, positioning the European research at the forefront of defining the specifications for future networks. Finally, the open approach to development is confirmed by **536 open-source activities**, which include **372 solutions used** and **64 contributions accepted** out of **100 submissions** by external communities, ensuring that the technology is accessible, validated, and integrated into the global software ecosystem. This balanced portfolio of outputs confirms the program is effectively achieving its mandate to lead 6G technological advancement and influence its standardization and deployment worldwide.

3.2 Detailed analysis of the questionnaire responses

This section provides a comprehensive overview of project activities across multiple dimensions, including events and publications, contributions to standards and intellectual property, proofs-of-concept, trials and pilots, open-source engagement, energy efficiency initiatives, and high-risk research at TRL 1-2.

3.2.1 Events and publications

Question 1: *How many events (webinars, workshops, sessions, panels, keynotes) has your project organized or contributed to in 2024?*

Figure 3 illustrates that the project's primary strategy for dissemination and engagement centres on participation in conferences (377 events) and workshops (233 events), which together account for the vast majority of activities. Participation is particularly strong in large-scale, structured events—such as **EuCNC & 6G Summit 2024** and **MWC 2024**— which provides a strategic focus on maximizing technical visibility and reaching a broad audience within established academic and industrial ecosystem. Those are followed by other prestigious, high-profile events like IEEE Globecom 2024 and IEEE PIMRC 2024 where the project's outputs are exposed to top-tier international stakeholders.

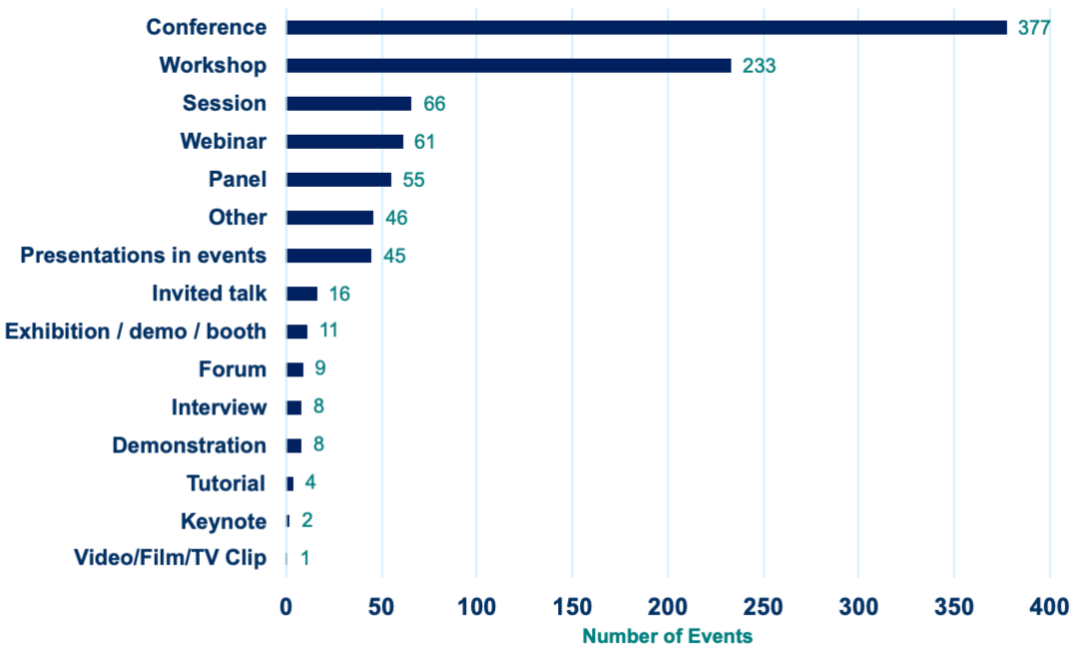


Figure 3: Number of events organized or contributed to by SNS JU projects in 2024

The relatively high frequency of other formats such as sessions (66) and webinars (61) reflects a diversified outreach effort; however, the core activity remains focused on leveraging major platforms for formal knowledge exchange. Overall, the projects primarily contributed to (79%, or 733 events) rather than organized them (21%, or 194 events), focusing resources on content preparation rather than in logistical management.

Key insights further quantify project engagement, showing an average of approximately 15 events, indicating a very high level of community involvement.

Question 2: *How many publications (Article in journal, Publication in conference proceeding / workshop, Books / monographs, Chapters in books, Thesis/dissertation, White paper, etc) has your project authored in 2024?*

The project publication data, as depicted in Figure 4, reveal a focused approach on dissemination through conferences by publication in conference proceeding/workshop with an output of 651. publications While the conference output is significant, the substantial volume of articles in journals (376) indicates a strong commitment to long-term scientific validation and establishing authoritative contributions. The remaining categories, such as white papers (29) and chapters in books (7), contribute to broader technical communication and standard-setting. Still, the core strategy is anchored in formal, peer-reviewed technical contributions. This strategic mix of quick-dissemination and high-impact archival publications, **totalling 1107 publications**, ensures scientific impact.

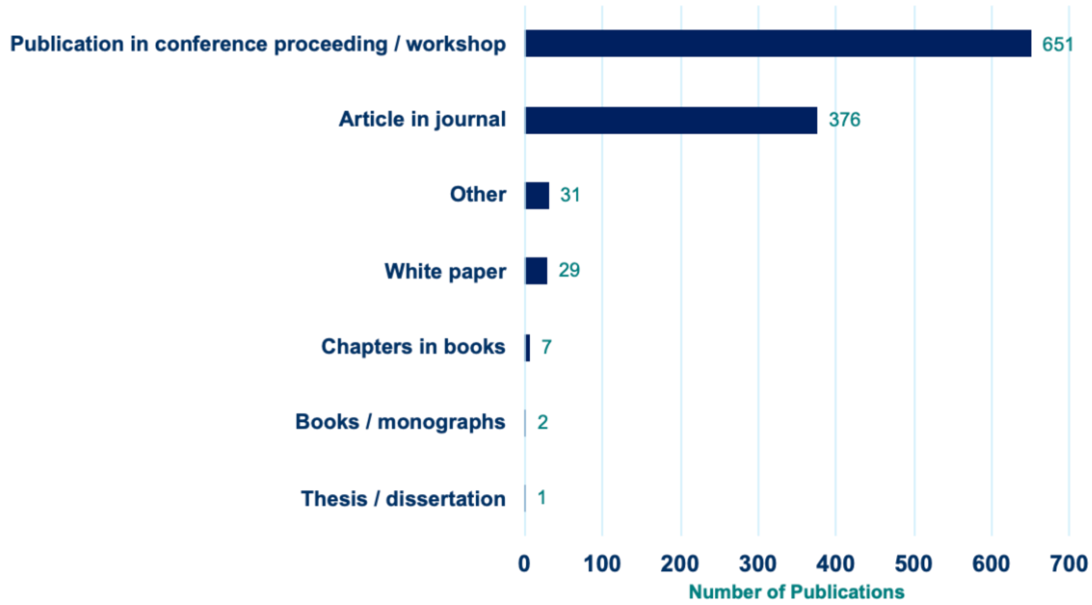


Figure 4: Number and type of publications by SNS JU projects in 2024

With an average of around 18 publications per project, the portfolio exhibits a robust and engaged research community. Based on the analysis of the targeted venues also provided by the projects via the questionnaire, publication venues are predominantly IEEE-sponsored platforms, including:

- IEEE Open Journal of the Communications Society
- IEEE Wireless Communications and Networking Conference (WCNC)
- IEEE Global Communications Conference (GLOBECOM)
- European Conference on Networks and Communications & 6G Summit (EuCNC/6G Summit)
- IEEE Transactions on Vehicular Technology

This confirms the project's strategic aim to target top-tier, globally recognized journals and conferences, maximizing both visibility and prestige within the telecommunications research domain. Furthermore, the explicit mention of 110 publications resulting from collaboration with other projects or SNS bodies signifies a successful internal synergy mechanism. This demonstrates that the high volume of publications is not merely a sum of individual efforts but is actively enhanced by cross-project cooperation, strengthening the collective impact of the overall research program.

3.2.2 Contributions to standards and IPR

Question 3: *How many contributions to standards organizations (SDOs) have been submitted by project partners in 2024, stemming directly from project related activities?*

The number of standards contributions per SDO as depicted in Figure 5, reveals a strong commitment of SNS projects to influence the development of global standards, with a total of 574 contributions across various bodies. This standardization work is heavily focused on the core telecommunications and internet architecture groups, led overwhelmingly by 3GPP (221 contributions), which is essential for defining 5G and 6G specifications. Closely following are the IETF (167 contributions), which is responsible for a number of internet protocols, and ETSI (124 contributions), a European leader in telecommunications standardization.

Beyond the top three, the contributions drop off sharply, with O-RAN (15), IEEE (8), and other influential bodies receiving comparatively fewer, yet still significant, inputs. Overall engagement intensity is substantial, with the average project contributing approximately 14 inputs. This high average across the project portfolio reflects the strategic importance of standardization work, ensuring that technical innovations move beyond research papers and demonstrates the project's goal of shaping the future global telecommunications ecosystem.

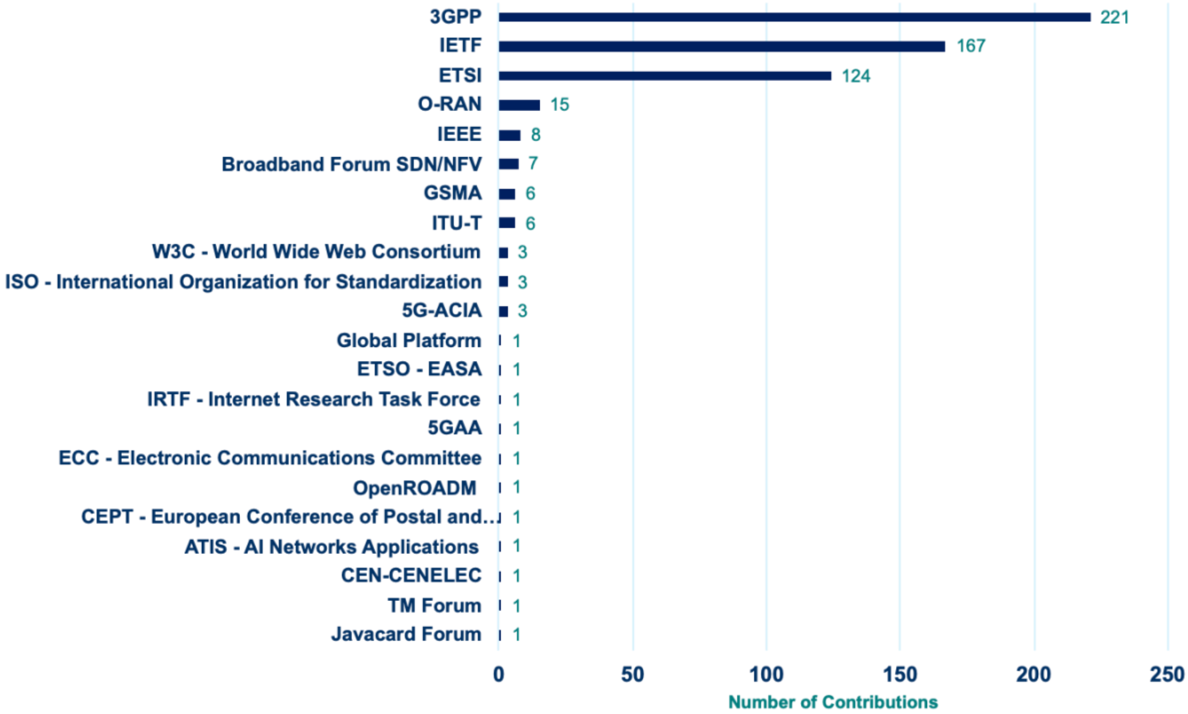


Figure 5: Number of standards contributions by SNS JU projects in 2024

Question 4: *How many Patent or other IPR (Intellectual Property Rights) protection applications, stemming directly from project related activities, have been submitted by project partners in 2024?*

The number of patent/IPR applications submitted by SNS JU projects in 2024 by project stream are depicted in Figure 6; and by SNS JU Call in Figure 7. Data indicates that the focus of innovation and patenting activity is strongly focused on Stream B, which accounts for a dominant 50 out of the 59 total applications. This high concentration shows that low-TRL Stream B projects, which typically focus on novel/longer-term technologies are primarily responsible for generating the strategically protected inventions and innovations. On the contrary Streams A and C projects show only minimal activity with 6 and 3 applications, respectively; while Stream D and the CSA have no IPR generation, which is reasonable given the focus of these projects.

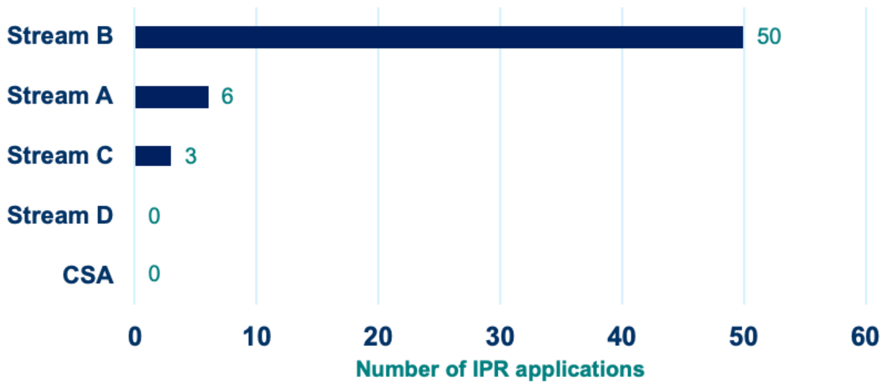


Figure 6: Number of patent/IPR applications by SNS JU projects in 2024

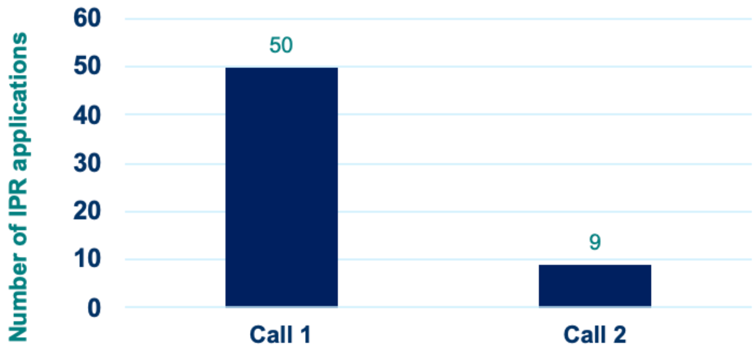


Figure 7: Number of patent/IPR applications by call in 2024

Call 1 projects generated 50 applications compared to only 9 from Call 2, which is also reasonable as Call 1 projects have been operational much longer and have reached the maturity necessary to formalize and protect their inventions. Despite the total of 59 applications being filed during 2024, the process is still in its early stages, with only 8 applications accepted and the majority remaining under evaluation. Based on additional information provided via the questionnaire, patent/IPR applications focused particularly in fields such as:

- Satellite Communications
- Network Management and Optimization
- Machine Learning and AI
- Security and Privacy
- Radio and Wireless Technologies
- Internet of Things (IoT)
- Emerging Network Technologies

3.2.3 Experimentation & Validation

Question 5: *How many Proofs of Concept (PoCs) (i.e. TRL3) and/or Lab Tests (i.e. TRL4) has your project executed in 2024?*

Figure 8 depicts the number low-TRL experiments (PoCs and lab tests) performed by SNS JU projects in 2024. Data reveals a significant and expected concentration of activity in Call 1 projects, which have executed a dominant 232 PoCs. This sheer volume of activity reflects the longer running time and established research maturity of Call 1 projects compared to Call 2 projects, which have only reported 27 PoCs. The PoCs focus on TRL 3-4 (Technology Readiness Level 3-4), which involves experimental proof of concept and validation in a lab environment. The focus on practical applicability and potential industrial uptake is clearly demonstrated by the replicability and vertical targeting metrics. Out of the total 138 PoCs executed, 96 are replicable (nearly 70%). Only 25 PoCs explicitly address verticals, with the remaining 113 PoCs primarily targeting general telecom use cases. In Call 1, the 25 Vertical PoCs represent a substantial effort to apply early-stage research directly to specific industrial sectors, laying the ground for future trials and possible commercial deployment.

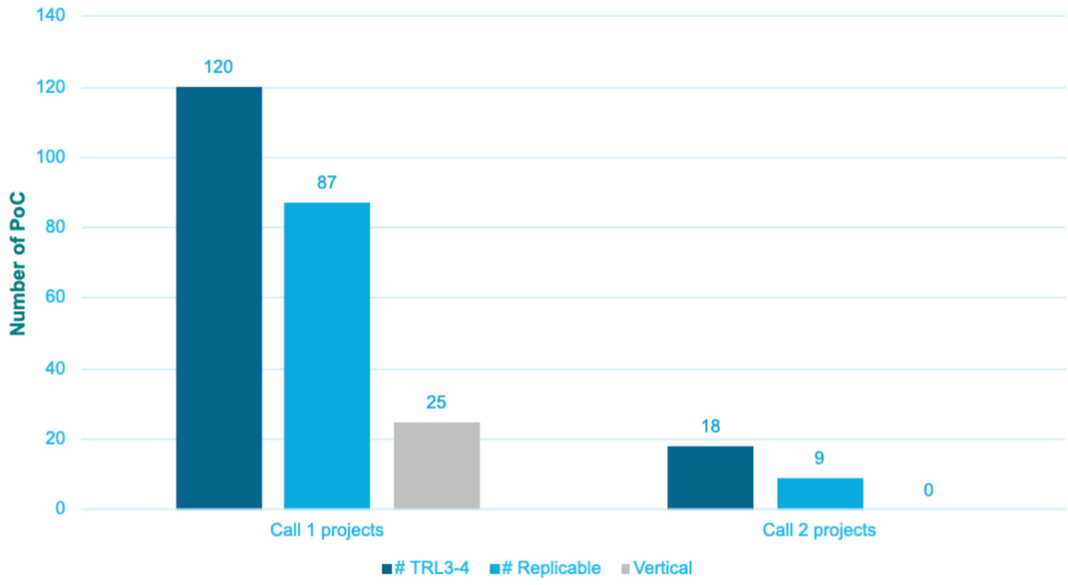


Figure 8: Number of PoCs and Lab tests performed by SNS JU projects in 2024

Question 6: *How many Trials (i.e. TRL5/6) or Pilots (i.e. TRL7) has your project executed in 2024?*

Figure 9 depicts the number higher-TRL experiments (Trials & Pilots) performed by SNS JU projects in 2024. Data reveals a clear shift towards advanced maturity and practical application, with 60 T&Ps executed in total. This activity is overwhelmingly dominated by Call 1 projects, which account for 59 of those at demonstration level (TRL 5-7). The stark difference between Call 1 and Call 2 (only 1 T&P) is expected, reflecting the longer lead time required to mature technologies to a level where they are ready for close-to-real-world testing environments.

Out of the 60 T&Ps, 42 are replicable (or 70%). This means that a high percentage of the advanced testing is conducted using methodologies that can be easily adopted and scaled by industry partners, thereby maximizing the potential for broader ecosystem adoption. Furthermore, the commitment to specific end-users is evident, with 31 T&Ps explicitly addressing verticals.

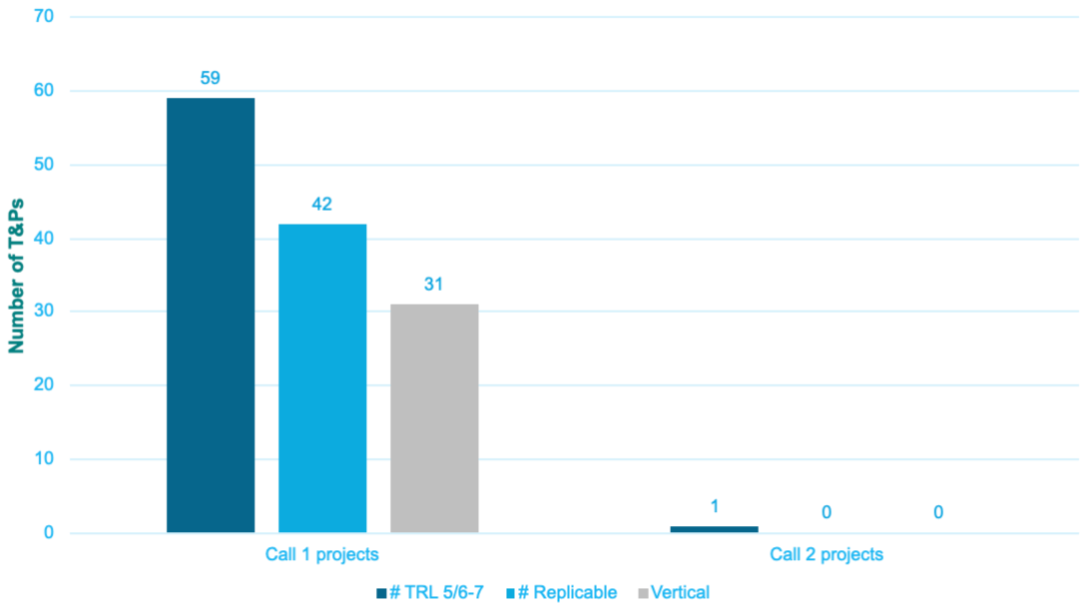


Figure 9: Number of Trials and Pilots performed by SNS JU projects in 2024

3.2.4 Open-source activities

Question 7: *How many open-source solutions has you project made use of in 2024?*

The analysis of open-source tool usage depicted in Figure 10, reveals that the most frequently adopted solutions are Open5GS and Kubernetes, both utilized by 9 projects. The high adoption of Open5GS (an open-source core network implementation) and Kubernetes (the dominant container orchestration system) evidences the interest of the projects in prioritizing Cloud & Virtualization alongside the rapid development and testing of core 5G & Network Technologies. This foundation is complemented by the prominent use of monitoring and observability tools like Prometheus (5 projects) followed by free5GC (5 projects), Docker (4 projects).

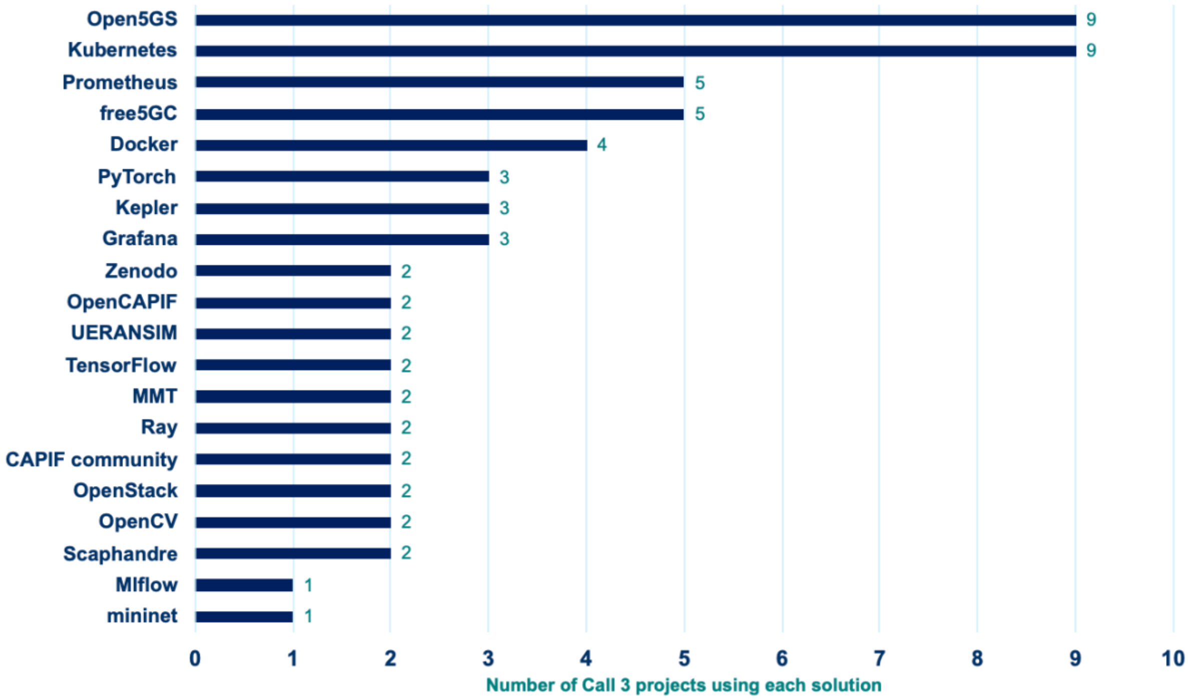


Figure 10: Number of Open-Source solutions used by SNS JU projects in 2024

The distribution of the remaining solutions highlights the diverse and multi-disciplinary nature of the research portfolio. This broad usage pattern across 240 responses demonstrates that the projects are strategically integrating best-of-breed open-source software to address a wide spectrum of technological domains such as:

- Data Management & Analytics
- Edge & IoT
- Robotics & Computer Vision
- Energy Efficiency & Green ICT
- 5G & Network Technologies
- AI & Machine Learning
- Blockchain & Security
- Cloud & Virtualization

Question 8: *How many open-source contributions has your project generated & submitted and how many were accepted in the relevant communities in 2024?*

Figure 11 depicts the number of approved open-source contributions by SNS JU projects in 2024. The projects achieved a high success rate in translating their research into publicly accessible code and knowledge, with **64 out of 100** submitted Open-Source contributions being approved. The dominant platforms for these contributions are the EU Open Research repository (Zenodo) and GitHub, both receiving **12 approved contributions**. While these two platforms have no formal acceptance criteria, their high usage underscores their importance for direct, immediate community engagement and making research artifacts openly discoverable. This focus on Zenodo and GitHub establishes the project's dual commitment to fulfilling open science mandates. The contributions to ETSI TeraFlowSDN (TFS) (9) and ETSI OpenSlice (OSL) (8), which are key European industry bodies, indicate a strategic intent to shape specific Software-Defined Networking and slicing frameworks. Furthermore, activity in Gitlab (4), kata-containers (4), and the OAI community (3) shows a practical focus on containerization, virtualization, and the core development of open wireless access networks.

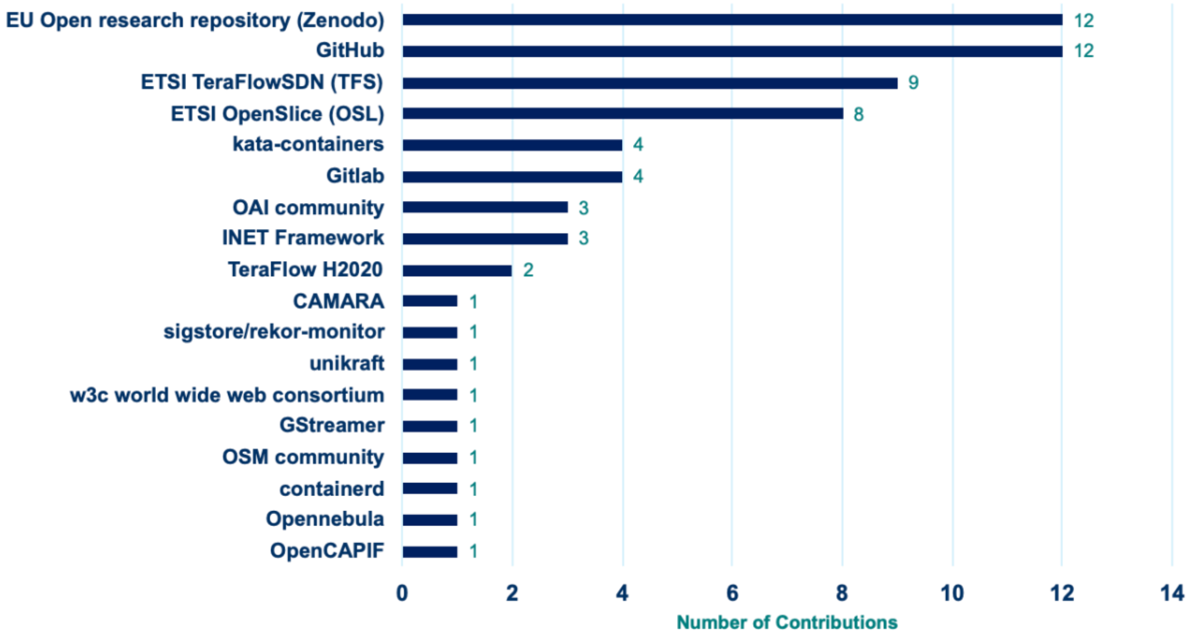
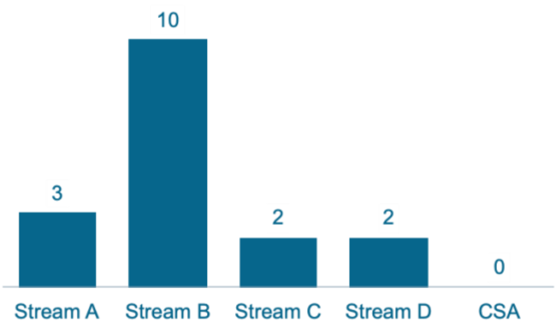


Figure 11: Number of approved open-source contributions by SNS JU projects in 2024

3.2.5 Energy efficiency

Question 9: *Has your project experimented with Energy Efficiency (EE) solutions in 2024?*

Figure 12 indicates a focused commitment to **Energy Efficiency (EE)**, with 17 projects in total actively experimenting with EE solutions. This dedication is most pronounced in Stream B, which accounts for 10 out of the 17 projects involved. Given that Stream B typically targets novel technologies for commercial networks in the mid-to-long-term, this concentration suggests that sustainability and efficiency are core architectural pillars for the future network designs being researched. Projects in Streams A, C, and D also contribute to a lesser extent (3, 2, and 2 projects respectively), indicating that EE is considered a horizontal requirement across different research domains, from evolutionary improvements (Stream A) to large-scale trials (Stream D).



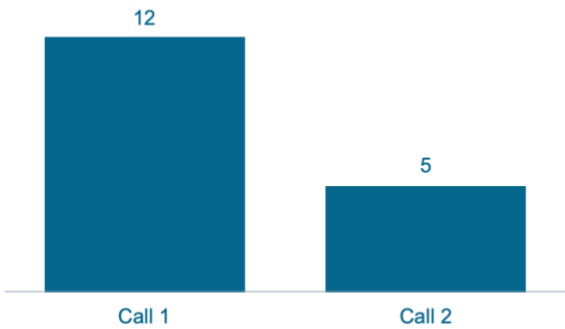


Figure 12: Number of SNS JU projects that experimented with energy efficiency solutions in 2024 i) by stream (left) and ii) by Call (right).

A breakdown of the EE focus areas and call distribution reveals the comprehensive nature of this work.

The EE solutions are applied across critical topics, including:

- Energy Efficiency in Open RAN
- Blockchain & Security-Based Energy Efficiency
- Hardware and Computing Power Efficiency
- Wireless Communication and IoT Energy Efficiency
- Sustainability Metrics and Experimental Validation

This demonstrates an effort to optimize power consumption across the entire network stack, from the radio access network to device-level communications, and also in the underlying computing infrastructure. Furthermore, the commitment to the topic is consistent across the program's lifecycle, with Call 1 projects leading with 12 projects and Call 2 projects showing early commitment with 5 projects.

3.2.6 High risk research

Question 10: *High-risk research: Please give your best approximation of what percentage, in terms of budget share, of activities in your project are at levels TRL 1 and 2, and therefore correspond to "high-risk" research?*

Figure 13 illustrates the volume of high-risk research carried out by SNS JU projects It demonstrates a clear and sustained commitment to long-term foundational research by addressing Technology Readiness Level 1 (TRL 1) topics, with 10 projects actively contributing to this very early stage of innovation. The focus areas are highly speculative and frontier-based, signalling an intent to lay the intellectual groundwork for technologies far beyond the current commercial horizon. Key research areas include:

- Semantics-based Innovation for IoT Devices
- Human-machine intent interface design
- Quantum architecture
- RF wireless power transfer
- Zero-crossing modulation (ZXM)
- Network architecture for integrated ISAC (Integrated Sensing and Communications)
- Highly accurate time/frequency sources
- Physical Layer of THz Communications
- Mesh-based Radio Access Network

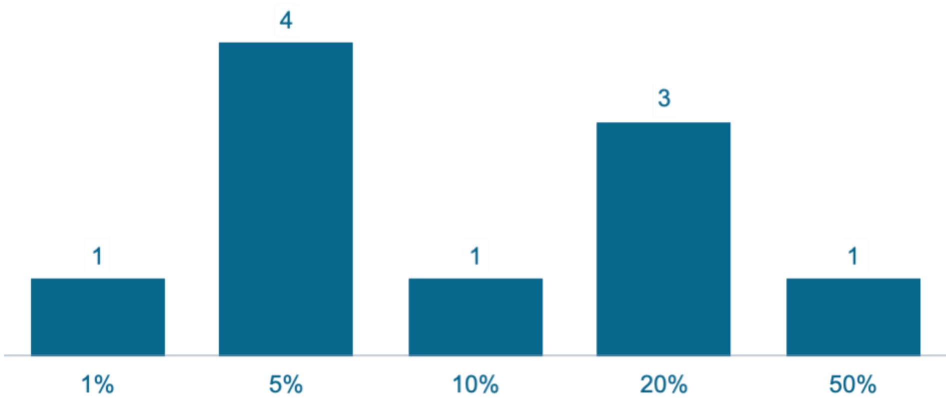


Figure 13: Number of SNS JU projects addressing TRL 1 at different budget shares.

The most common budget share for TRL 1 activities are 5% (4 projects) and 20% (3 projects). The small, focused investment of 5% suggests many projects are running parallel, low-cost exploratory tracks, while the 20% allocation shows that some projects are placing a more significant bet on specific foundational topics. The presence of extreme outlier 50% (1 project) ensures high-risk research for long-term innovation. As research on a TRL level of 2 can also be considered as 'high-risk', this data was also collected and is depicted in Figure 14.

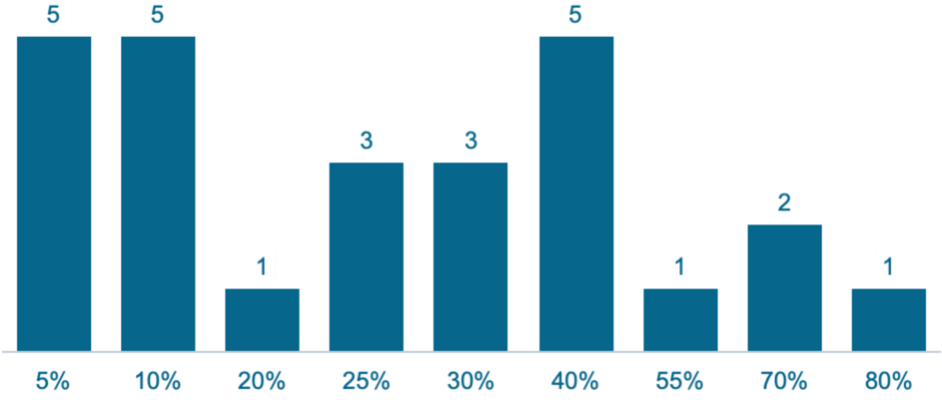


Figure 14: Number of SNS JU projects addressing TRL 2 at different budget shares.

The TRL 2 data, based on responses from 26 projects, highlight a crucial stage of technology formulation and concept validation beyond the foundational TRL 1 level. The research is highly technical, focusing on the development of core components for future networks. The most prominent topics are listed below:

- AI/ML Solutions for 6G Network Automation
- Steerable Optical Wireless Communications
- Security and Resource Allocation in 6G
- Radio Protocol and Network Enhancements
- Development of Novel Optical Transmitter Architectures
- MAC Protocols and THz RF Front-Ends
- Service Base Architecture and Frameworks
- Physical Layer Security and Trustworthiness in AI/ML
- Materials Development for Reconfigurable Intelligent Surfaces (RIS) Unit Cell Control
- Medium Access Control Solutions and AI-Based Resource Management
- Development of Integrated Dual-Polarized Lens Front-End
- Advanced Communication Schemes for Joint Communication and Sensing Paradigm (JCCSP)

The budget allocation for TRL 2 is more widely distributed and higher than for TRL 1, reflecting the increased resources needed for analytical study and experimental validation in a lab environment. The most popular budget shares are clustered at 5%, 10%, and 40% (5 projects each), The broad distribution, ranging from 5% up to 80% (for 1 project), confirms that TRL 2 is a flexible stage where projects dedicate varied amounts of budget to validating core technical elements. This flexible approach ensures that the project can accommodate a wide range of TRL 2 activities, from validating complex systems to confirming the technical feasibility of key individual components.

4 SNS JU Outlook – Call 3 projects

This section provides the detailed analysis of the third edition of the SNS CO-OP questionnaire (2025), addressed at the newly started Call 3 projects (15 in total). The analysis follows the structure of the questionnaire, and the results are presented according to the questionnaire sections, namely, technical, vision and market aspects.

4.1 Technical Aspects

This sub-section provides the analysis and conclusions related to the 10 technical questions raised in the questionnaire.

4.1.1 Addressed Key Performance Indicators (KPIs)

The KPIs foreseen to be measured and used for the validation of the performance of the developed solutions/technologies, within the SNS JU projects, are arguably one of the most important aspects of the projects' work, as they offer the capability to assess the effectiveness of the developed mechanisms, the offered improvement as well as to cross-validate and cross-compare solutions. A list of traditionally addressed KPIs in the development of mobile networks has been offered to the projects to select the ones that each of them focuses on, while the opportunity to mention additional KPIs (more specific and targeted to the specific project's mission) was also provided. The question addressing the KPIs, was formulated as follows in the SNS OPS questionnaire.

Question T1: *Which of the following main KPIs will your project address? Please mention any additional KPIs addressed within your project in the elaboration box?*

Figure 15 below, depicts the most popular KPIs addressed by the 15 Call 3 R&I projects. The received responses indicate that *Energy Efficiency* is addressed by all Call 3 projects, indicating its importance within this call, while Reliability is addressed by 87% of the projects making it the second most important KPI in Call 3. Those trends indicate the alignment of the selected Call 3 projects with the scope of the Work Programme, where Energy Efficiency and Reliability played a central role.

Traditional network KPIs such as User-experienced data rate and Peak data rate, latency, mobility and connection density maintain a solid momentum in Call 3 projects, as expected, while the interest in spectrum efficiency points to another critical aspect that SNS JU projects are investigating, and which is considered key for the development of even more demanding services, covering the entirety of the population.

Perhaps the most interesting insights come from the project responses regarding additional KPIs addressed beyond the traditional ones included in this list. An important surge in AI-related, Security-related, sensing -related and computing-related KPIs can be observed among Call 3 projects, differentiating them from previous calls. This is a direct consequence of the focus topics of the addressed WP Programme, but it also reflects the trends in the European R&I ecosystem.

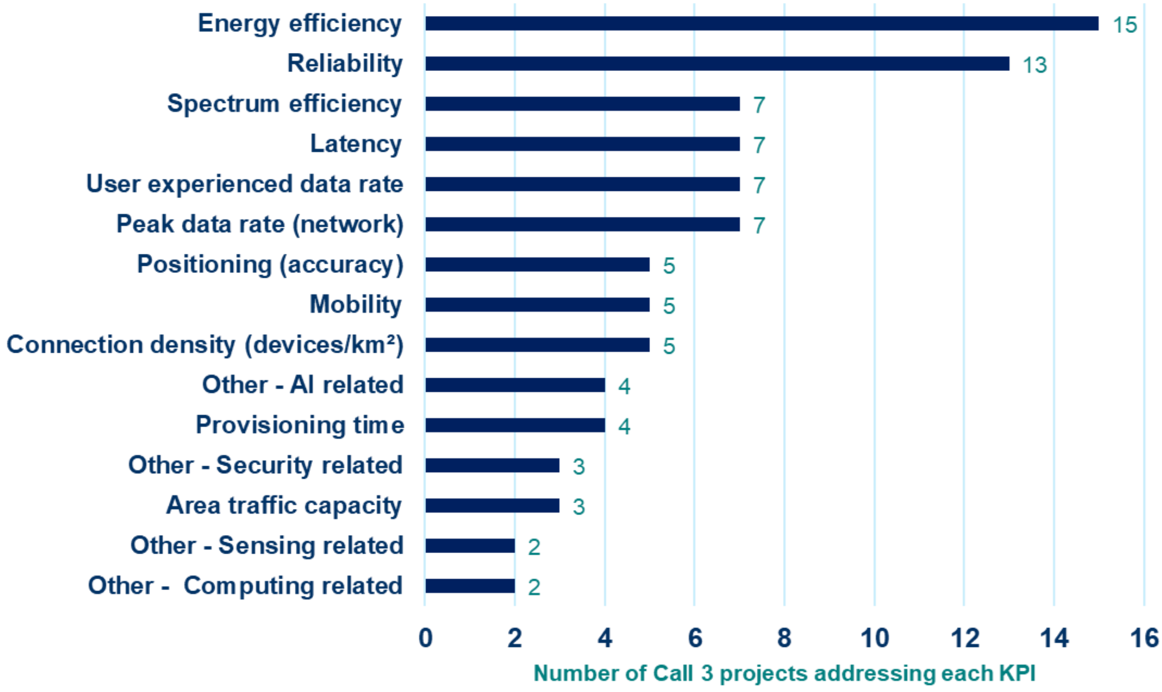


Figure 15: Most popular KPIs addressed by SNS Call 3 projects

It is also interesting to analyse the aggregate results of all active SNS JU projects, regarding the SNS JU-wide KPIs. By combining the results from the analysis of Call 1 and Call 2 project responses in D1.2 of SNS OPS with the new responses from the Call 3 projects, the aggregate results for all 78 active SNS JU projects can be obtained, as shown in Figure 16. As expected, the top 5 of KPIs remains unchanged: Energy Efficiency, URLLC KPIs, peak data rate and spectrum efficiency, aggregate most of the interest of the SNS JU projects. A clear preference can be observed for *Energy Efficiency, Reliability and Latency* as more than 65% of projects address these three KPIs, while a secondary group of KPIs (Peak data rate, spectrum efficiency, user experienced data rate and positioning accuracy) can also be observed, which also aggregates significant interest from the active SNS JU projects (~40% - 50%). These exact same trends and groupings were observed when comparing results between Call 1 and Call 2 answers.

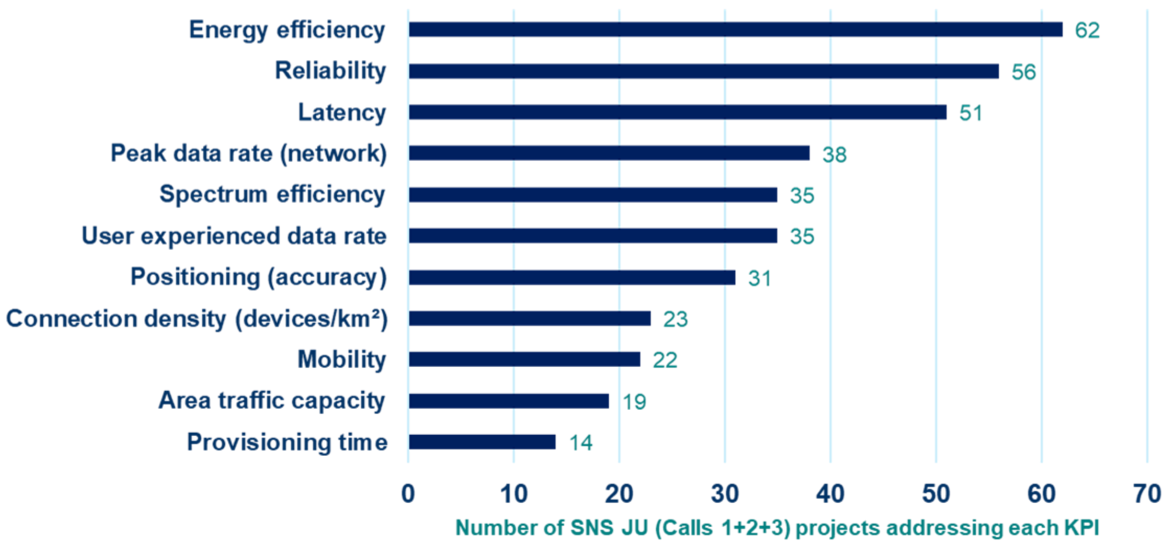


Figure 16: Most popular KPIs addressed – Aggregate Call 1, Call 2 and Call3 projects

By cross-comparing Figure 15 and Figure 16, it can be observed that Latency, is no longer a 'tier-1' KPI for Call 3 projects, as it attracts the interest of approximately half the Call 3 projects, while the interest for Energy Efficiency and Reliability has actually increased in the third call. Besides that, interest in traditional KPIs does not seem to fluctuate much, while a new batch of technology specific KPIs has gained prominence in Call 3 projects.

Key Insights

Some key insights can be extracted by the above analysis of the KPIs addressed by the Call 1, 2 and 3 SNS Projects:

- Good coverage and overlap of all main KPIs by both SNS projects offering cross-validation opportunities.
- Energy Efficiency and URLLC type KPIs are the most popular KPIS across all three SNS JU calls.
- Peak & User Experienced Data Rate, Spectrum efficiency and positioning are also very well addressed across the three project calls.
- Connection Density, Mobility and Area Traffic Capacity are also well addressed but with a smaller interest.
- Additional technology-specific KPIs are gaining ground in the latest SNS JU calls addressing AI, Security, Sensing and Computing scenarios

4.1.2 SNS Project Technological Focus

The goal of this section is to get a better understanding of the technological focus of the SNS Call 3 projects and the technologies, features and mechanisms investigated in each project, along with the precise network or service aspect being investigated.

Question T2: *Which of the following technological issues/aspects will your project address? Please mention any additional issues/aspects that you may address in the elaboration box?*

Figure 17 reveals that *AI/ML powered technologies* is the most addressed topic in the SNS Call 3 projects, closely followed by *System network architecture and control and Energy efficiency solutions*. This trend is similar to what was observed for the previous SNS Calls (see SNS OPS D1.4) and match very well the EU and global research trends (as analysed in the SNS ICE deliverable D1.2). AI-enabled mechanisms are potentially the hottest research topic at this stage, while sustainable and energy efficient solutions, are considered to be significant building blocks of the future 6G networks and services. The significant number of projects looking into *System architecture and control* indicates that the work on the basic building blocks of 6G networks is still ongoing.

Another group of heavily researched areas within the SNS Call 3 projects consists *of Edge and Ubiquitous computing, Management & Orchestration of resources (incl. VNFs/CNFs), Trustworthiness (Security, Reliability, Privacy) and Cloud Native Networking.* These categories reflect very well the focus of the current SNS JU Work Programme as well as global trends regarding promising technologies for the development of 6G networks. In particular, the proliferation of softwarization and the edge-cloud continuum along flexible resource utilization, are considered the key technologies that will deliver the promises of 6G, from global stakeholders. The prominent position of Trustworthiness is also noteworthy, as the current political and socio-economic climate has elevated this aspect to a critical component of future networks

Besides the mainstream technologies and aspects mentioned before, there are several additional technologies also investigated by Call 3 projects, including sensing, devices/HW, micro-electronics, optical-wireless, integration with NTN, new antenna technologies and Quantum computing among others. The broad range of technologies and solutions investigated by Call 3 projects, ensures that all relevant aspects and solutions will be evaluated in the SNS JU and the most suitable and capable ones, will be promoted for 6G standardization. It also reinforces confidence in the continuous development of EU expertise across multiple domains and contributes to the technological sovereignty of Europe.

Figure 17: Technological issues/aspects addressed in SNS JU - Call 3 projects

Similarly, with the KPI analysis, it is of particular interest to investigate the aggregate picture of all active 78 SNS JU projects from Calls 1, 2 and 3. Figure 18 provides the aggregated figures for all 78 projects from the three Calls in terms of investigated technologies. No major difference can be observed with Figure 17 since the main trends remain the same, with *AI/ML technologies* and *System architecture and control* being by far the most investigated technical aspect in the SNS JU. *Edge and ubiquitous computing* and *Orchestration of resources* are emerging as the second most important duo of technologies investigated in the SNS JU, allowing SNS research to keep in pace with the 3C network (Connected Collaborative Computing) initiative.

What is potentially one of the most significant insights is that even for less popular technological aspects, there are at least a few SNS projects investigating them, which offers significant cross-validation opportunities and ensures that even less-explored aspects will be investigated while a larger validation field will be achieved. The fact that there are more than 22 different technological aspects investigated by the SNS JU projects, provides confidence that a broad range of technologies will be evaluated by EU researchers, enabling robust, cross-validated conclusions, that will contribute to delivering the optimal version of 6G.

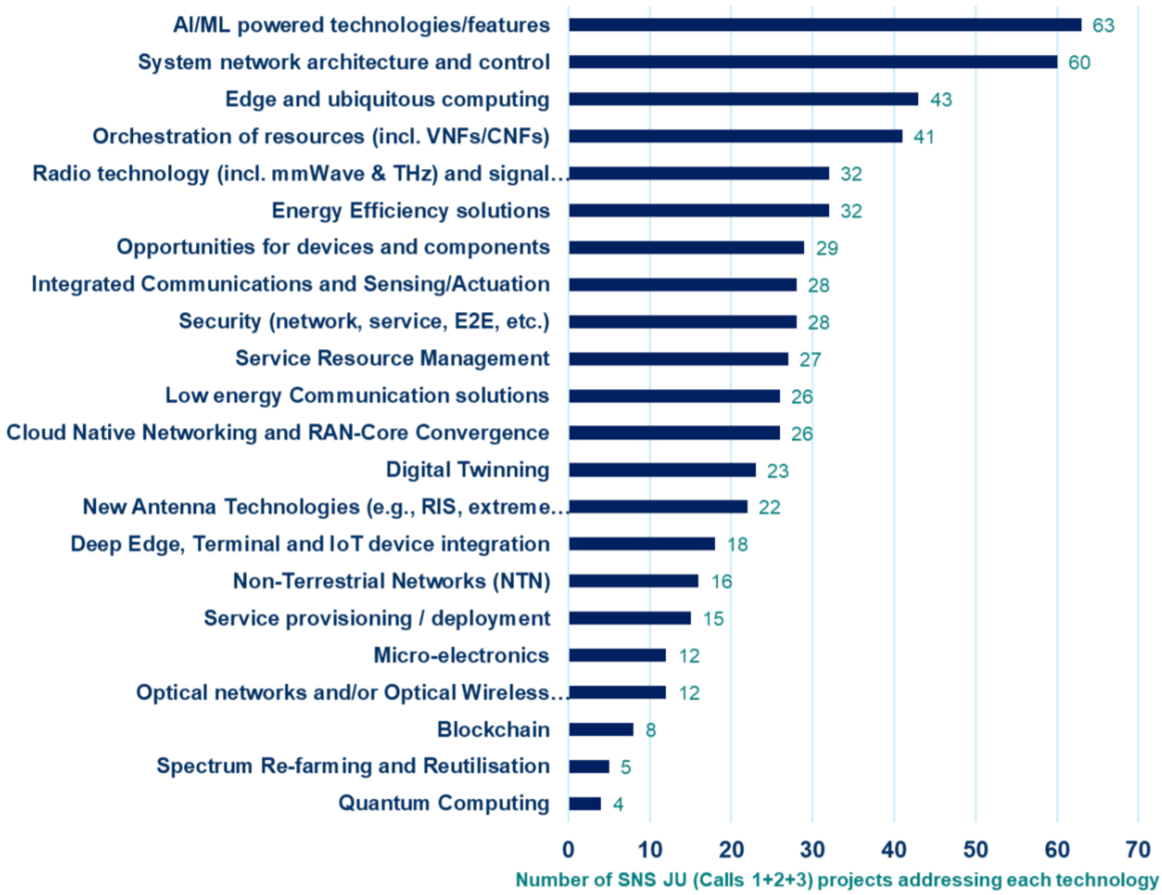


Figure 18: Technological issues/aspects addressed in SNS JU – Aggregate Call 1,2 and 3 projects

Key Insights

Some key insights that can be drawn based on the above analysis are:

- AI/ML and System Architecture remain at the top of the preference of SNS JU researchers.
- Call 3 specific technologies have been boosted (e.g., Sustainability, Edge and ubiquitous computing, Trustworthiness, Low energy communication)
- The current political and socio-economic climate has boosted the engagement with certain technologies/aspects such as Trustworthiness, Edge & Ubiquitous computing/3C networks, Sustainability/Energy efficiency technologies and Sensing.
- A very broad range of technologies/issues (22+) are investigated by SNS projects, allowing for cross-comparison of results that will assist the validation of the outcomes and extraction of common insights.
- Additional service-specific and obscure enablers are also investigated, offering possibilities for significant breakthroughs/insights and ensuring EU expertise in across all sectors.

4.1.3 SNS projects targeted Verticals & Use-Cases/Applications

As the success of the upcoming 6G standard depends on its adoption by the various vertical industries and the applications that it will support (as shown by the involvement of vertical stakeholders from a very early phase of the SNS JU)), two questions were asked to the projects in order to assess their targeted vertical sector and specific applications that they will be developing and to assess the way in which the projects interact with vertical stakeholders.

Question T3: *Which of the following Vertical sectors and use cases/applications will your project support? Please mention any additional sectors and/or applications in the elaboration box?*

Figure 19 depicts the number of Call 3 projects addressing each of the major vertical sectors identified within the SNS JU with a high potential of making use of upcoming 6G networks. It is encouraging to note that a broad range of vertical sectors are covered by Call 3 projects as more than 10 vertical sectors are addressed in the third SNS JU call alone (following the trend from previous SNS calls). The most prominent sectors are Security/PPDR and Industry 4.0/Manufacturing. The increase of interest in security/PPDR applications reflects the current socio-political climate, while Industry 4.0/Manufacturing is traditionally one of the strongest sectors of Europe. The Smart Energy and automotive sectors follow closely behind, indicating the significance of these two sectors for Europe as well. Several additional sectors are addressed by multiple projects, offering a broad portfolio of solutions to vertical stakeholders. Some changes in the prominence of different vertical sectors can be observed in comparison with previous SNS calls (SNS OPS D1.4), e.g., Smart city and Tourism & Culture verticals are less prominent among Call 3 projects (compared to Call 2) while Smart Energy and Security are more popular, reflecting the focus of the current SNS Work Programme.

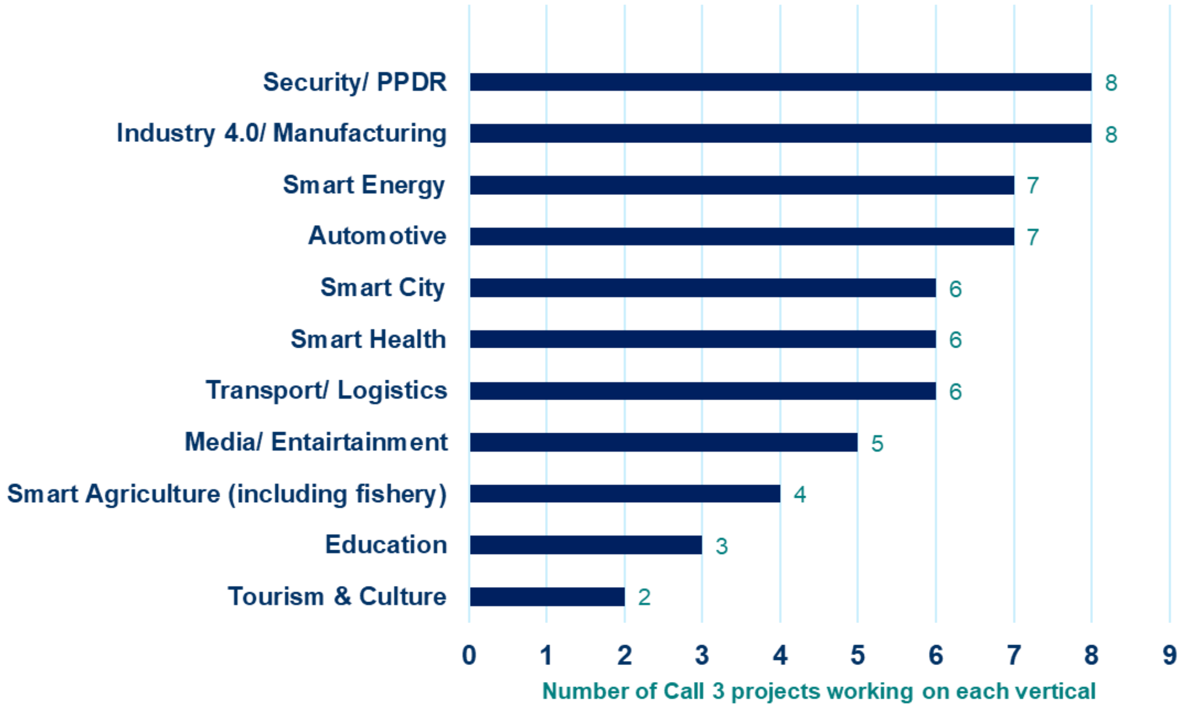


Figure 19: Main vertical sectors addressed in SNS JU - Call 3 projects

In order to get improved insights into the exact applications and use cases developed by Call 3 projects for each of these vertical sectors, an additional question was included in order to identify the specific applications developed by the SNS JU researchers. Figure 20 depicts the results from the received responses by Call 3 projects, indicating that Intelligent Operation Network (cross-cutting application) is the most popular application, followed by predictive maintenance and digital twin applications, which are applied to the strong industrial sectors of Europe such as Industry 4.0, Automotive, Transportation, etc. Another interesting insight is the significant engagement of SNS JU researchers with collaborative robots, ISAC/JCAS and Metaverse technologies which are currently considered cutting edge applications with huge market prospects.

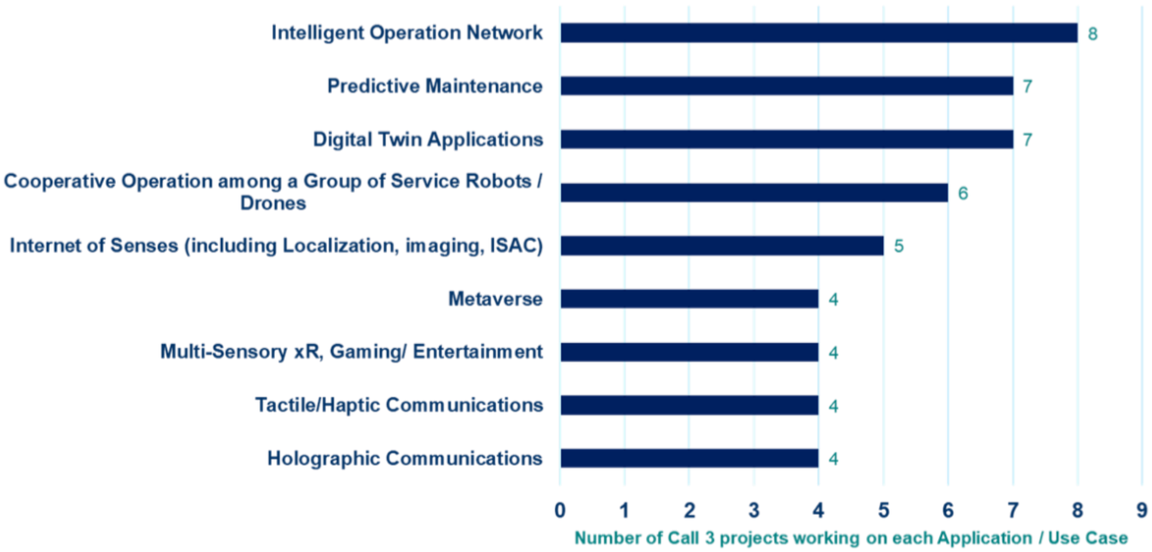


Figure 20: Applications/Use Cases addressed in SNS JU - Call 3 projects

Some potentially more interesting insights may be derived from the analysis of the applications/use cases developed by all the 78 active SNS JU projects (Call 1, 2 and 3), as depicted in Figure 21. As expected, Industry 4.0 applications remain at the top, confirming the strong influence of this vertical in European 6G R&I activities, while Smart City & Tourism is a clear second, once again confirming that this is considered one of Europe's stronger industries. The strong interest of Call 3 projects in Smart Health and Security applications, has boosted these sectors in the third and fourth place of the aggregate SNS results, while more 'traditionally' addressed sectors such as Automotive, Media and Transport follow closely behind. The overall view indicates once again, that SNS JU researchers are developing multiple solution for key industrial sectors in Europe, ensuring European expertise in all affected sectors.

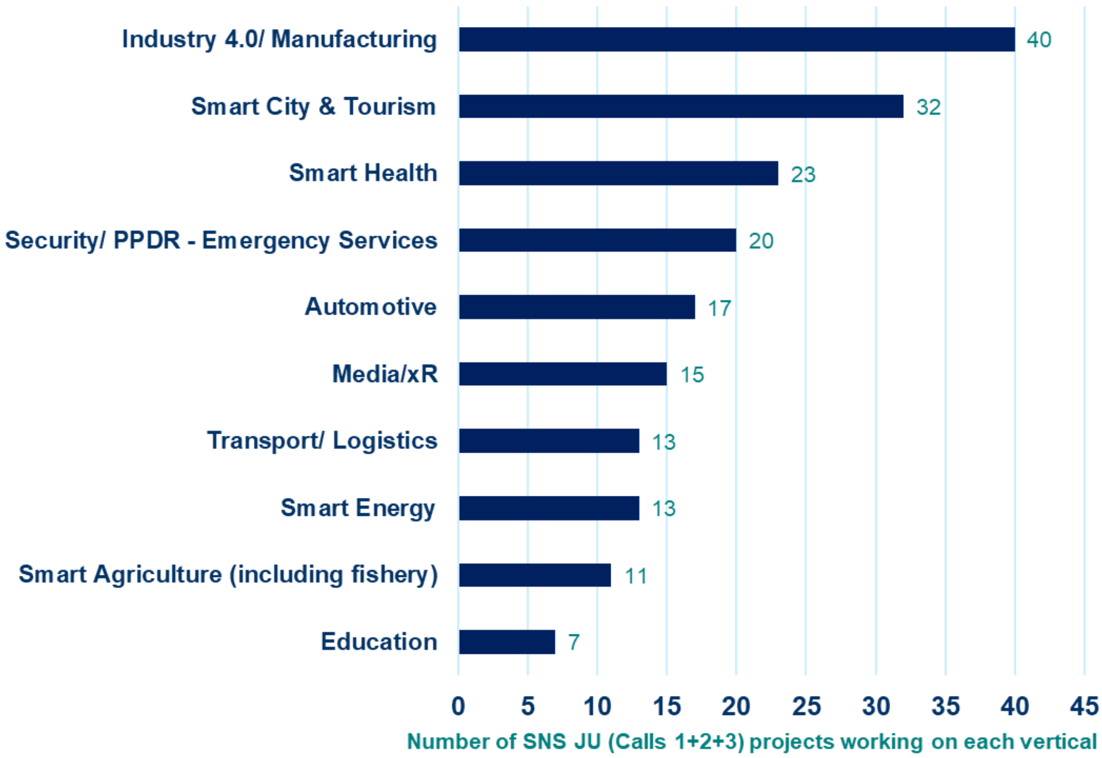


Figure 21: Main Use Cases/Applications developed – Aggregate Call 1, 2 and 3 projects.

Question T9: *How do you engage verticals in your project? What is the role of the verticals in your project?*

In addition to the vertical sectors addressed and the corresponding applications being developed, it is also of great interest to understand the way in which the SNS JU projects interact with vertical stakeholders and the exact role that these vertical stakeholders play in the respective projects. To that end, Question T9 was addressed to the projects. Figure 22 below presents how the different projects engage vertical stakeholders in Call 3 (top) and what is the exact role of the vertical stakeholders in the project (bottom).

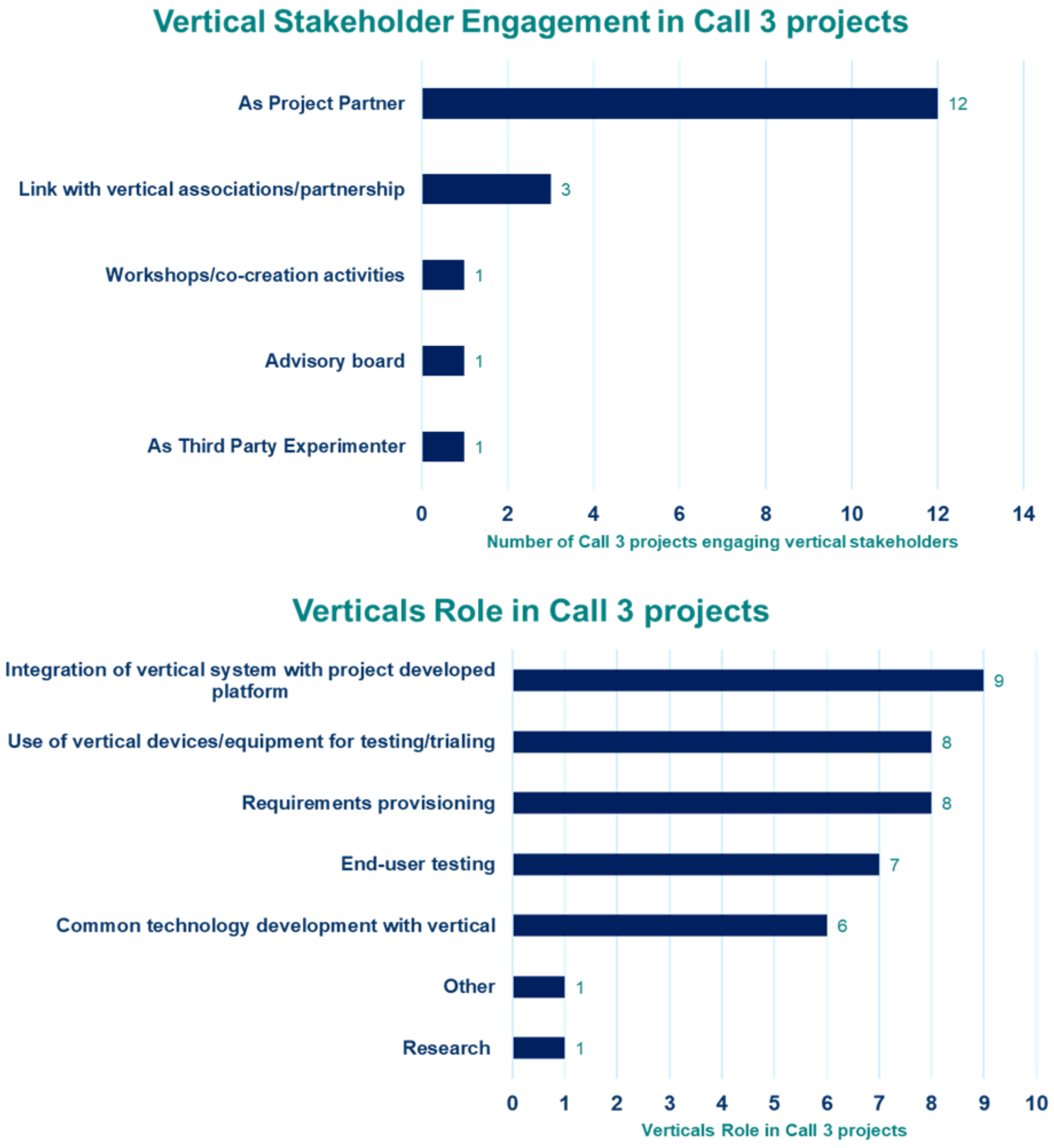


Figure 22: Engagement of Vertical stakeholders and their role in SNS JU projects – Call 3 projects

Based on the data presented in Figure 22, a significant integration of vertical stakeholders within the projects can be observed, as in most cases they are onboarded as full project partners, receiving both the perks and responsibilities of the partnership and ensuring their engagement in a meaningful way. Additional ways of engagement can be observed, such as links with vertical associations and collaborative activities, but they occur far less frequently.

Regarding the vertical stakeholders' role in the projects, in most cases they are asked to integrate their proprietary solutions with project-developed platform, in order to validate the project solutions in real vertical sector conditions and environments, while the use of vertical devices and equipment for testing and trialling and the provisioning of requirements by vertical stakeholders are also very important. By taking into account the remaining categories as well (end-user testing, common technology development, etc.), it can be observed that vertical stakeholders are not treated as 'add-ons' to the project life, but rather as an integral part of the project's mission and way of working.

It is also of great interest to observe the overall trend across all active 78 SNS JU projects (Calls 1,2 and 3) regarding the role of the vertical stakeholders, as depicted in Figure 23. Requirement provisioning is by far the most popular role for vertical stakeholders, as they have been engaged in the design of the initial 6G technologies, ensuring that the future 6G networks will address real-life challenges coming straight from the vertical stakeholders. The use of vertical devices for testing and trialling and the integration of vertical solutions with project platforms are also very popular, indicating the significant overall integration of vertical sector stakeholders in the every-day life of SNS JU projects.

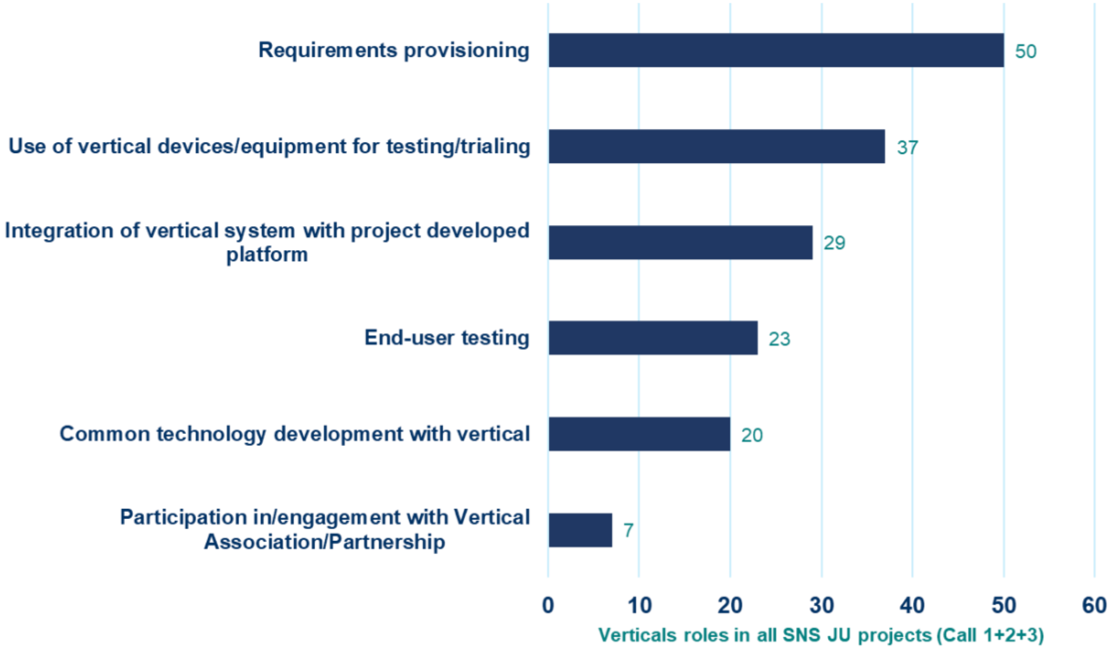


Figure 23: Engagement of Vertical stakeholders in SNS JU – Aggregate Call 1,2 and 3 projects.

Key Insights

Some key insights that can be drawn based on the above analysis are:

- Traditionally strong European sectors such as I4.0, Automotive, Smart City / Tourism remain at the forefront of the SNS JU research, while new sectors (Security/PPDR, Smart Energy) are also gaining momentum
- Strong interest in multiple novel sectors with significant overlap offering cross-validation and verification opportunities.
- Cutting edge use case being developed such as collaborative robots, ISAC/JCAS, Digital twins, with application in multiple vertical sectors
- Strong engagement of vertical stakeholders in SNS JU projects, not as ‘add-ons’ but as integral parts of the consortium offering key services.
- Very encouraging that most vertical needs, requirements and challenges seem to be provided directly from vertical stakeholders.

4.1.4 Use of AI/ML in SNS Projects

It’s been well established that the use of Artificial Intelligence (AI) and Machine Learning (ML) mechanisms will be extensive in the future mobile network generations, so much so that several 6G proponents are pushing for an AI-native 6G architecture. With that in mind, it is important to understand the degree to which AI/ML is used in the SNS JU projects, the exact functionality that it will serve within the networks, as well as to obtain information regarding the used AI data sets. and the type of AI/ML mechanisms developed by the projects. To that end, Question T4 was addressed at the projects as follows:

Question T4: *i) Will your project make use of AI/ML? ii) Do you plan to deliver/provide access to your AI training data sets, after the project's completion? iii) For which of the below items do you plan to use AI/ML functionality?*

Figure 24 below depicts the number of Call 3 projects planning to publish their AI data sets for model training by others, as this could be beneficial for the research community. This issue remains a challenge for many projects as only 33% of projects (5 out of 15) were able to confirm at this stage that they will share their AI training data, while 4 projects (26%) have already eliminated this as an option (due to the sensitivity/privacy of their selected training data). The other 40% of projects is currently seeking ways to make at least some if their data available in agreement with the relevant partners.

The questionnaire further inquired about the type of AI/ML mechanism being developed by the projects and the network layer it would be used in. The responses are provided in the bottom graph of Figure 24. Based on this graph, similar trends are followed by Call 3 projects, as Management and Orchestration mechanisms remain the primary focus of AI-enabled solutions followed by RAN and device aspects. This result indicates a strong trend in the expected use of AI mechanisms at least during the early years of 6G networks deployment.

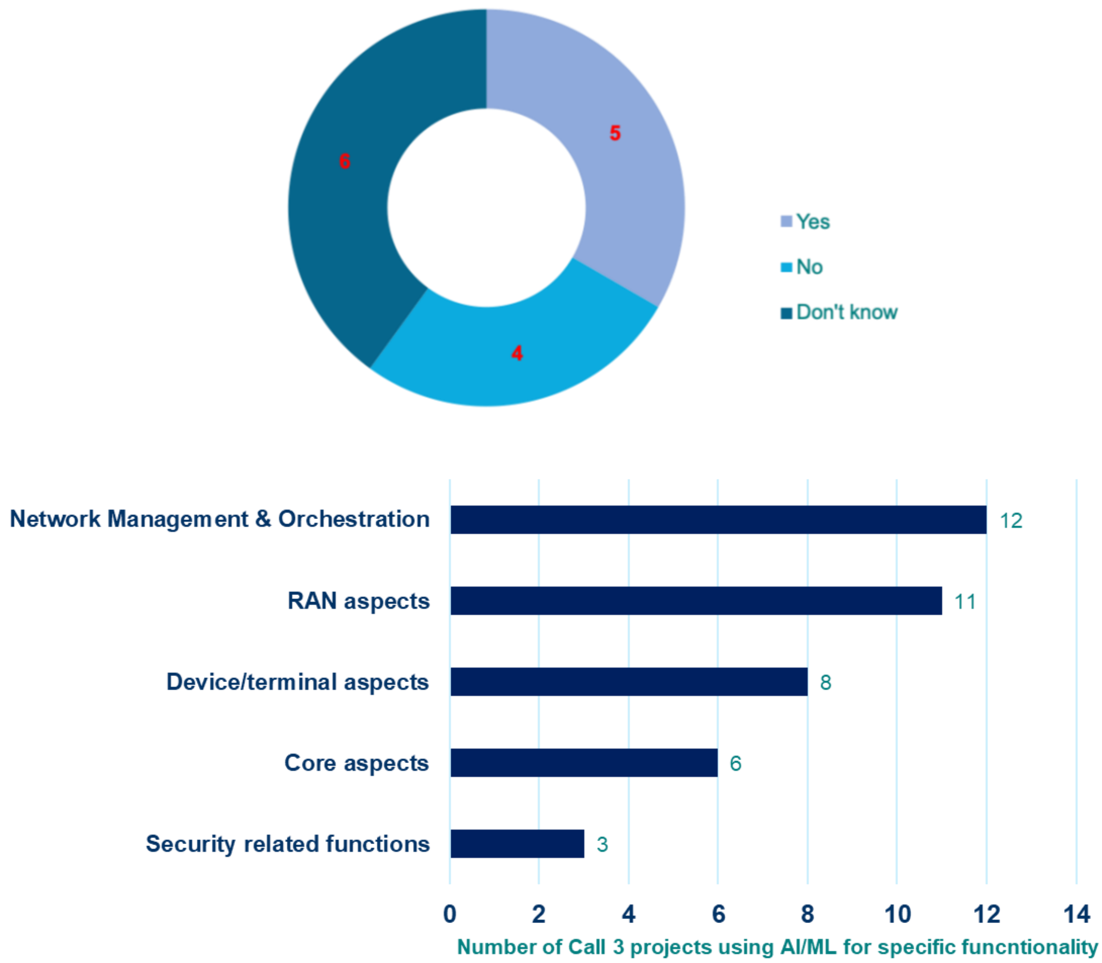


Figure 24: Projects providing access to their AI training data (top) and AI functionality (bottom)

By combining data from all previous editions of the questionnaire, covering Call 1, 2 and 3 projects, the complete picture of the AI/ML use within SNS can be drawn, as depicted in Figure 25. The received responses suggest that the majority of the developed AI/ML mechanisms are targeting *Network Management & Orchestration* functionalities (as expected). Such mechanisms could, for instance, be used for automated coverage optimization, traffic dependent RAN planning, optimization of resource efficiency and more. The second most popular area for deploying AI solutions appears to be the *Radio Access Network* where functionalities like automated gNB configuration/tilting could be very beneficial. Finally, several other mechanisms are being developed for all layers/segments of the future network, showcasing the versatility of AI-mechanisms and the broad range of their applicability. These results are very encouraging, as they indicate that European researchers remain at the cutting edge of research developments and that significant outcomes can be expected from the SNS JU projects in terms of AI-enabled network solutions, with potentially global impact.

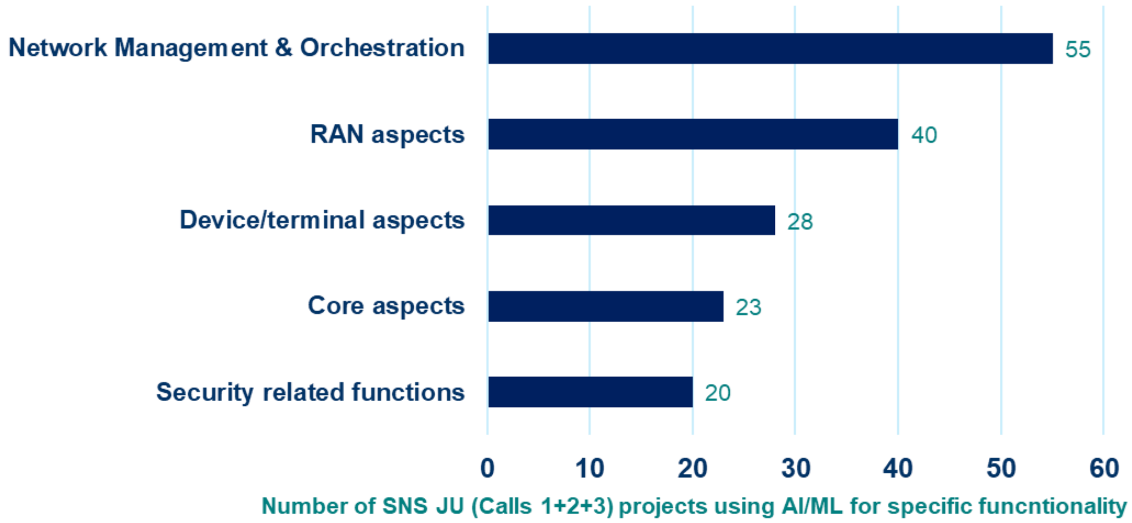


Figure 25: AI/ML targeted Functionality in the SNS JU – Aggregate Call 1, 2 and 3 projects.

Key Insights

Based on the analysis provided in this section, a few key insights can be drawn regarding the use of AI/ML in the SNS JU projects:

- The use of AI/ML is pervasive in the SNS JU as approximately 94% of active projects are making use of AI/ML functionalities (73 out of 78).
- The provision of suitable and proper AI training datasets remains problematic and one of the major challenges that need to be solved.
- The majority of AI/ML mechanisms developed in the SNS JU is targeting Network Management & Orchestration & RAN functionalities, which seem to be fruitful areas for the early deployment of AI/ML.
- The use of AI/ML will be pervasive in 6G networks, as relevant mechanisms are being developed for all the envisioned network layers/segments. The SNS JU researchers also embrace the idea of an AI-native network.

4.1.5 Targeted Standardization Bodies & associations by SNS Projects

The questionnaire then addressed a specific question related to targeted projects standardization/specification contribution. More specifically, the projects had to respond to the following question:

Question T5: *Which standardization/specification bodies will your projects target for contributions?*

Figure 26 highlight the targeted top 5 SDOs/pre-standards bodies by the Call 3 projects. 3GPP and ETSI are once again (as was the case with Call 1 and 2 projects) at the top of the preference of the Call 3 projects with 13 projects targeting 3GPP contributions and 12 projects targeting ETSI contributions. ITU and IETF/IRTF follow closely with up to 7 projects claiming their intentions to contribute there, while IEEE is also mentioned as a potential target. These results are encouraging, as they indicate that standardization impact is a crucial part of the workflow of all Call 3 projects, while the trends are perfectly harmonized with the priorities set by the SNS JU. Five projects also mentioned their intention to participate and contribute to other, specific (pre) standardization bodies, depending on their specific technological focus.

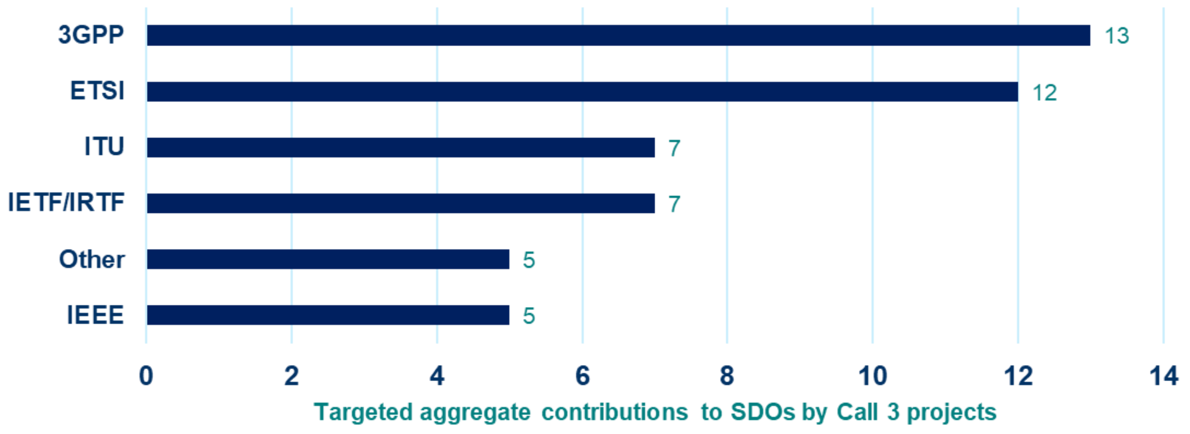


Figure 26: Target for SDO contributions by SNS Call 3 projects

It is also interesting to note how the SDO target trend has evolved over all active SNS projects, considering the responses from the previous editions of the questionnaire and aggregating the data for Call 1, 2 and 3, as depicted in Figure 27. The clear winners are once again 3GPP and ETSI with the majority of projects making them their primary target of standardization impact, while a significant number of projects are also planning to engage/have already engaged in ITU and IETF/IRTF activities.

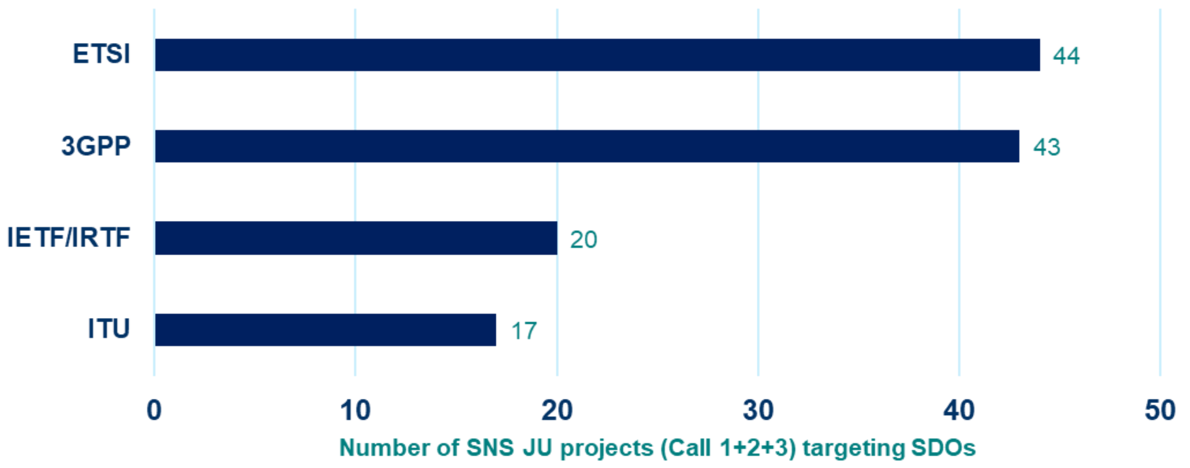


Figure 27: Target for SDO contributions by SNS JU projects – Aggregate Call 1, 2 and 3 projects.

When analysing the targeted specific standardization/specification groups from Call 3 projects as provided by the projects (Figure 28), several specific groups and sub-groups can be identified. The most popular groups identified are:

- 3GPP: RAN1, SA2, SA1 and RAN2
- ETSI: MEC, TC CYBER, TFS, ISG ENI, ISG NFV and ISG ZSM
- Additional targeted groups: ITU WP5D, IEEE 802.11, IETF TEAS

Despite the relatively small number of projects in Call 3 (15 projects), a very broad range of targeted SDO groups can be observed, indicating the commitment of the projects and their determination to achieve significant impact across multiple technological domains.

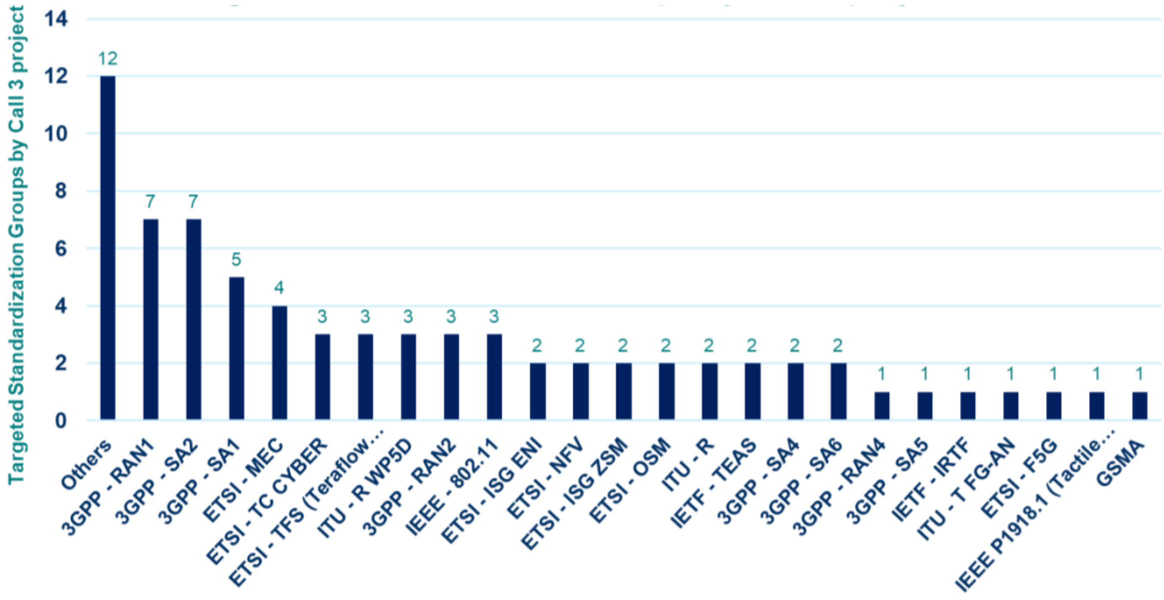


Figure 28: SDO groups targeted by SNS Call 3 projects

An additional question (T6) was asked in order to determine the projects' ambition regarding the open-source organizations and how contribution to them is planned by the projects.

Question T6: *To which Open Source organisations does your project contribute?*

Figure 29 depicts the number of open-source organizations targeted by Call 3 projects. Collectively, Call 3 projects cover a very broad range of open-source organizations, indicating very high activity in this field. Contributions and engagement with O-RAN and OpenAirInterface are by far the most popular options, while Open-source MANO, SRS RAN, CAMARA, Open Day Light and others, also receive their fair share of attention by Call 3 projects. Open source solutions and engagement with open-source bodies seems to be a significant part of Call 3 projects workflow.

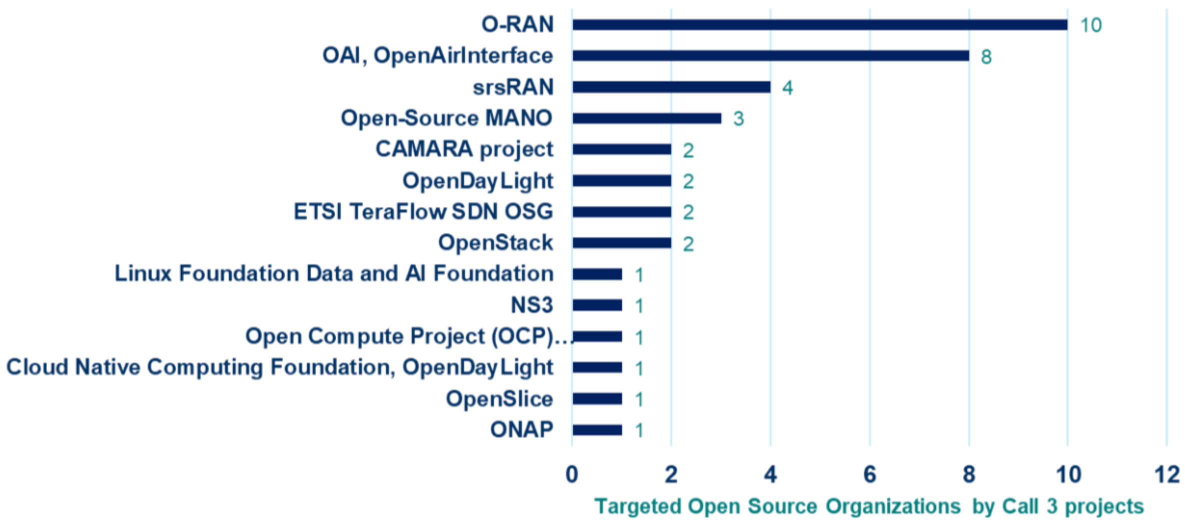


Figure 29: Targeted Open-Source organizations by SNS Call 3 projects

Furthermore, it is interesting to analyse the aggregated figures for the targeted standardization groups by Call 2 and 3 projects, as depicted in Figure 30. O-RAN and OAI are once again the most targeted groups by far, while CAMARA, ETSI TFS, Open Source MANO and SRS RAN are also quite popular. The broad range and diversity of the targeted groups holds promise for a strong presence from SNS in multiple relevant technological fields and open source bodies.

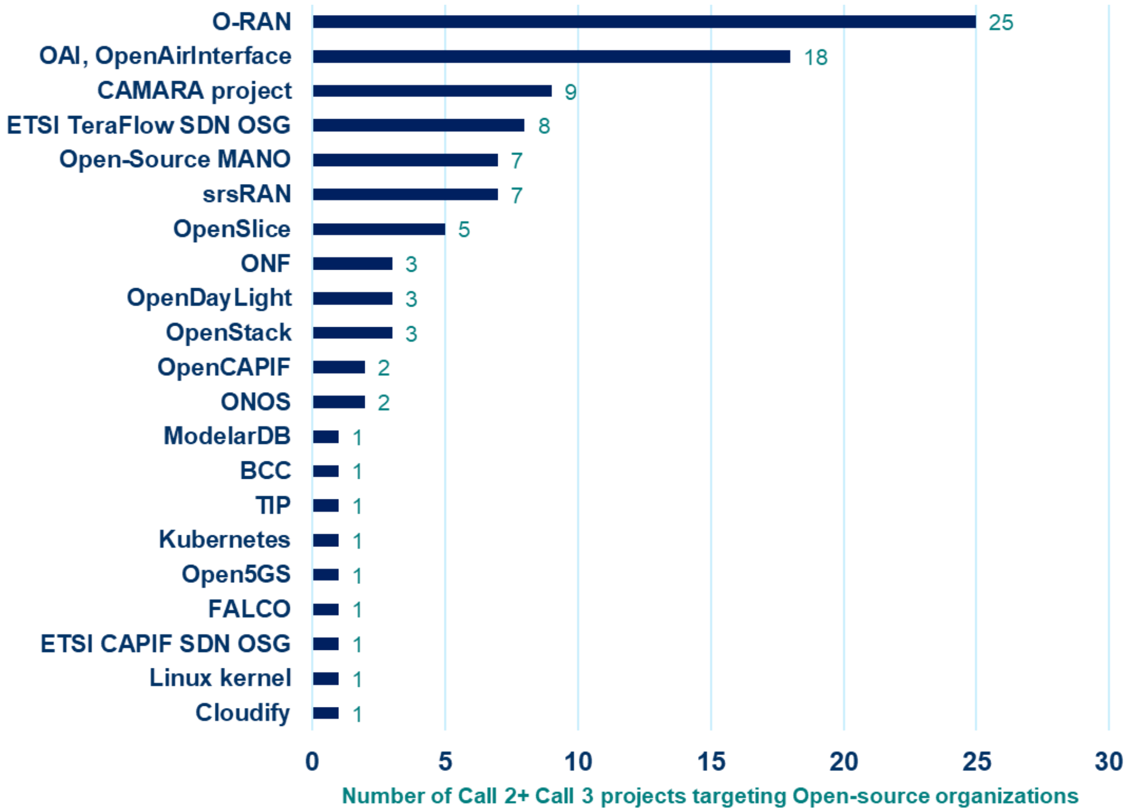


Figure 30: Targeted Open-Source organizations by SNS JU – Aggregate[5] Call 2 and 3 projects

Key Insights

Overall, when evaluating the outcomes of the questions targeted at standardization (T5 & T6) the following key insights may be extracted:

- ETSI and 3GPP are steadily the most popular SDOs targeted by SNS projects and this is also the case for SNS Call 3 projects.
- A vast range of different sub-groups is targeted in each of the SDOs, indicating significant diversity of targeted technologies, being developed in SNS projects.
- ORAN and OAI is by far the most targeted open-source organizations (for both Call 2 and Call 3 projects), however a significant range of other open-source bodies (more than 20) are also targeted.

4.1.6 Validation Methodology/Equipment & Targeted Trials/Tests

Following question on standardisation, the questionnaire also included specific questions on targeted demonstration, trials and pilots. Question T7 addressed the type of end-user equipment, while question T8 addressed the validation methodologies to be adopted by the projects.

Question T7: *What type of (End User) Equipment will be used for testing / trialling in your project?*

The results for Call 3 projects are depicted in Figure 31. The most popular devices are clearly Mobile Phones, followed by IoT Sensors, Modems/Routers, Robots/Cobots and CPEs. Additional UEs are mentioned such as Satellite Receivers, XR Equipment, Drones, On-Board Units (V2X) and other Networking Equipment. The answers show a great coverage of devices for targeted tests and trials.

[5] No call 1 data available for this question

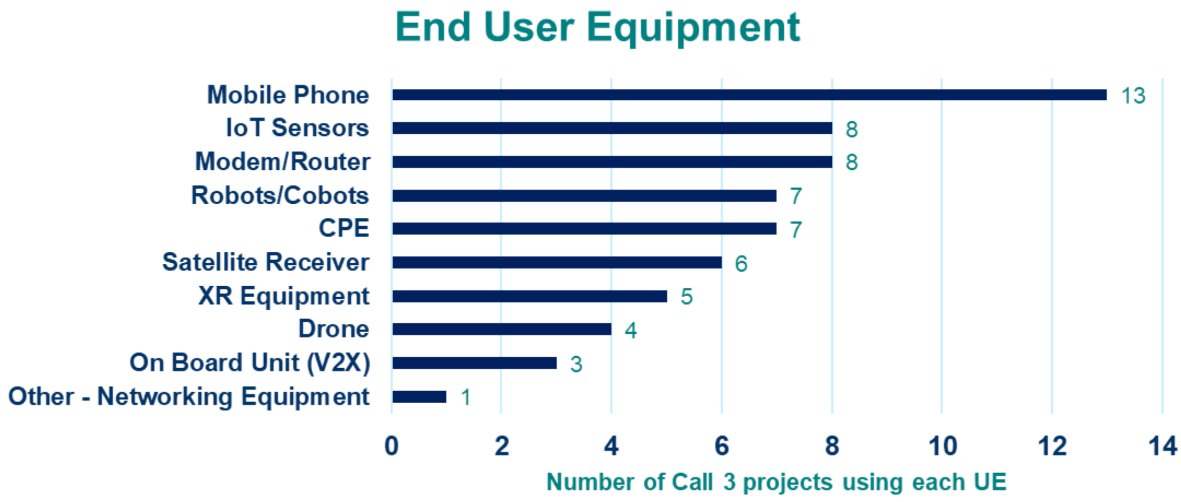


Figure 31: Use of End-User Equipment in testing and trialling by SNS Call 3 projects

It is interesting to analyse how the targeted devices of Call 3 projects are consistent with the ones from Call 1 and Call 2 projects and what are the overall trends and numbers in terms of equipment in the SNS JU, taking into account all 79 R&I active projects (Calls 1, 2 and 3). Figure 32 depicts the aggregated statistics in terms of targeted equipment, as provided by the 79 Call 1, 2 and 3 projects.

Mobile Phones are clearly the most popular UE for projects (65%). The second group includes IoT Sensors, CPEs and Modems/Routers (around 40%), the third group Drones (22%) and the fourth group includes On Board Units (V2X), Robots/Cobots, XR Equipment and Satellite Receivers (around 15%). As reminder, there were no Robots/Cobots& XR Equipment in Call 1 projects and no Satellite Receiver in Call 2 projects. As reported in previous deliverables, Stream C and Stream D projects offer a large variety of testing/trialling equipment, also knowing that those expand their scope/use-cases and stakeholders through their Open Calls.

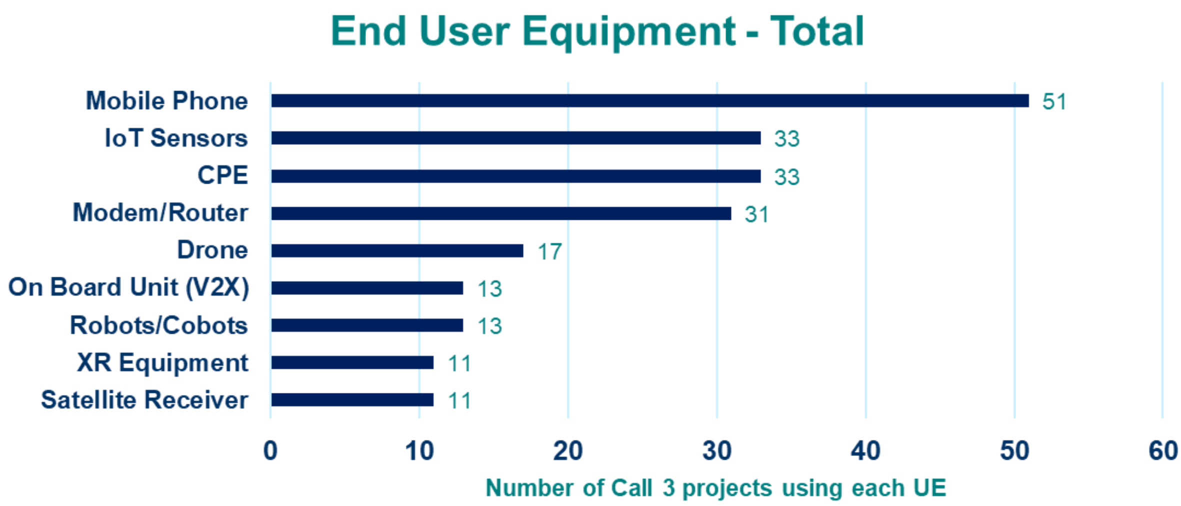


Figure 32: Use of End-User Equipment in testing and trialling – Aggregate Call 1, 2 and 3 projects.

Key Insights

Based on the analysis provided in this section, a few key insights can be drawn regarding the use of end-user equipment in the SNS JU projects:

- Mobile Phones are the most popular UE for projects of calls 1, 2 and 3.
- Stream C and Stream D projects offer a large variety of testing/trialling equipment.

- Relatively steady trends across the 3 calls.
- Each category of End-user Equipment is used at least by 14% of projects.

Question T8: *Which methods will your project use to validate the technologies developed? Indicate the method, trial date and location as well as the potential replicability of the use case.*

Figure 33 depicts the statistics in terms of validation methods and related planning, as provided by Call 3 projects. Analysing the received inputs, projects will use alternative approaches to test or validate their developed technologies. The major validation method that is mostly preferred by the projects is Trials (TRL 5/6), followed by Experimental PoC (TRL 3) and Lab Validation (TRL 4). These methodologies are selected/preferred by the majority of the Call 3 projects, while it can also be observed that there are very few planned Pilots (TRL 7).

Concerning the timing for the validation, unsurprisingly Call 3 projects that kickstarted in January 2025 will implement their validation mainly in 2027, that is, in the second year of the project.

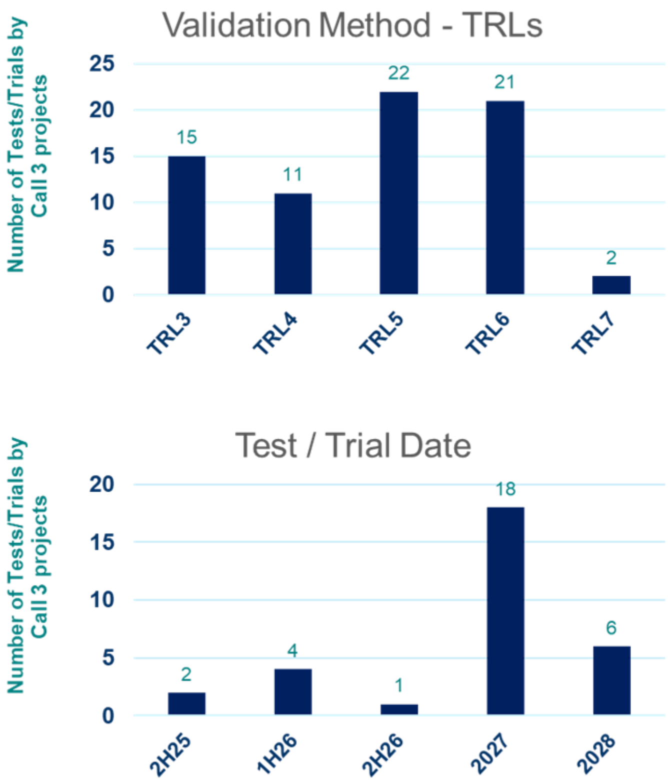


Figure 33: Validation methods for developed technologies and related planning –Call 3 projects.

Figure 34 depicts the statistics in terms of countries where the validation activities will take place, as provided by Call 3 projects. The experiments/trials take place in 18 EU countries and there is clearly a good spread of test/trial sites across Europe for Call 3 projects. The country with the most validations taking place is Greece, followed by the groups of Germany, Spain and Italy, France and Belgium, while validation activities are taking place in multiple other countries as well. Similar trends can be observed by the aggregated data of Call 2 and Call 3 projects as depicted in Figure 35.

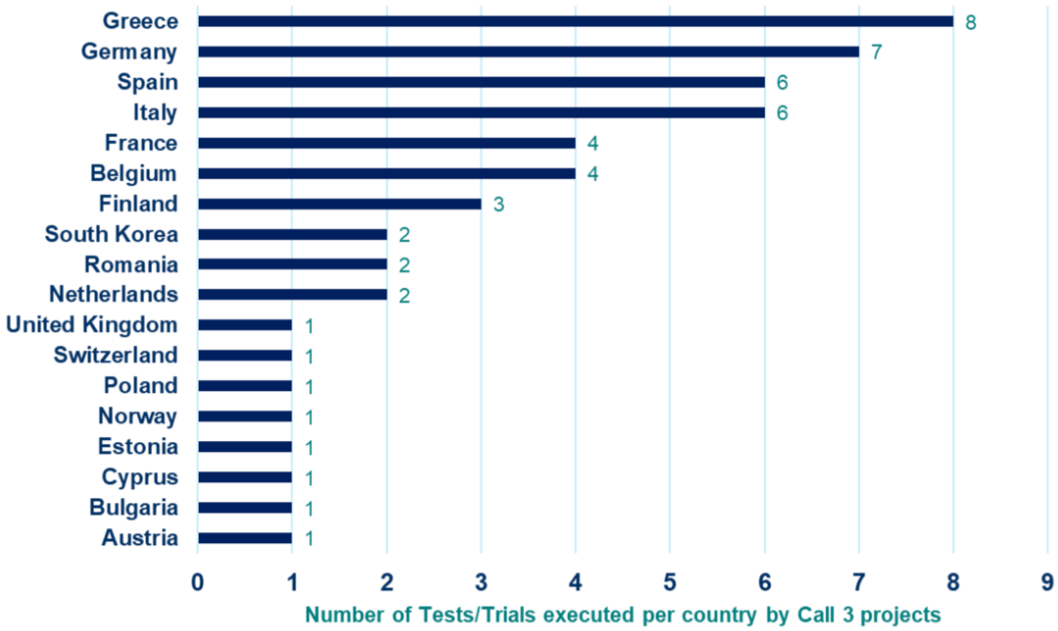


Figure 34: Location of SNS JU validation activities –Call 3 projects.

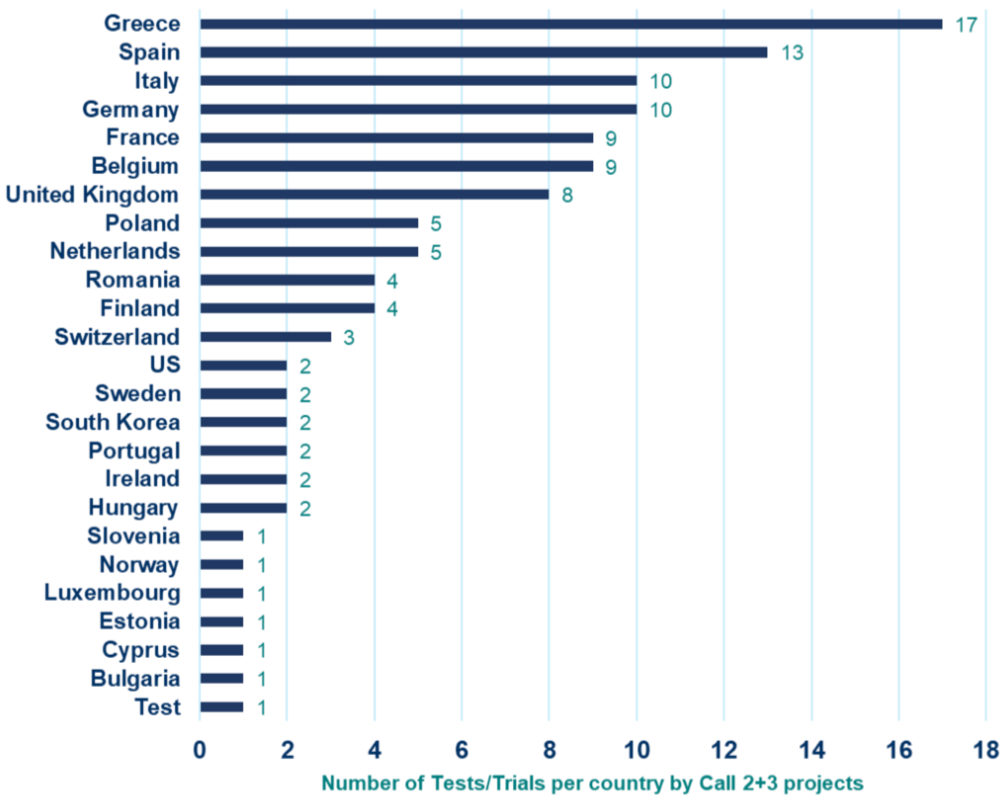


Figure 35: Location of SNS JU validation activities – Aggregate[6] Call 2 and 3 projects.

Figure 36 depicts the statistics in terms of replicable use cases that Call 3 projects are planning to experiment via PoC, trials and pilots. Among the 25 use cases planned to be tested via PoC, 6 will be replicable and among the 23 use cases planned to be experimented via Trials and pilots, 6 will also be replicable. Most of these use cases will target verticals, the other will address connectivity technologies usable for any verticals.

[6] No call 1 data available for this question

These replicable use cases will be identified in the Vertical Engagement Tracker with a specific label and the corresponding replicability level that they will get via the online Replicability assessment tool.

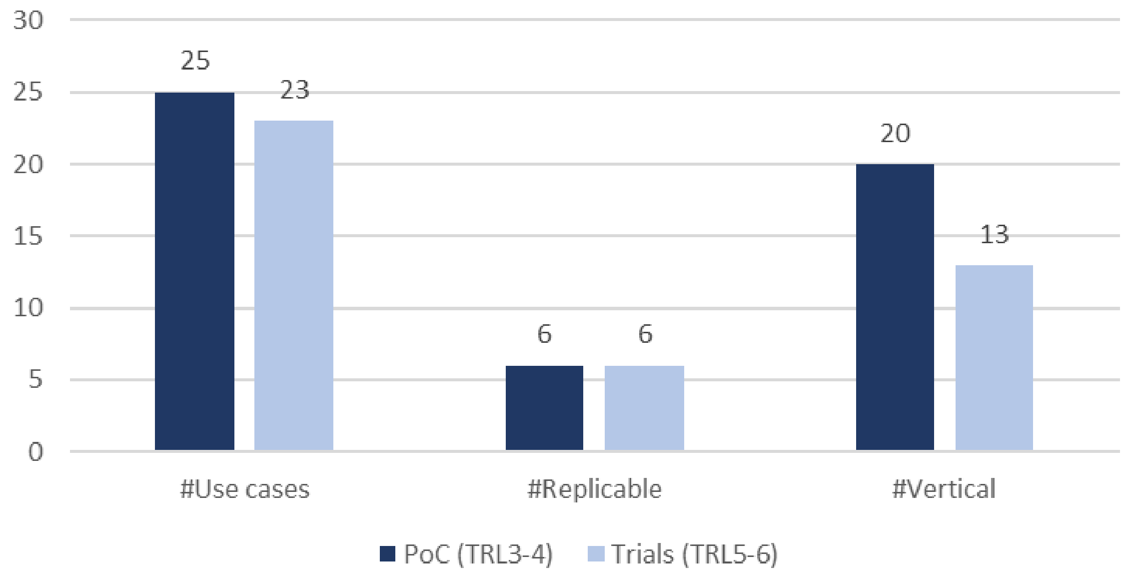


Figure 36: Provisional vision of Replicable use cases developed by Call 3 projects

Key Insights

Based on the analysis provided in this section, a few key insights can be drawn regarding the validation methods and countries in the SNS JU projects:

- Trials (TRL 5/6) is the most popular validation method among Call 3 projects.
- Experimental PoC (TRL 3) and Lab Validation (TRL 4) are also well covered in Call 3 projects.
- No 'high-risk' experiments in Call 3 projects.
- Projects still need time to prepare their experiments/trials (most are planned for 2H27).
- Early experimentation set to begin in 2026.
- Experiments/trials to take place in 18 EU countries. Good spread of test/trial sites across Europe detected for Call 3 projects.
- Greece, Spain, Italy and Germany are among the top locations for experimentation.
- Additional insights expected from the Vertical Engagement Tracker (VET).

The projects' answers to the Questionnaire provided interesting insights with regards to the targeted validation methods, end-user equipment for testing and trialling and planned Trials & Pilots. The inputs are directly shared with the 6G-IA Trials WG for further use, including further input to (1) Projects to be invited to make contributions/presentation in the Trials WG online meetings and (2) to the forthcoming SNS T&Ps Brochures.

4.1.7 Energy Efficiency Solutions

In this third edition of the questionnaire, addressed at the newly funded Call 3 projects, a new question was added to provide insights into the intended Energy Efficiency mechanisms to be developed by the projects.

Question T10: *Does your project plan to address energy efficiency issues, and if so, how?*

Figure 37 shows the responses by the Call 3 projects, indicating that the majority of projects prefer the development of a software solution to address energy efficiency goals, while in their vast majority the developed solutions will be applied either in the RAN or the application/service layer. However, additional solutions applied to the core, transport and device layers are also developed by the projects, ensuring a holistic approach and investigation of energy efficiency. Some projects will also develop relevant hardware solutions.

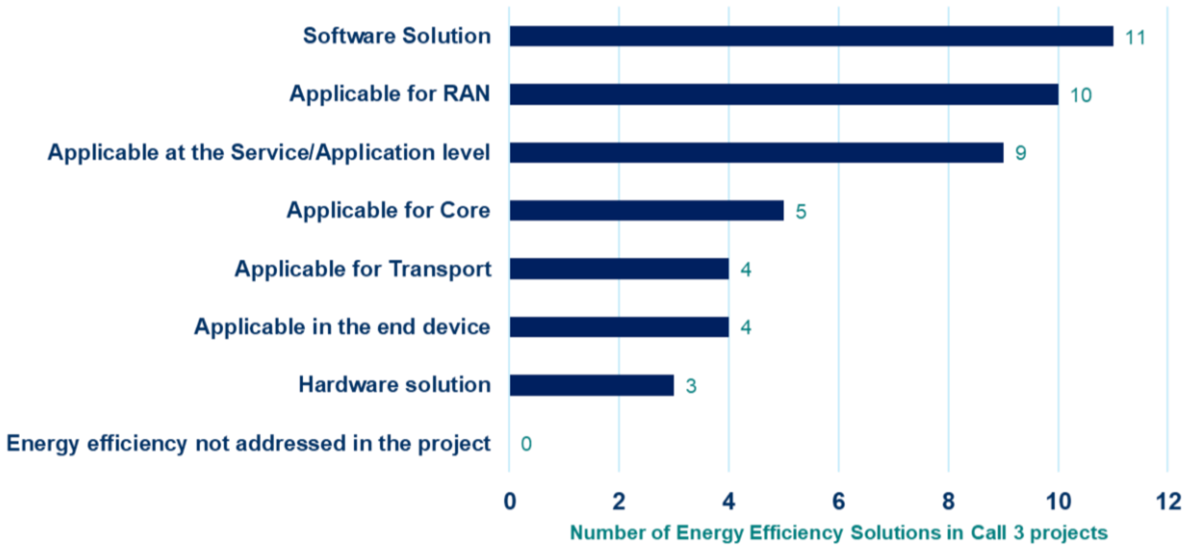


Figure 37: Energy Efficiency solutions developed by SNS Call 3 projects

Key Insights

Based on the analysis provided in this section, some key insights can be drawn regarding the targeted Energy Efficiency mechanisms to be developed the SNS JU projects:

- The vast majority of the developed EE solution will be software-based, however hardware-based solutions are also investigated by some projects
- RAN and Service/Applications layers are the most fruitful for implementation of EE mechanisms according to the focus of the SNS projects.
- Additional solutions applicable at the core and transport layers as well as on the device side, ensure a well-rounded investigation of Energy Efficiency by SNS projects.

4.2 Vision Aspects

The vision section of the questionnaire is comprised by five questions, all multiple choice. All questions were open for free text comments. Specifically, the survey addressed the following aspects: societal challenges, societal values, KVIs, 6G Vision, and sustainability. The purpose of this section is to understand how the projects from Call 3 view their contributions to the broader goals and vision of the SNS programme.

4.2.1 Societal challenges

Question V1: *Which SNS Societal Challenges are addressed in your Project?*

Figure 38 shows the responses received in from all Call 3 projects. The focus of the projects is strong on sustainability, but also on new business models and market segments, and a strong European impact. Compared to the Call 2 survey in 2024 documented in SNS OPS deliverable D1.4 [3], this time sustainability has been classified as a challenge, instead of as a value (see next question). It is still significant the support to cyber-security and technological sovereignty. In the lower end, we find challenges on the digital divide and social inequality, ethical procurement, and green growth.

The observations in the lower end are related to environmental challenges. Green growth is associated with decoupling of economic activity from negative sustainability impacts. At the same time, sustainability and new business models are regarded top challenges. This apparently contradicting viewpoints may call for a more in-depth discussion. The SNS JU Workprogramme 2025[7] formulates an objective on societal and political aspects where the achievements of the EU Green Deal's targets are included. How that will be manifested in the Call 4 portfolio of projects is still to be seen.

Key Insights:

- Sustainable 6G is in focus
- 6G needs to enable the creation of new business models and market segments
- It is important that Europe has a strong impact on 6G standardization

[7] https://smart-networks.europa.eu/wp-content/uploads/2025/01/sns-work-programme-2025-clean-lay-out-18_11_24_final-draft-without-annex-2.pdf

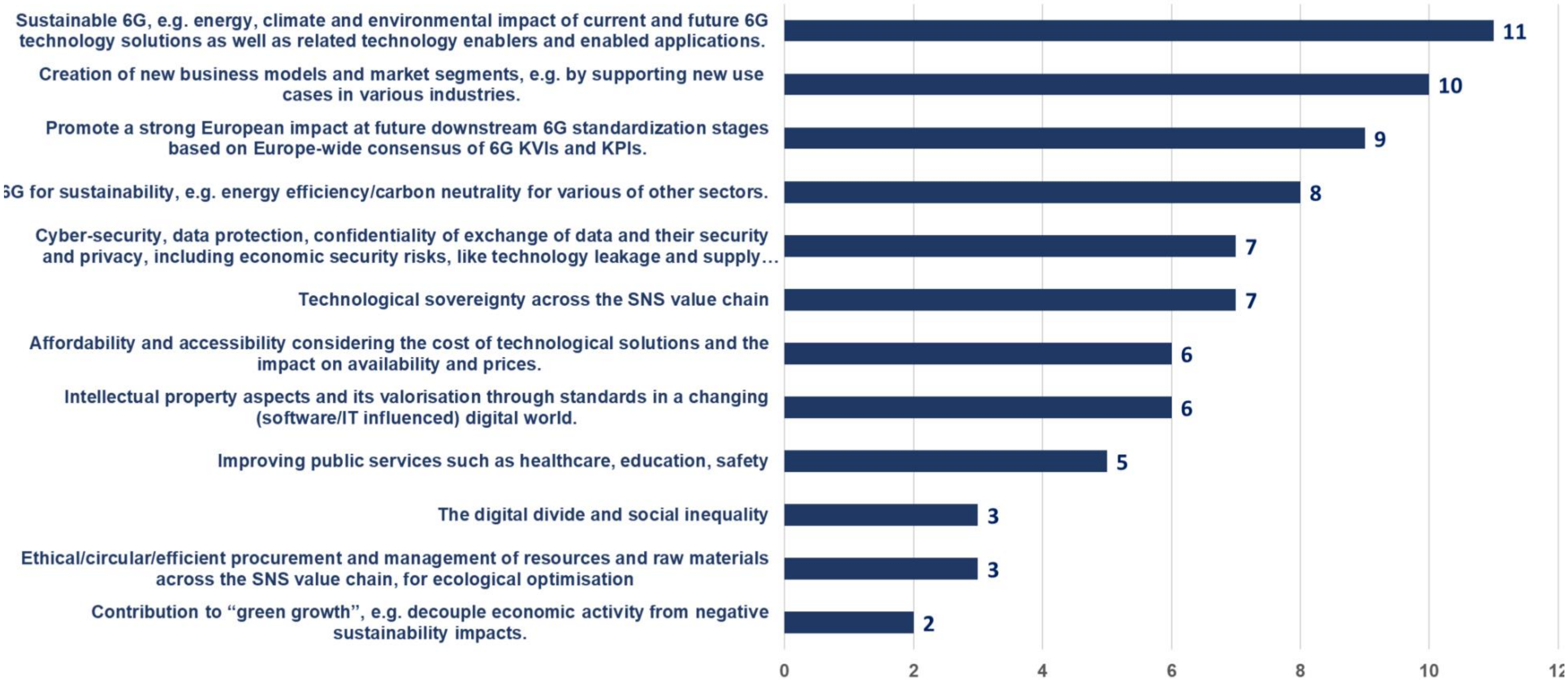


Figure 38: Contributions to societal challenges by SNS JU Call 3 projects (all streams).

4.2.2 Societal values

Question V2: *Does your project address any societal values mentioned below, and if not please mention which societal values are addressed in your project in the box below.*

The collected responses are depicted in Figure 39, where it can be observed that all projects address energy efficiency as an important societal value. Close followers are privacy, security and human safety, environmental impact, and cost. At the lower end, it is interesting to note that values like social resilience, trust and democracy are not in focus for Call 3 projects.

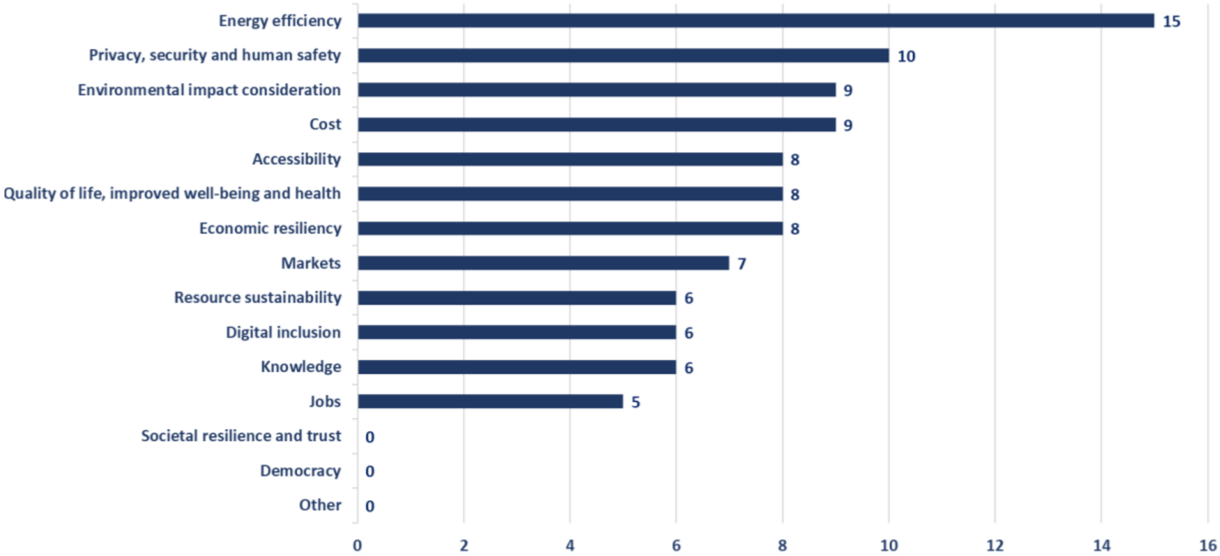


Figure 39: Societal values addressed by SNS JU Call 3 projects

Figure 40 performs a comparison between Call 2 and Call 3 responses for some societal values.

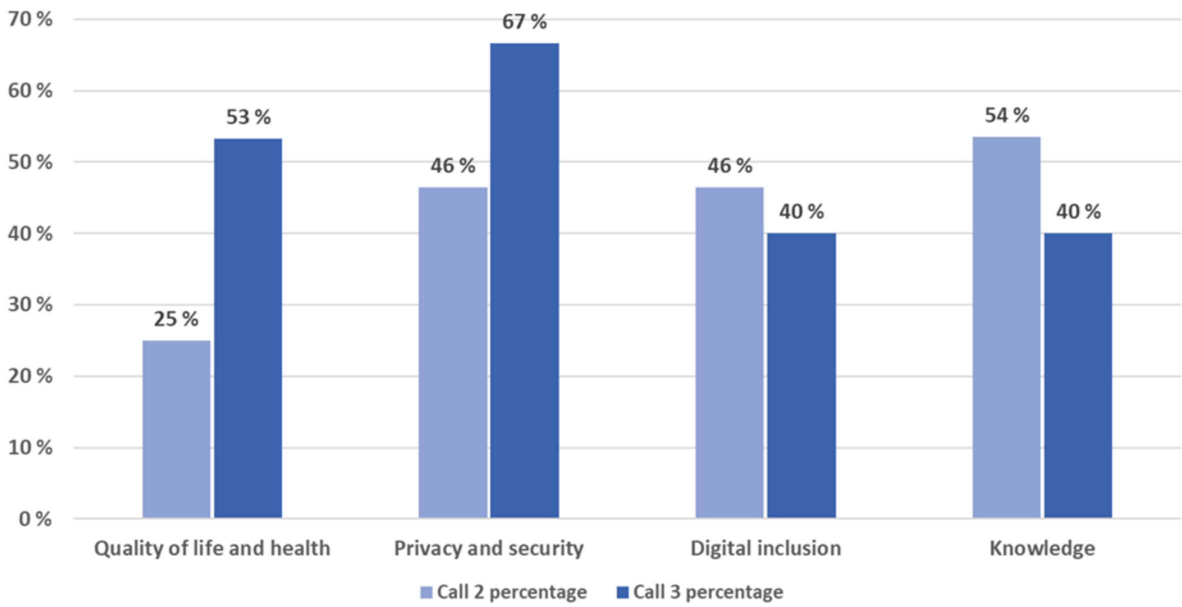


Figure 40: Changes in emphasis on selected societal values from Call 2 to Call 3 projects

By comparing this year's Quality of life, improved well-being and health with last year's Personal health and protection from harm, the focus has increased from 25% to 53%. It can also be observed that privacy has gained more focus. Privacy, security and human safety have a higher score that last year's Privacy and confidentiality, though the term might have been understood differently. Digital inclusion and Knowledge have decreased from Call 2 to Call 3.

The top score on energy efficiency resonates well with the observation from V1 where sustainable 6G is on top. This indicates that these values and challenges are regarded important for the success of 6G.

Key Insights:

- Energy efficiency is addressed by all projects
- Privacy, security and human safety have increased emphasis compared to Call 2
- Societal resilience, trust, and democracy have no focus in Call 3. They were also low in Call 2.

4.2.3 Key Value Indicators (KVIs)

Question V3: *Does your project assess Key Value Indicators (KVIs)? If yes, which validation and assessment methods do you plan to use?*

Figure 41 depicts the received responses regarding the preferred KVI validation methods. It can be observed that Trials and experiments in lab are the preferred methods, however example use cases, scenarios or case studies are also popular. Next comes the use of twinned systems or simulations. Slightly less than half of the projects (7/15) plan to perform measurements on deployed networks. Further, below middle point, the involvement of users and stakeholders can be found, together with the study of technical and economical enablers. In the free text answers, performing Proof-of-Concept demonstrations on large-scale testbeds and infrastructures is mentioned. This option might have fallen between trials in the lab, measurements on deployed networks, and trials and experiments involving users.

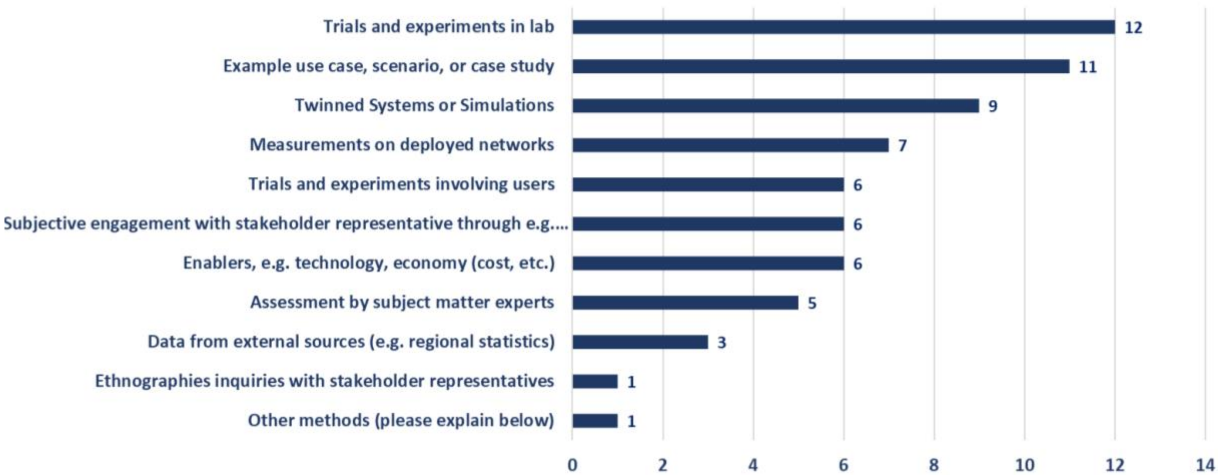


Figure 41: Approach for addressing Key Value Indicators (KVIs) by SNS JU Call 3 projects

Question V3 in Call 1 was significantly different from those in Call 2 and Call 3. In Call 1, V3 enquired about which KVs were addressed. This is now handled in the technical section. Call 2 and Call 3 questions focus on KVI assessment methods. From Call 2 to Call 3, three options were continued: Trials and experiments, Measurements on deployed networks, and Assessment by subject matter experts.

All three options have an increased focus in Call 3 compared to Call 2, if the number of projects in each call is considered. Table 2 shows a comparison between top KVI assessment methods between Call 2 and Call 3.

Table 2: Comparison of top KVI assessment methods between Call 2 and Call 3

	Call 2	Call 3	
Trials and experiments	54.5%	**Lab**	80%
		With users	40%
Measurements on deployed networks	33.3 %		46.7 %
Assessment by subject matter experts	15.2%		33.3 %

Two options were replaced. Instead of asking about Interviews and Focus groups, the question focused on more specific subjects towards stakeholders on Subjective engagements and Ethnographic inquiries. Four new options were introduced: Use cases, scenarios and case studies; the use of Twinned systems or simulators; Technology or economic enablers; and Data from external sources. The inclusion of "Ethnographies inquires with stakeholder representatives" was to check if any projects would address possible national or cultural differences in the value assessments, but only one project expressed plans to use this method.

Key Insights:

- Most projects plan to use trials and experiments to assess KVIs.
- Example use cases, scenarios or case studies are also important methods.

4.2.4 6G Vision

Question V4: *How do you contribute to the 6G Vision in your project?*

Figure 42 shows the received responses to this question. Many projects consider a smooth transition from 5G to 6G of utmost importance. This connects well with the interest of addressing potential shortcomings in 5G, which more than half of the projects (8/15) consider as one of their contributions. Interoperability and service continuity has been addressed in two of the options projects could choose among. This has a high score when combined with new service capabilities, while less focus in the context of beyond connectivity services.

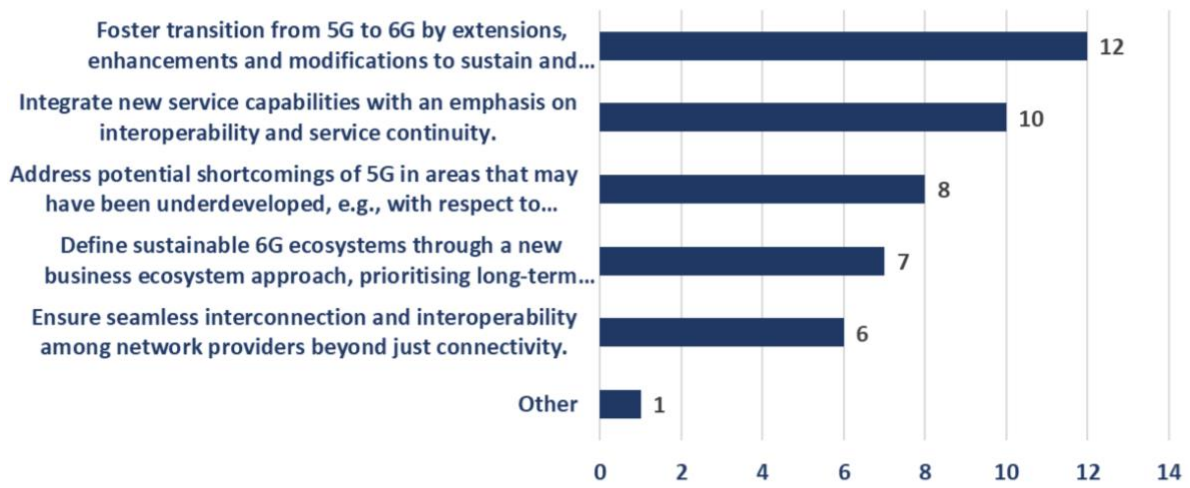


Figure 42: 6G Vision contributions as reported from the Call 3 SNS JU projects

In the free-text boxes, advancing 6G through AI/ML-driven predictive wireless communications; Development and standardisation of novel antenna concepts; and Creation of open, disaggregated network architectures were reported.

The importance of avoiding a disruptive change has become more important for projects and partners, thus the combination of evolving 5G, but also enabling new capabilities is highly rated. The third most important option addresses the experience of 5G not reaching take-up by verticals to the extent it was almost promised in the 5G vision work. Otherwise, sustainability is part of an overarching vision, where long term thinking should be prioritized over short-term interests. Options in Call 3 are different from Call 2, reflecting the development in the objectives of the work programme.

Key Insights:

- Projects are focusing on transition from 5G to sustain and enhance 5G innovations.
- The integration of new service capabilities is also important.

4.2.5 Sustainability

Question V5: *Which UN Sustainable Development Goals (SDGs) will your project contribute to?*

This question remained unchanged for all three surveys so far allowing for a straightforward comparison in Figure 43. The SNS Work Programme explicitly promotes four specific SDGs: Promote sustained, inclusive, and sustainable economic growth (SDG 8), Build resilient infrastructure, promote inclusive and sustainable industrialization (SDG 9), Make cities and human settlements inclusive, safe, resilient, and sustainable (SDG 11), and Climate Action (SDG 13).

Figure 43 reveals that all the four targeted SDGs are top priorities for Call 3 projects. For Call 2 projects in the 2024 survey, SDG 17, Partnerships to achieve the goal caught the fourth place before SDG 13, but this time it is number 6. It is also interesting to note that SDG 5, Gender equality has dropped out of the list, while it was in the middle region for Call 1 and Call 2 projects.

In Call 2, SDG 13, Climate Action, had a temporary drop in support, but is now among the top four again. It is also interesting to note that SDG 12, Responsible Consumption and Production, has maintained position from Call 2 to Call 3.

Key Insights:

- Call 3 projects have all the targeted SNS SDGs as top priorities.
- There is a significant increase in support for SDGs 12, 6, 15 and 17 from Call 1 to Call 3
- There is a significant drop in support for SDG 5, Gender equality from Call 2 to Call 3

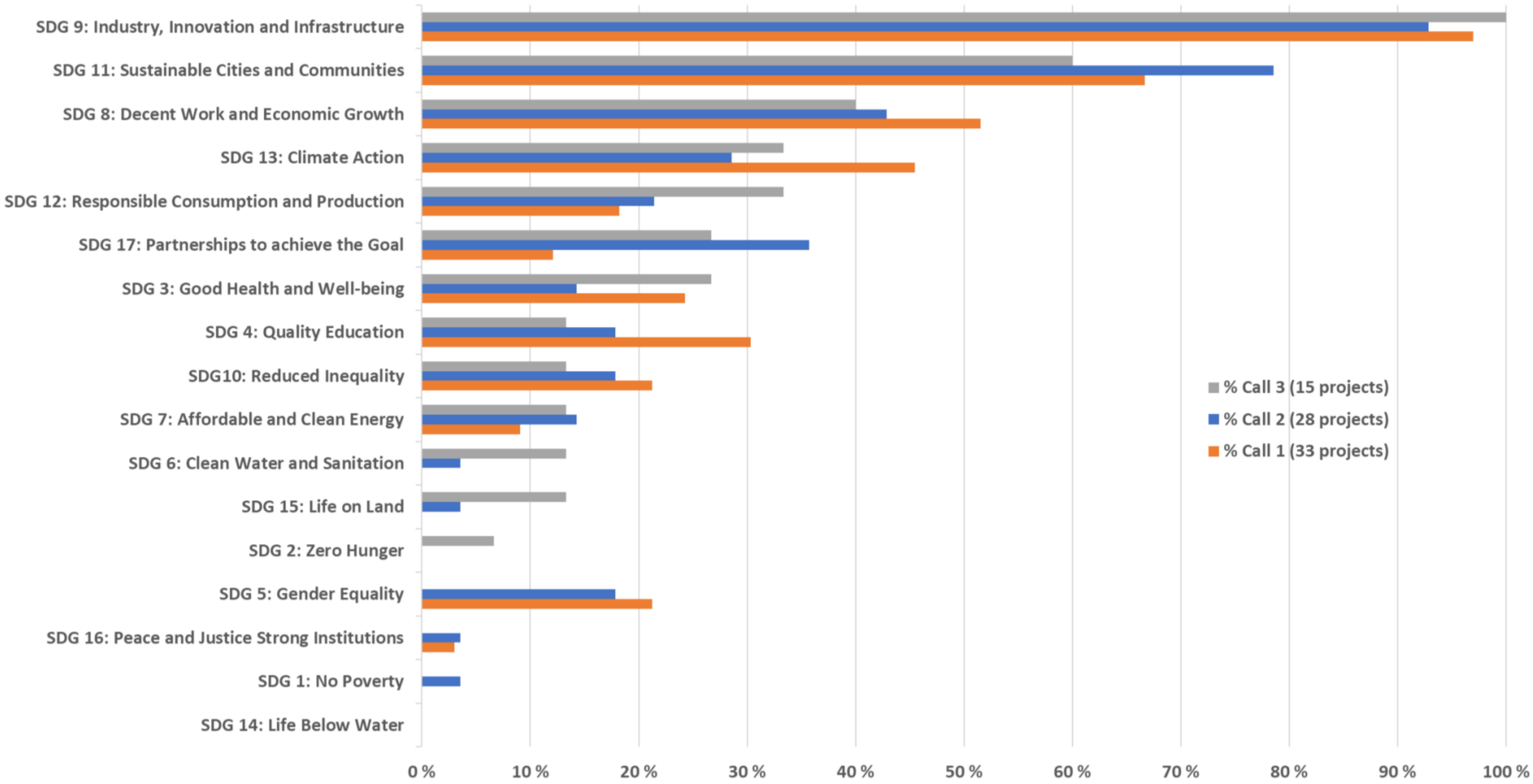


Figure 43: Contributions to UN SDGs by SNS JU Call 1, 2 and 3 projects – compared

4.2.6 Additional comments to the vision aspects

As in previous surveys, the projects were given the opportunity to give open comments to the vision aspects of their work. A few projects took this opportunity, and some comments have been mentioned in previous sections. Besides this, the following comments were given:

- **A "Network of Networks" vision:** "… intelligent, distributed, and modular 6G ecosystem that seamlessly integrates terrestrial and non-terrestrial networks (NTNs), ensuring scalability, resilience, and ultra-low latency."
- **From performance to purpose:** "… the emphasis on semantic and goal-oriented communications … a major paradigm shift from traditional performance-centric networking toward intelligent, efficient, and purposeful communication, which significantly reduces network resource usage, enhances energy efficiency, and contributes to overall sustainability."
- **The importance of data:** "Remove the barrier of 6G dataset scarcity, by building the first comprehensive 6G Dataspace."
- **European sovereignty:** "… addressing European Technology Sovereignty from Silicon and III-V Processes foundries to Networks in a vertical value chain."

Through the surveys from Call 1 to Call 3, questions V1 Societal Challenges and V2 Societal Values have undergone continuous revisions since they experienced some issues (e.g., sustainability addressed in both questions). Looking specifically at the development in projects' focus on these two aspects, it can be observed that sustainability has been top rated by projects in all three calls. For Call 1 and Call 2, sustainability was discussed as a societal value, but in the Call 3 questionnaire, this was moved to the question on societal challenges. Related challenges comprise aspects of energy consumption and efficiency, carbon footprint etc. Sustainability has been rated to have medium to high importance by projects in all three calls.

Security, confidentiality and privacy was rated above medium for Call 1 (value and challenge), This gained slightly lower attention in Call 2, while more important again in Call 3.

Sovereignty has been asked for using the same question asked for all three calls and has been rated medium and stable. The European perspective was not explicitly addressed in the first questionnaire (Call 1) in 2023. For Call 2 and Call 3 this was addressed in the question on challenges referring to European value-based approach, and European impact on standardization, respectively, and received top three ratings both times.

4.3 Market Aspects

This section analyses the projections and expectations regarding the evolution of the 6G market over the next years. The focus is on SNS Call 3 (2024), which is then contextualised by providing a comparison with previous SNS project cohorts. The outcomes will help SNS understand whether the subject and work of the projects are aligned with the expected developments of the market, where the potential challenges lie, and overall, they will feed the SNS vision and strategy.

The market section of the questionnaire comprised nine questions: six were multiple choice and three were free text questions. All multiple-choice questions offered the possibility to elaborate on the response, including the addition of options that were not listed in the pre-defined answers list.

The questions addressed a variety of topics related to the SNS market:

- Key technologies and innovations for 6G.
- Main market trends in the advent of 6G.
- Impact of 6G in different vertical sectors
- Vertical sectors expected to be impacted by 6G.
- Methods used in the validation of business opportunities, including 6G return of investment (RoI).

- Main obstacles to the development of 6G.
- Novel markets for 6G development.
- Key exploitable results (KERs) and Technology Readiness Levels (TRLs).
- SME participation.

The analysis of each multiple-choice question showcases the aggregated responses of the 15 SNS projects for each option, whereas the analysis of the free text questions followed a bottom-up approach. The answers were examined to find commonalities that would enable to group them and subsequently, to establish high-level categories. Likewise, specific insights from the projects that would enrich the data obtained were highlighted.

This mixed approach of qualitative and quantitative questions provides a robust mechanism to identify trends and correlations, as well as to draw valuable conclusions about the key topics addressed. Moreover, a comparison between the responses of Call 1, Call 2 and Call 3 projects is also provided to showcase the evolution in the responses.

4.3.1 Market changes expected with the advent of 6G

The advent of 6G is poised to significantly transform the telecommunications sector. Question M1 is aimed to investigate the views of the Call 3 projects regarding the impact of 6G in the market, the technologies and innovations most anticipated and the vertical sectors that are expected to be affected the most.

Question M1: *Which are the biggest market changes you expect in your domain/market area with the advent of 6G?*

According to Figure 44, **s**ustainability and increased openness and variety of solutions and integration with vertical markets are anticipated to experience the biggest market change with the advent of 6G, according to 67% of the projects.

In general, 6G is defined as a "network of networks", integrating all technologies and vertical industries. Projects provide specific examples such as the integration of hybrid terrestrial and non-terrestrial networks (multi-orbit, multi-link, multi-network), which are showing a great potential to impact the transport sector, i.e., airline digital services, passenger connectivity, operational efficiency improvements, and reduced carbon footprint.

The integration of technologies is closely related to the optimisation of resources, with a project indicating that 6G networks could achieve a 90% energy efficiency improvement compared to 5G. Moreover, the use of eco-friendly hardware materials, AI innovations, renewable energy sources, network architectures that minimize energy consumption without compromising performance or decentralised computing will be also paramount to accomplish sustainability goals.

Interoperability, trustworthiness and market disrupters generating new businesses and models are also expected to undergo a remarkable transformation with the development of 6G. Technologies such as SDN, NFV, AI/ML, edge computing, blockchain, and quantum computing support seamless integration of diverse networks, devices, and protocols, ensuring compatibility and scalability across heterogeneous environments.

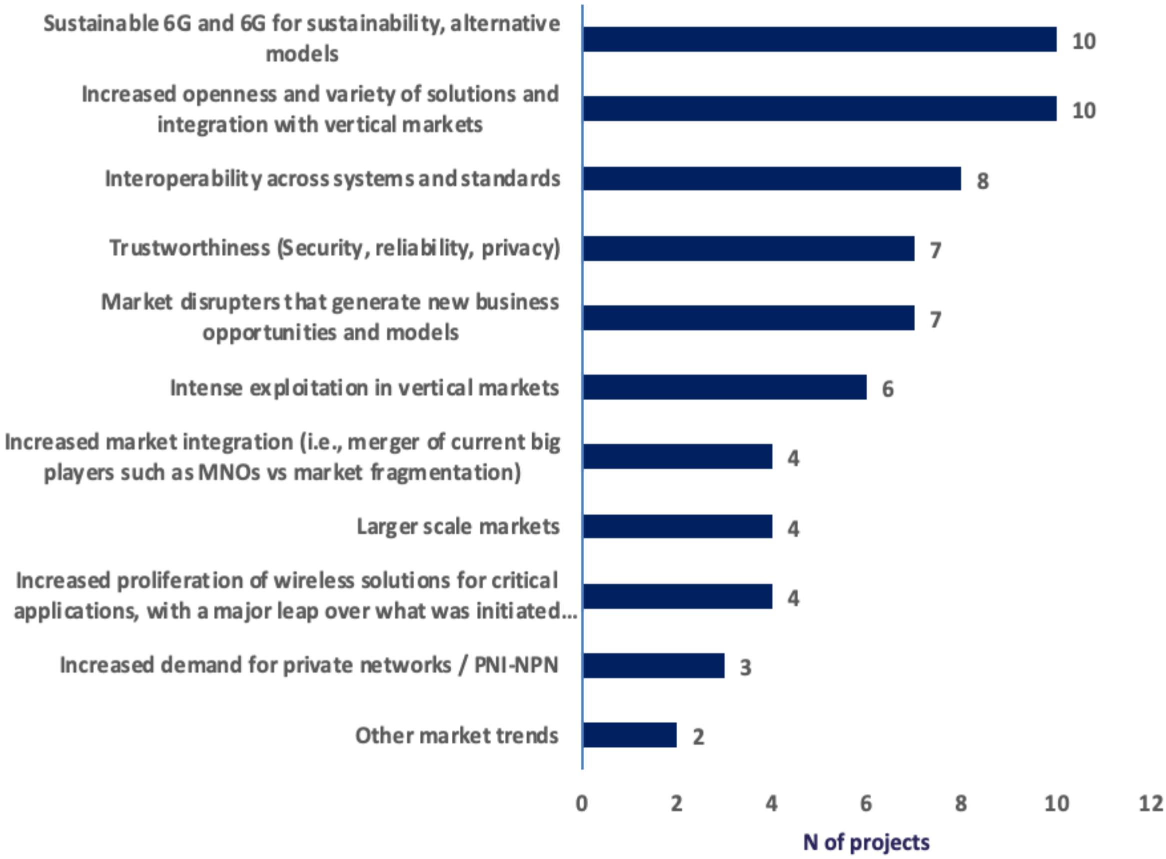


Figure 44: Biggest market changes expected with the advent of 6G

The evolution of 6G networks will require innovations to ensure trustworthiness. In this respect, AI-driven security is emphasised by many projects as a game changer. Some examples include AI for intrusion detection and threat mitigation, AI-powered cyber threat intelligence, and federated learning, which allows devices to collaboratively train AI models preserving data privacy. Zero-trust security frameworks, quantum-resistant cryptography, distributed ledger technology (DLT) and blockchain are also perceived as central to guarantee the trustworthiness of operations, building trust among users and providers.

In terms of market disrupters, O-RAN and open-source technologies are believed to lower entry barriers making it easier for new players and SMEs to compete with established vendors. Standardised interfaces and cloud-native architectures will also contribute to foster competition, accelerating interoperability, reducing fragmentation, and building a unified marketplace for 6G solutions.

Industry-specific solutions, for example supported by intent-based APIs, will be crucial in the creation of new markets and specialised services that address the needs of a wide range of verticals. Advanced radio frequency (RF) technologies and Reconfigurable RF components i.e., fluid antennas and Reconfigurable Intelligent Surfaces (RIS), are expected to impact disrupt traditional hardware markets. Stronger security and trust frameworks, integration of AI/ML-based applications (xApps/dApps), and the massive growth of IoT and connected devices are also highlighted as key areas of change. The cross-industry collaboration is also seen as central for the co-creation of innovative applications and services.

Almost half of the projects foresee an intense exploitation in vertical markets facilitated by 6G. Most projects will carry out demonstrations for real-life use cases. Showcasing the potential of 6G in a concrete manner is expected to prove the technological and economic viability of 6G and to boost its adoption by verticals. Market acceptance will also rely in the joint work with verticals, aligning the technology, innovations and standards with societal, environmental, and economic sustainability goals.

On the contrary, a gradual integration of the market, the development of larger scale markets, and the increased proliferation of wireless solutions for critical applications are only considered relevant by one-third of the projects. The increased demand for private networks is projected to have the least impact overall.

Sustainability and increased openness and variety of solutions and integration with vertical markets are expected to experience the biggest market changes driven by 6G according to both Call 2 and Call 3 projects. Nevertheless, the later has experienced a stark decline in importance with respect to the previous year (see Figure 45).

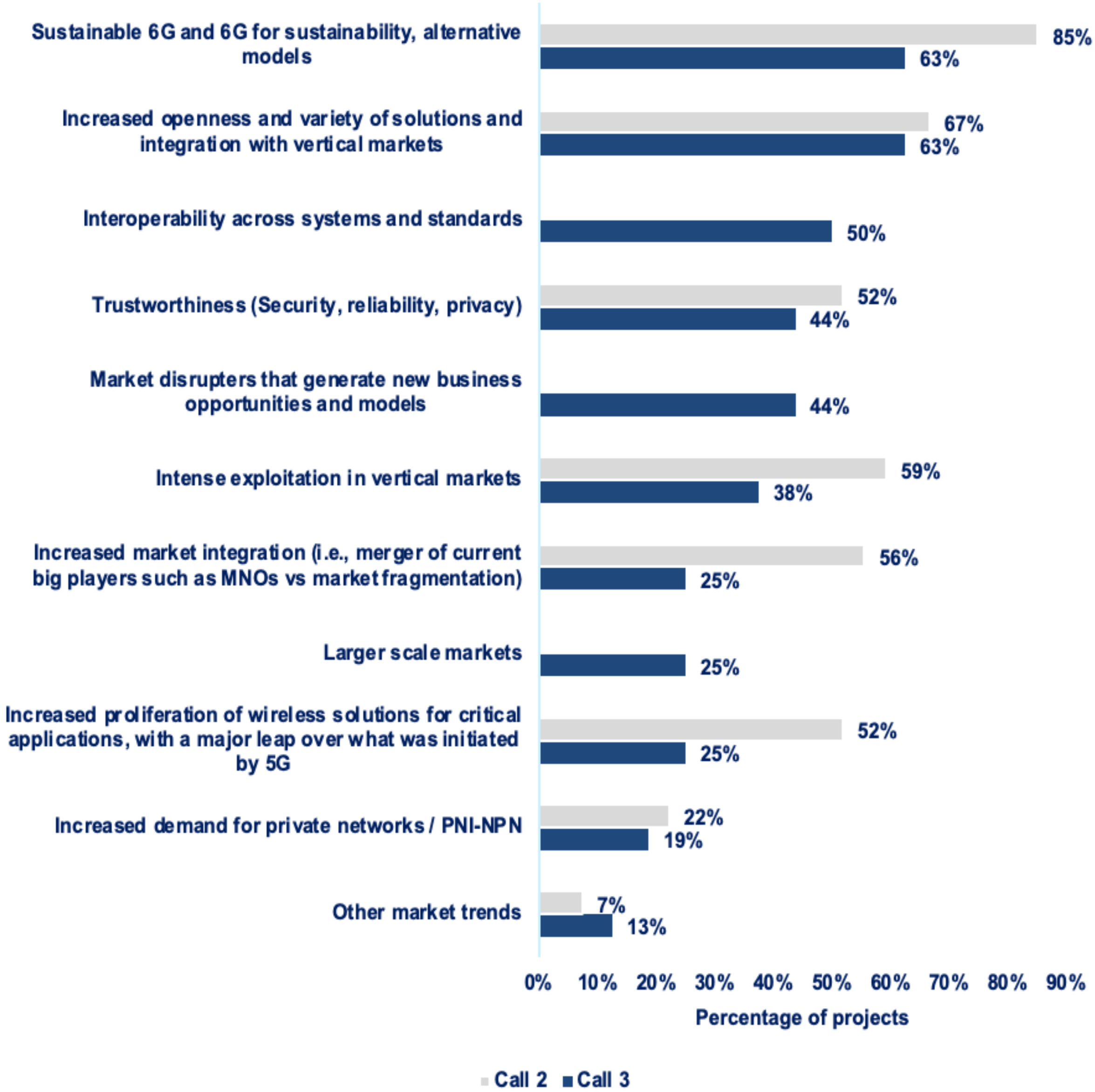


Figure 45: Comparison of responses between Call 2 and Call 3 SNS JU projects

The positive prospects concerning the exploitation in vertical markets, the increased tendency to market integration and the proliferation of wireless solutions for critical applications have also sharply decreased among Call 3 projects compared to Call 2. Inversely, trustworthiness, has gained importance in Call 3. Interoperability across systems and standards is also perceived as relevant. The demand for private networks is seen by both cohorts as the least relevant market when it comes to 6G.

<u>Key insights</u>

- Sustainability, 6G for sustainability and sustainable 6G, as well as increased openness and variety of solutions and integration with vertical markets, are expected to be the most impacted areas by 6G, according to Call 2 and Call 3 projects.
- Interoperability, trustworthiness and market disrupters generating new businesses and models are also anticipated to be remarkably transformed by 6G.
- Private networks/PNI-NPN are considered to have the least impact overall.

Question M2: *Which of the following technologies/innovations do you expect to play an important role in the telecommunications market in the coming years?*

All Call 3 projects anticipate that AI-based solutions constitute the main driver in future telecommunications market, as shown in Figure 46. Trustworthiness and Edge Cloud Continuum/Multi-Access Edge Computing (MEC) are tied in the second place, with 80% of the projects indicating these two technologies will be key enablers.

Most projects also agree that open and disaggregated solutions, as well as increased technical integration will also play a significant role. Other noteworthy innovations and technologies include increased technical integration and dynamic spectrum sharing. On the other hand, automation for lowered technological barriers is considered the least relevant innovation. Additional innovations and technologies noted include semantic and goal-oriented communications and advanced RF technologies.

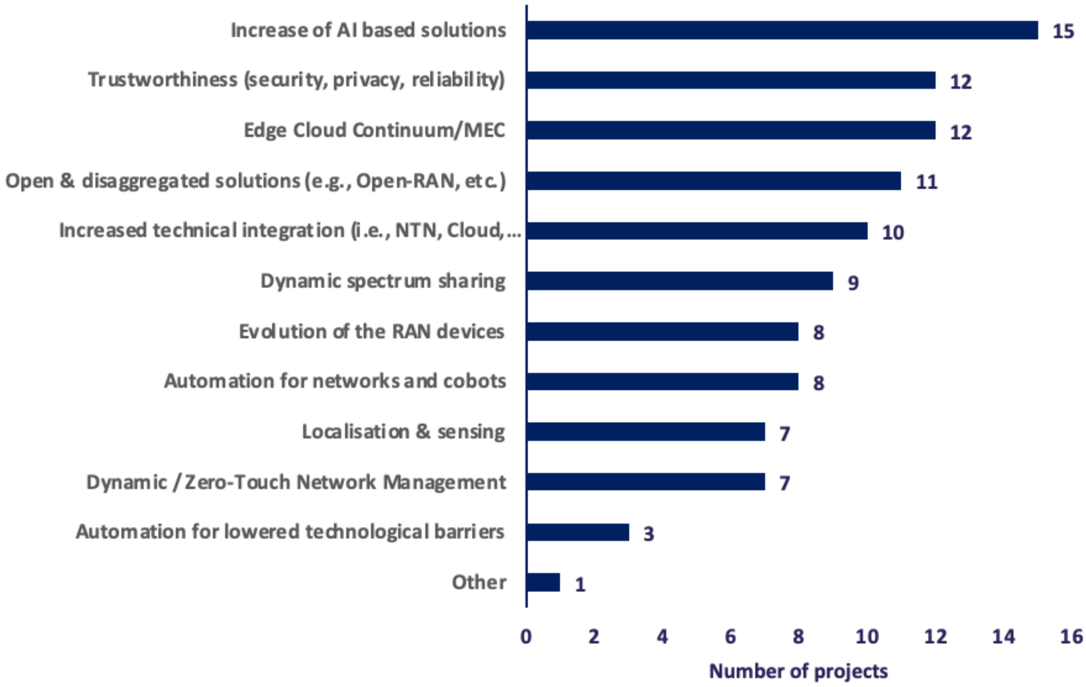


Figure 46: Technologies/innovations expected to play a major role in the telecoms market

Figure 47 depicts a comparison across calls regarding the technologies and innovations expected to disrupt the telecommunications market. Most projects across the three calls agree that AI-based solutions are critical to deliver more high-level and efficient services in telecommunications markets. Trustworthiness and edge cloud are predicted to be significant disruptors. Likewise, a boost in the relevance of the technical integration can be observed amongst Call 3 projects compared to previous years. Although to a lesser extent, this is also true for dynamic spectrum sharing and RAN devices.

The prominence of location and sensing and dynamic/zero-touch network management has declined compared to previous calls. While the latter dwindled rather steadily over time, the difference in the opinions of Call 3 and Call 2 projects regarding localisation and sensing is stark. However, both remain important themes in the telecommunications landscape, according to 44% of the projects in Call 3.

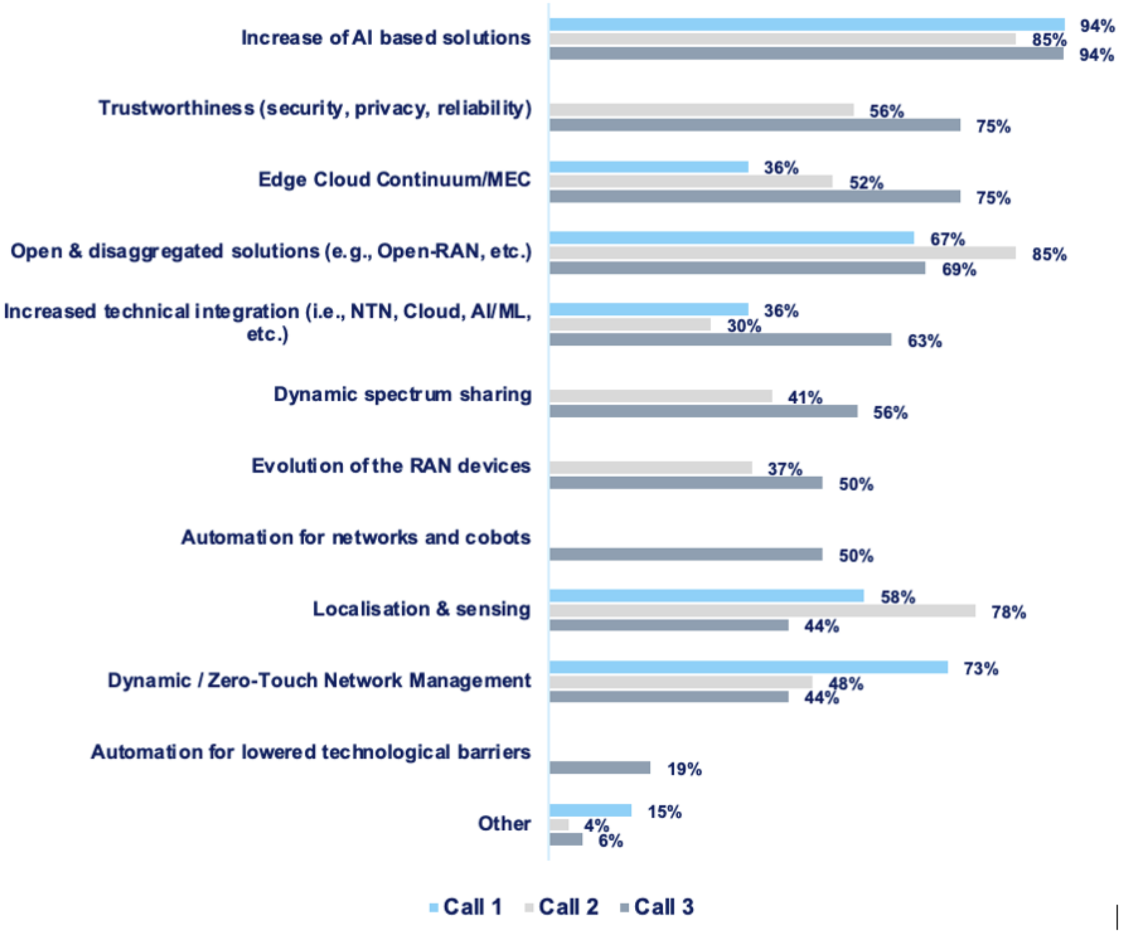


Figure 47: Technologies and innovations in the telco market, comparison across calls

Key insights

- Most projects across calls agree that AI-based solutions are key in the future of telecommunications.
- Trustworthiness and Edge Cloud Continuum (MEC) have gained significant importance over the last years, with 75% of Call 3 projects expecting them to be central in the telecommunications market.
- Localisation and Sensing technologies appear to be less central, after peaking in 2024. The domain remains remarkable though.

Question M3: *Which vertical sectors do you expect to be affected the most with the advent of 6G?*[8]

Industry 4.0/Manufacturing is predicted to be the vertical most impacted by the advent of 6G, according to nearly 75% of the Call 3 projects (Figure 48). The opinions are very divided with regards to the other verticals in question. Still, Automotive, followed closely by Transport & Logistics and Healthcare, are anticipated to be amongst the most affected fields.

Interestingly, energy and smart cities are rather low in the ranking despite the emphasis in sustainability and the various ways in which 6G could transform essential elements of smart cities, improving the resilience, quality and sustainability of the services, from transport to public safety. Agriculture & Farming is the sector in which 6G is estimated to have the least impact. No project has noted Construction nor Tourism and Culture.

[8] It is important to note that projects were limited to three responses. Results must be considered within this context.

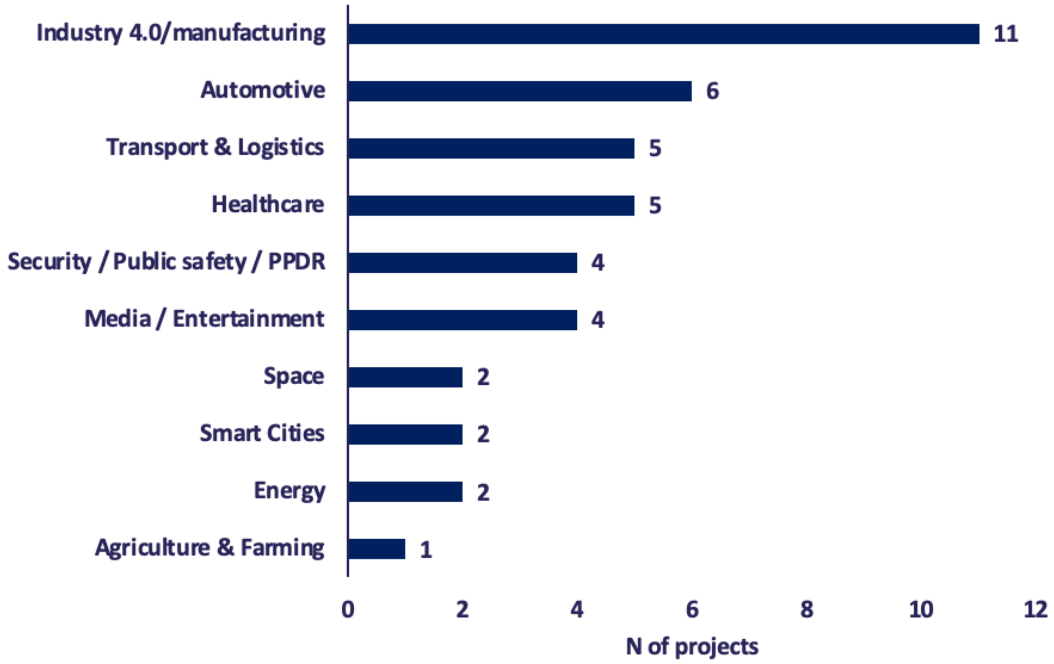


Figure 48: Vertical sectors anticipated to be most impacted by 6G

From Figure 49, where Calls 1, 2 and 3 are compared, Industry 4.0/Manufacturing is expected to be the vertical most profoundly affected by the emergence of 6G. This reflects a strong need for industrial digitalisation and the relevance 6G will have in diverse technologies such as automation or robotics. Whilst remaining at the forefront, the estimated impact of 6G on automotive and transport and logistics declined significantly when compared to Call 1. A minor increase (1%) was registered from Call 2 to Call 3 in both sectors.

There is a growing consensus on the impact of 6G in security, public safety and PPDR. For instance, public and mission-critical services is seen as one of the novel markets driven by 6G. The predictions concerning healthcare have remained stable. Space seems to have gained relevance amongst the sectors to be transformed by 6G. The recent MoU with ESA may strengthen this scenario.

The potential impact of 6G on Media/XR, which in Call 1 rivalled with that of Industry/Manufacturing, continues to decline. This could be partially explained by the media-specific projects in Call 1. In later calls, the interest focuses on immersive technologies and metaverse applications. However, the biggest change from Call 2 to Call 3 is on smart cities, which only 13% of the later projects consider to be among the most impacted sectors. Ecology, Education, Tourism & Culture and Agriculture & Farming are the verticals anticipated to be less affected by 6G. None of the projects across calls indicated any impact of 6G in Construction. The lack of projects specifically addressing these topics could account for these results.

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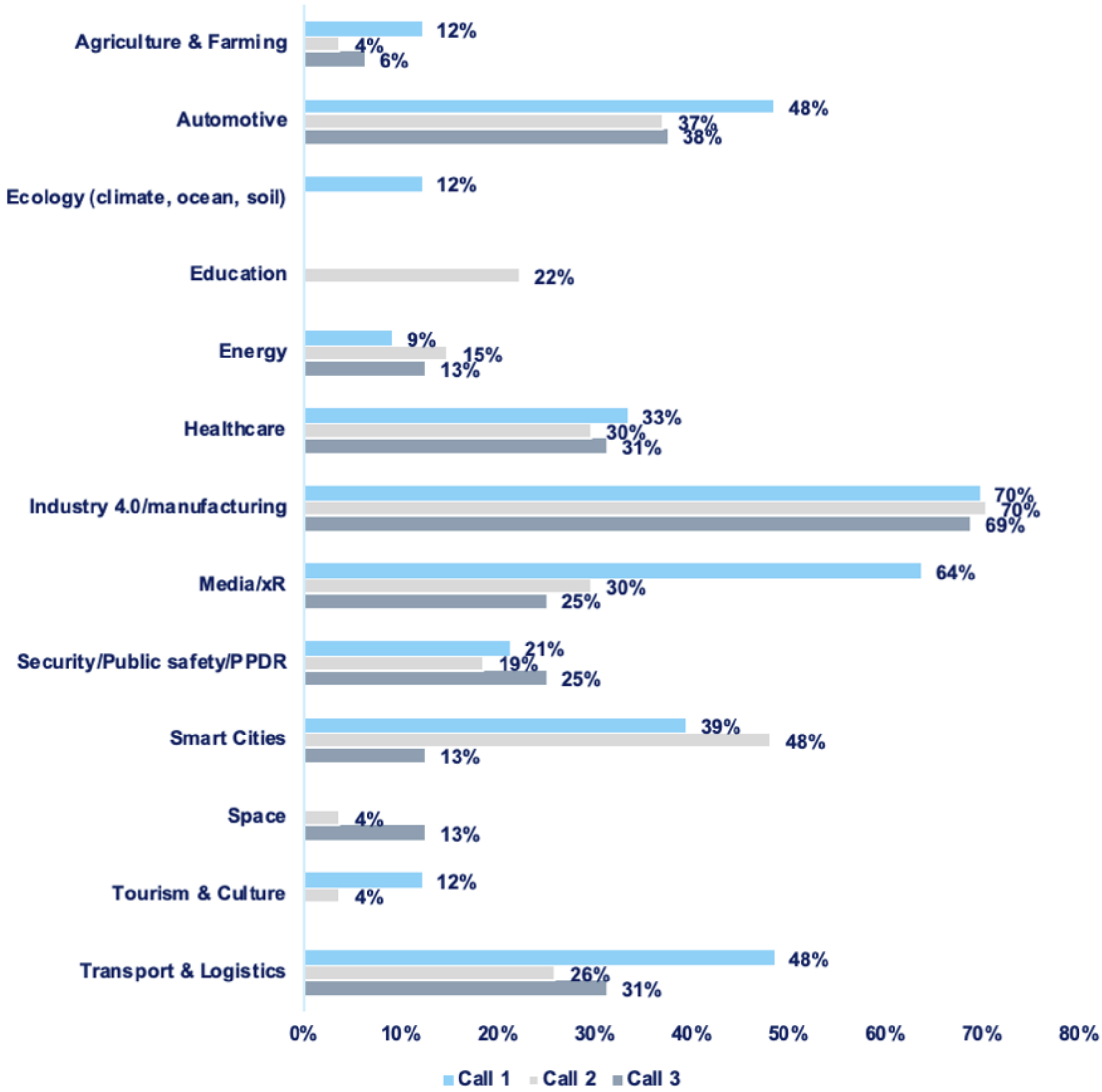

Figure 49: Vertical sectors anticipated to be most impacted by 6G, comparison across calls.

Key insights

- Industry 4.0/Manufacturing is expected to be the vertical sector most impacted by the advent of 6G.
- Automotive and Transports & Logistics are also anticipated to be highly influenced by 6G. Although to a lesser extent, the Healthcare vertical sector is also forecasted to experience an important transformation.
- There is a growing consensus on the impact of 6G in security, public safety and PPDR.
- Media/Entertainment is expected to undergo profound changes even with the decline observed over the last three years.
- Ecology, Education, and Tourism & Culture are the verticals anticipated to be less affected by 6G. No project has indicated that the Construction sector would be impacted by 6G.

4.3.2 Validation of business opportunities and commercial viability

Validating business opportunities and assessing the commercial viability of 6G is a top priority as the next-generation networks move closer to real-world deployment. Beyond technical breakthroughs, it is critical to analyse whether emerging 6G capabilities translate into sustainable market value. This is a complex exercise that involves an in-depth understanding of the market needs, new business models, adoption barriers and much more.

This section explores the methods and methodologies used by SNS projects to validate business opportunities in vertical sectors and assess the commercial viability of 6G.

Question M4: *How do you validate business opportunities in vertical sectors?*

Most SNS projects (87%) validate their business opportunities in vertical sectors by working with use case owners. Using the value proposition canvas is the second preferred method (60%) followed by the validation methods i.e., the five-step business modelling framework, suggested by 6G-IA (47%) (Figure 50). The development of hypotheses about potential business models for the technology being developed by the project or about vertical needs which may require technology in question are less common. Only one project indicated the use of open call mechanisms to bring external stakeholders to validate business opportunities in vertical sectors. It is important to note that the use of open calls is only viable for those projects offering cascade funding, which in Call 3 is only one.

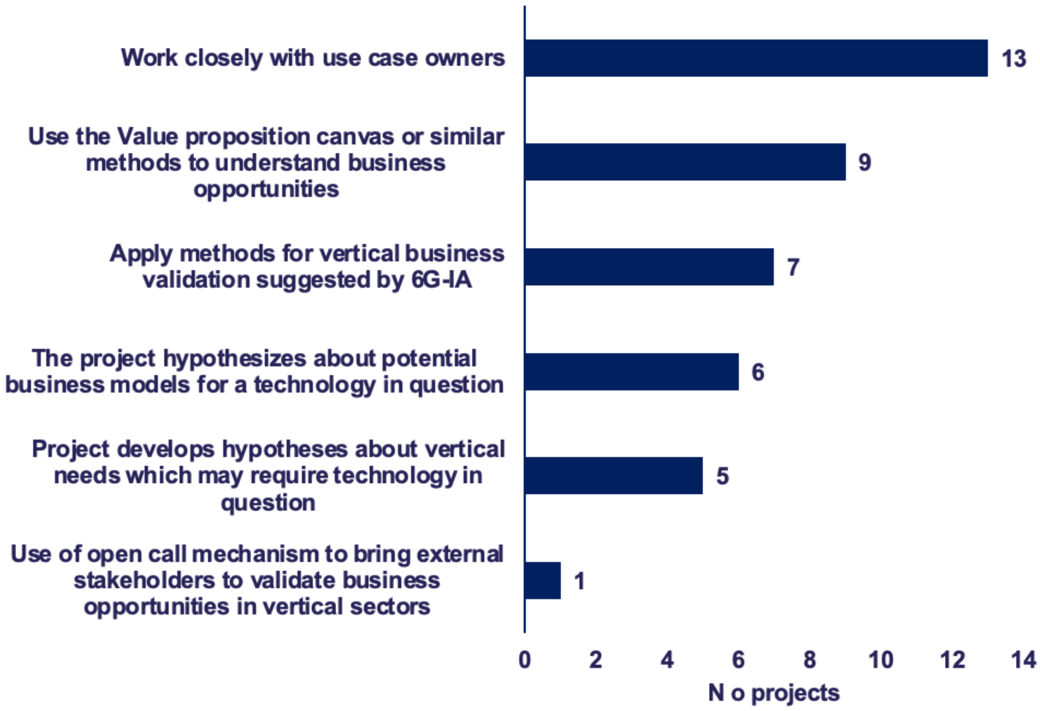

Figure 50: Validation of business opportunities in vertical sectors according to Call 3 projects.

Overall, in the last three SNS calls, as depicted in Figure 51, the development of hypotheses about vertical needs that may require the specific technology being developed as well as the work with use case owners are the preferred methods to validate business opportunities, with 64% of all projects choosing it on average.

The latter, alongside the development of hypotheses about vertical needs, are the two methods that have experienced the biggest changes in opinion across the different SNS calls. The views concerning other methods have remained rather stable.

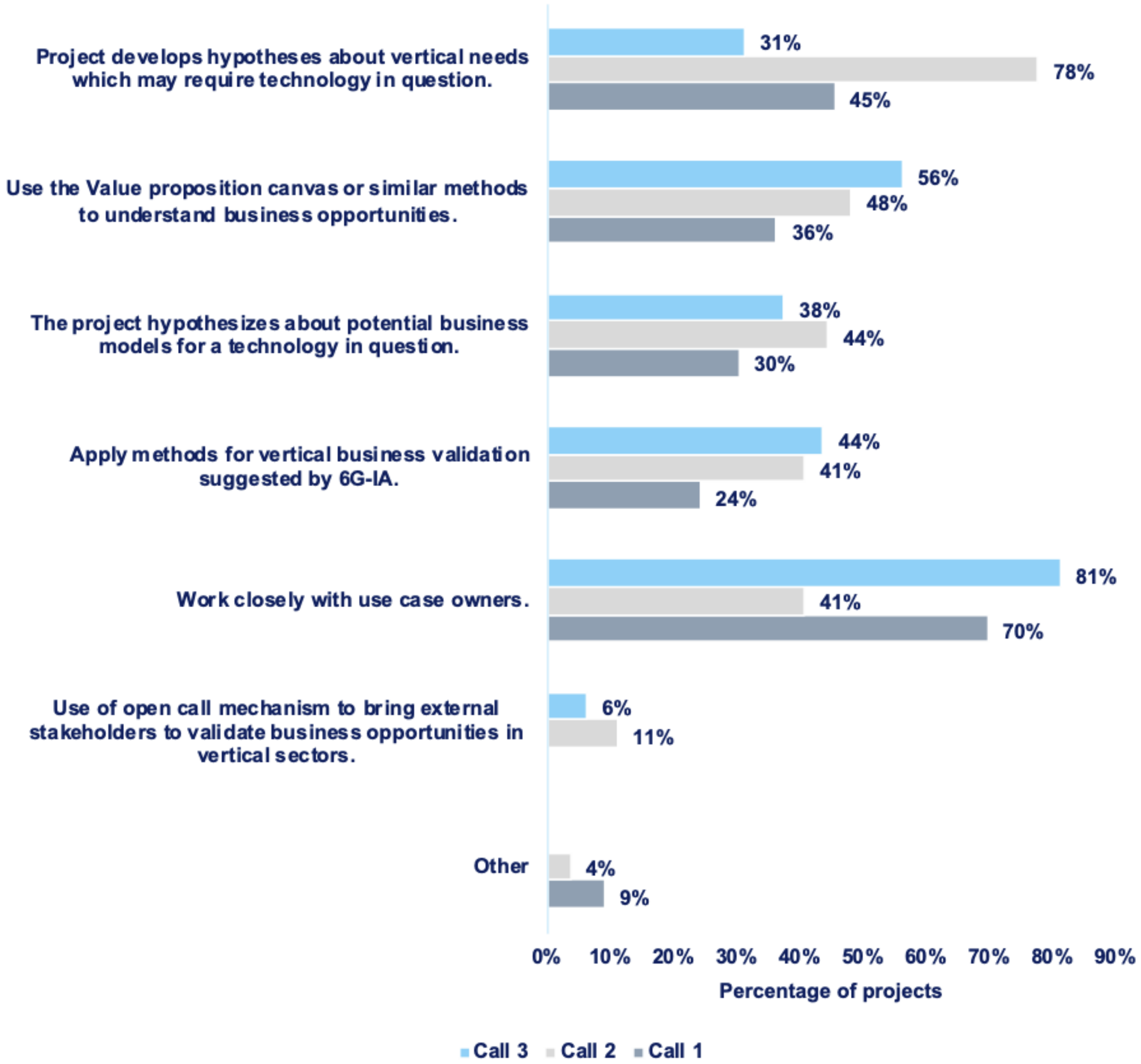

Figure 51: Validation of business opportunities in vertical sectors, comparison across calls.

Key insights

- Working with use case owners is the overall preferred option to validate business opportunities, with 64% of all projects choosing it on average.
- The development of hypothesis about verticals in need of a certain technology is ranked second.
- The value proposition canvas and the methods suggested by 6G-IA are used by around 35% of projects on average.
- The use of open call mechanisms is the least used method, which can be explained by the projects' limitation to access these.

Question M5: *How do you assess commercial viability (Return of Investment, RoI) from investing in and deploying 6G?*

Technoeconomic analysis is the most used method by Call 3 projects to assess the commercial viability of 6G. Yet only 53% of these indicated to have used it. Responses largely vary across the other options (Figure 52).

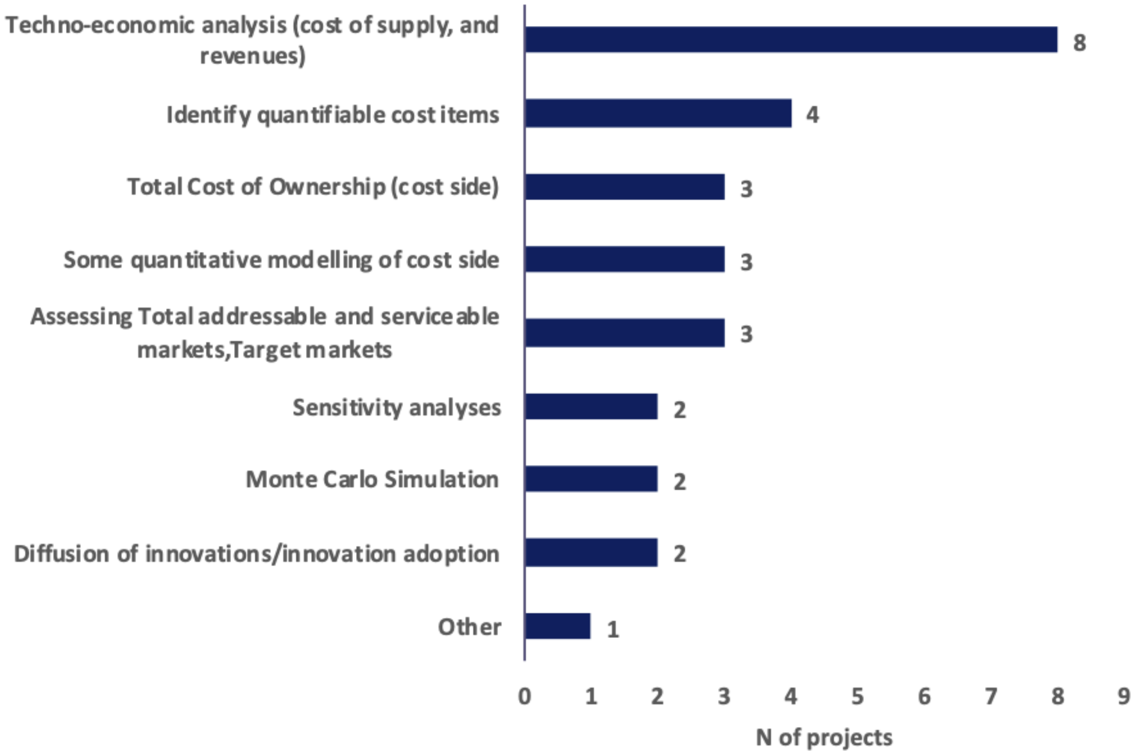

Figure 52: Preferred methods for assessing 6G RoI

As shown in Figure 53, which compares the use of different business validation methods across Call 2 and Call 3, the technoeconomic analysis is the preferred method to evaluate the RoI from investing in and rolling out 6G. An average of 66% of the projects surveyed across the three calls chose it. The assessment of target markets ranks second, but it was mainly used by Call 2 projects. An average of 24% projects assess commercial viability by identifying quantifiable costs items. The use of this method has remained rather stable over the years.

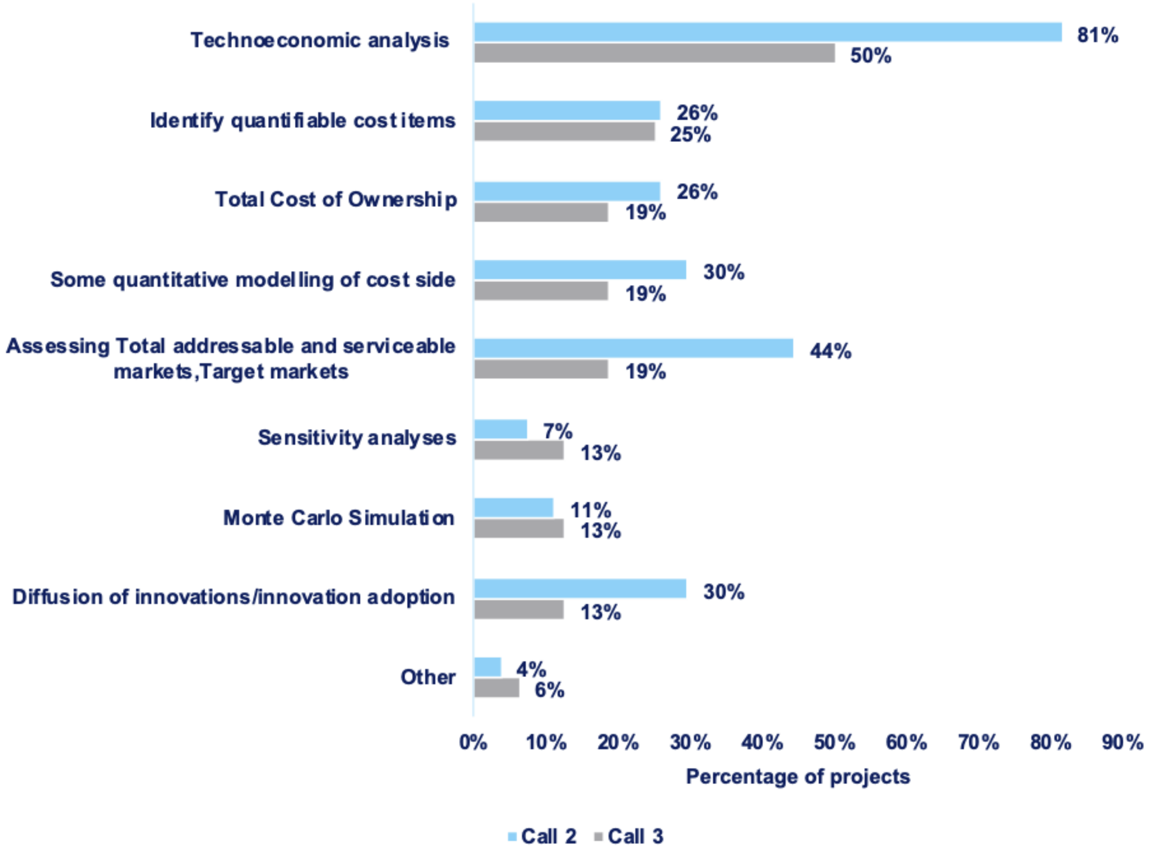

Figure 53: Preferred methods for assessing 6G RoI, comparison across calls.

On the other hand, the analysis of the commercial viability through the assessment of target markets and the diffusion and adoption of innovations has decreased notably from Call 2 to Call 3. The Monte Carlo Simulation and Sensitivity Analysis methods, both amongst the least used, have nonetheless experienced a minor increase, with 13% of the projects in Call 3 employing them.

Key insights

- Technoeconomic analysis is the preferred method to assess the commercial viability of 6G.
- The use of assessment of total addressable and serviceable markets and the diffusion of innovations and innovation adoption methods have declined sharply from Call 2 to Call 3.
- The Monte Carlo Simulation and Sensitivity Analysis methods are the less used methods.

4.3.3 Major obstacles to the deployment of 6G

Understanding the major obstacles to the deployment of 6G is crucial to shaping an effective roadmap for its development. The highly anticipated transformation of the digital landscape with the advent of 6G brings technical, economic, regulatory, environmental and societal challenges.

The present section examines the views of the SNS projects on these barriers. This will help inform policymaking and research priorities to proactively tackle any potential constrain, paving the way for a smooth transition to 6G.

Question M6: *What do you consider to be the greatest obstacle for the deployment of 6G networks?*

Figure 54 shows that there is a wide range of perceptions amongst Call 3 projects regarding the main obstacles for the deployment of 6G networks. The main pressing issues are deemed to be the lack of demand for unique 6G services and the spectrum availability, according to 53% of the projects. Deployment costs and trustworthiness are also considered significant hurdles, in view of 47% and 40% of the projects, respectively.

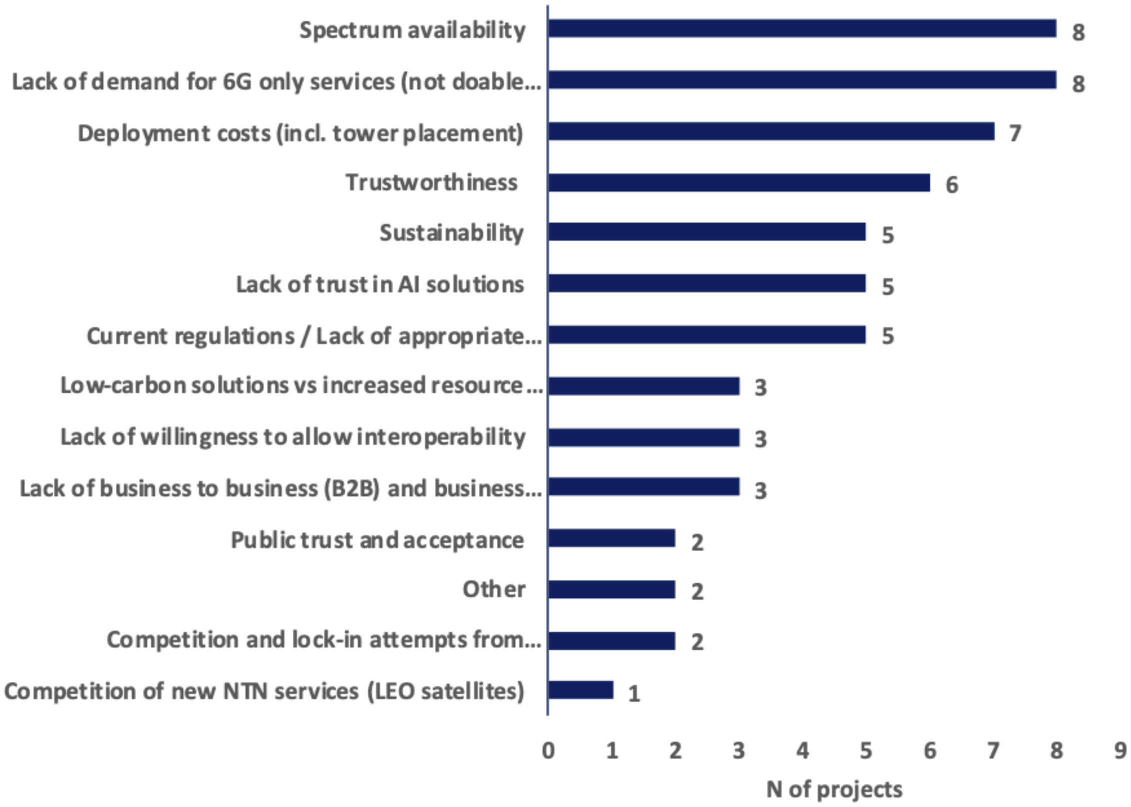

Figure 54. Greatest obstacles to 6G deployment

Sustainability, lack of trust in AI solutions and the lack of appropriate regulations are middle-level concerns for 33% of the projects. On the contrary, competition of new NTN services alongside public trust and acceptance and competition and lock-in attempts from incumbents appear to be the less threatening issues to 6G deployment.

Figure 55 showcases the evolution of the SNS projects views on the central obstacles to 6G deployment through Calls 1, 2 and 3. The lack of demand for unique 6G services and, to a lesser extent the deployment costs, are considered the most significant obstacles to the roll out of 6G (Views on both subjects have remained rather stable across all SNS calls, although the perceived cost-related barriers have eased over the years.

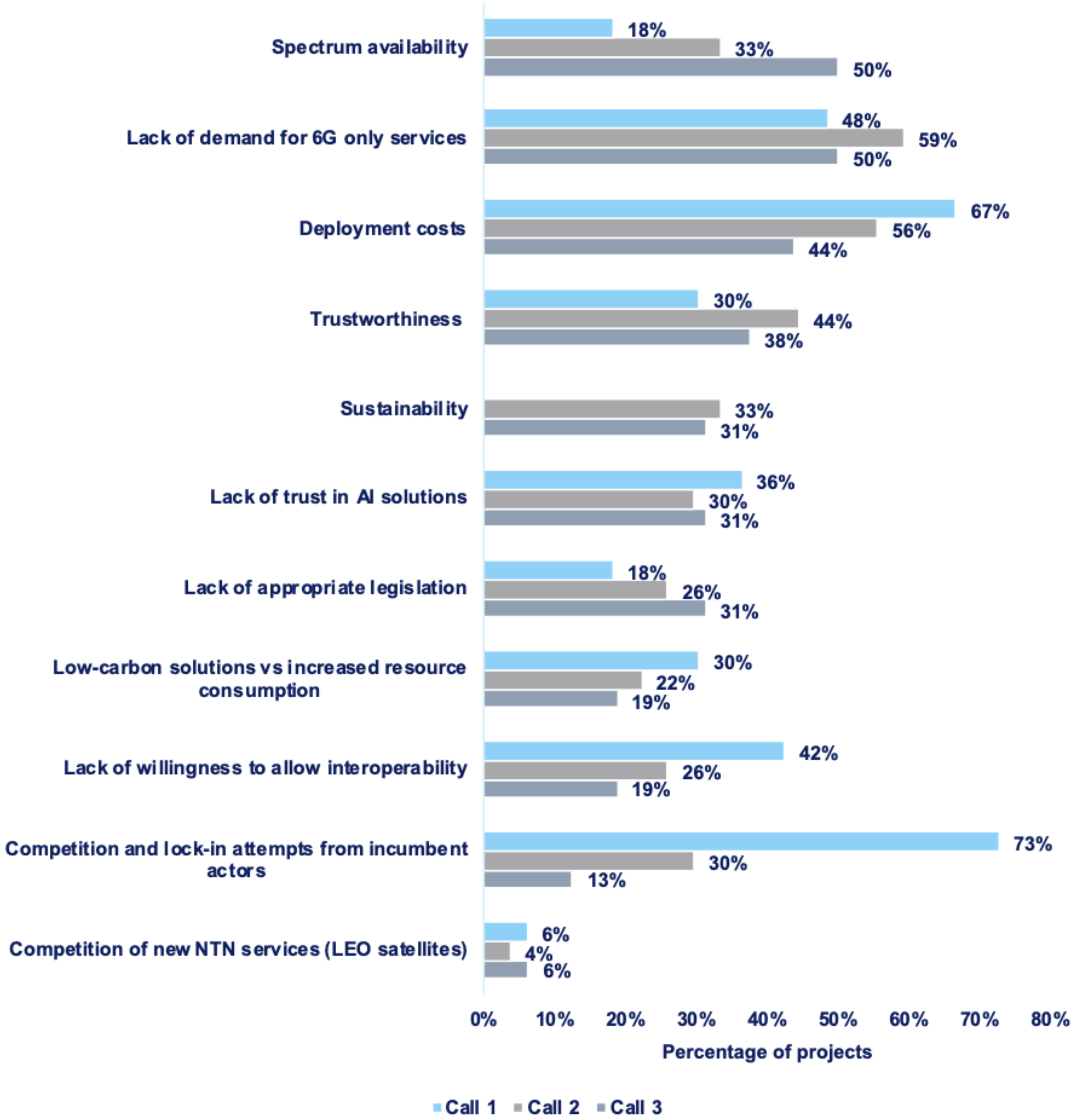

Figure 55: Central obstacles to 6G deployment, comparison across calls.

Trustworthiness, sustainability and lack of trust in AI solutions are deemed moderate concerns. Opinions in this respect fluctuate between 30% and 45% across the three calls. However, the absence of adequate regulation and especially spectrum availability, are increasingly perceived as a hurdle to 6G development. While in Call 1 only 18% of the projects viewed spectrum availability as an obstacle, this figure raised to 33% in Call 2 and 50% in Call 3.

Interoperability concerns have notably decreased over time, from 42% in Call 1 to 26% in Call 2 and 19% in Call 3. It also can be observed that the perceptions on the balance between low-carbon solutions and increased resource consumption have improved.

The assessment of competition and lock-in attempts from incumbents has experienced the most substantial change. In Call 1, 73% of the projects indicated this to be an impediment to 6G, whereas only 13% of the projects in Call 3 believe so. Competition of new NTN services consistently ranks at the bottom of the list of obstacles.

Other obstacles include the complexity and cost of migrating legacy network infrastructures to open, interoperable, and AI-driven 6G solutions, ensuring seamless interoperability and standardisation at global scale and the depletion of raw materials.

Key insights:

- Lack of demand for unique 6G services is deemed a significant obstacle across different calls.
- Trustworthiness, sustainability and lack of trust in AI are emphasised as some of the main issues to overcome for the implementation of 6G.
- Concerns regarding spectrum availability have risen notably. Similarly, the current regulation/lack of appropriate legislation is also becoming a pressing issue.
- The views on competition and lock-in attempts from incumbents have changed substantially, from ranking amongst the greatest obstacles in 2022 to be a rather minor concern in 2024. Likewise, opinions on interoperability have improved.

4.3.4 Novel markets enabled by 6G

The transformative nature of 6G is foreseen to unlock entirely new markets, creating opportunities for services and applications that are not feasible today. This will foster cross-sector collaboration and socioeconomic growth. This section analyses the new markets enabled by 6G as foreseen by SNS projects.

Question M7: *Do you believe enhancing 5G towards 6G can mobilise the ecosystem forward? If yes, which novel market sector(s) do you estimate that 6G may enable?*

There is a strong consensus around the transformative potential of 6G to revolutionise the digital landscape, integrating sectors and technologies that will unlock novel markets and drive socioeconomic progress. In line with previous calls, Call 3 projects foresee AI, ultra-reliable, low-latency connectivity, and IoT as the core technological enablers. Likewise, immersive and interactive digital services, AI-native and autonomous industries, and sustainable networks are anticipated to become key novel market segments. In addition, Call 3 projects emphasise the role of quantum communication and security as enablers while public services emerge as a dominant market sector. Embedding AI at all network layers is also expected to generate new business models such as Network-as-a-Service (NaaS) & AI as a Service (AIaaS).

Achieving truly immersive communication experiences is one of the most promising prospects of 6G-enabled technologies, including holographic communication, multi-sensory extended reality (XR), and metaverse applications. The “Internet of Senses”, incorporating haptic feedback, will merge the physical and digital worlds, blending the senses of touch, smell and taste with those of sight and sound. This transformation will redefine vertical sectors such as entertainment, education, and remote work, by creating more interactive, engaging, and seamless experiences for users.

In the industrial sector, 6G will drive the rise of AI-native and autonomous systems. Smart factories, intelligent energy grids, and dynamic supply chains will highly benefit from ultra-reliable, low-latency networks that support real-time decision-making and predictive maintenance. Strides on collaborative robots, with enhanced precision and coordination, as well as the integration of digital twins, enabling continuous monitoring and boosting efficiency, are also highlighted.

Public services and mission-critical services are also projected to experience a significant transformation. Telemedicine and remote surgery will become more reliable. Smart cities will leverage 6G to create more sustainable and responsive urban environments, with intelligent traffic management, waste reduction, and environmental monitoring. Emergency response systems will also see remarkable improvements, with enhanced coordination during crises.

New business models and economic opportunities are also expected to arise from 6G. NaaS will enable on-demand AI, compute, and network resources, creating an AI-powered cloud economy, whilst AIaaS will provide AI-driven services for both business-to-business (B2B) and business-to-costumer (B2C), enabling context-aware applications. The rise of ambient and zero-energy IoT is also widely anticipated, “*making every “thing” smart, connected and self-powered”*. This will pave the way for sustainable smart cities, better retail experiences, and personalised healthcare solutions, including monitoring and treatment.

In terms of security, 6G is expected to introduce zero-trust security, AI-driven threat intelligence, quantum-safe encryption, and blockchain-based trust mechanisms. Lastly, 6G is predicted to foster green ICT and sustainability, focusing on AI-driven energy efficiency and environmentally sustainable communication infrastructures.

Overall, 6G is poised to fundamentally transform industries, public services and everyday life, fostering cross-sector innovation, economic growth, and sustainability. Nevertheless, projects also stress the need for simpler and more efficient standards for 6G to ensure affordable, timely deployment and broad adoption. For instance, finding solutions that address the requirements of a large variety of verticals instead of large numbers of tailored ones would avoid the complexity and end-user costs seen in 5G.

Key insights

- 6G is expected to be a catalyst that will revolutionise the digital landscape, transforming industries, public services, and citizen's daily lives, creating new opportunities and driving socioeconomic progress.
- The integration of 6G and AI is considered the central driving force behind the transformation of a wide range of verticals, enabling intelligent network management, enhanced user experiences, real-time decision-making and monitoring, predictability, and optimisation of resources supporting sustainability, among other factors.
- Immersive communication, AI-native automation and industry 4.0, and public and mission-critical services are seen as the most promising market sectors.
- 6G will introduce new business models such as NaaS and AIaaS. It will also foster sustainability, with AI-driven energy efficiency and zero-energy IoT devices, among others.
- Developing simpler, cost-efficient standards will be one of the key factors determining the success of 6G. Balancing innovation with pragmatic, affordable deployment is of foremost importance.

4.3.5 Key Exploitable Results and Technology Readiness Levels

Analysing the Key Exploitable results (KERs) and the technology TRLs to be obtained/reached by the SNS projects is essential to assess the maturity of the results, highlighting those that can be further developed. This ensures that research is used to produce concrete innovations closer to the market. Moreover, the project outcomes constitute an important source of evidence in support of 6G and its applications.

Question M8: *What are the Key Exploitable Results (KERs) expected to be delivered by your project? At which Technology Readiness Levels (TRLs) is each of them expected to be delivered?*

The KERs expected to be delivered by Call 3 projects are very diverse. Nonetheless, a general categorisation can be established according to the main topics tackled, as presented in Table 3. Overall, the categorisation of the KERs remains largely aligned with that of previous calls. The main differences are the rise in microelectronics and hardware-related KERs, likely due to the topics covered in Call 3, while those addressing standards have declined. The focus on trustworthiness and communication and sensing is remarkably stronger among Call 3 projects.

Table 3: Main KERs targeted by Call 3 projects.

CATEGORY	KERs
AI & ML	• AI/ML for enhanced device performance • AI-native 6G architecture: AI-native 6G air interface design, AI-native 6G RAN architecture • Solutions for optimised RAN and Core • AI/ML-enabled cloud-edge continuum • MLOps framework, RLOps environments, Hyperparameter Optimisation (HPO) as a Service, deployment of AI/ML models via MLOps. • Federated learning (FL), context-aware FL protocols

Advanced Network Management	• Intent-Based APIs for automated network orchestration • Compute-as-a-Service orchestration • Automated network orchestration • Zero-touch (ZT) network/service orchestration • MP6R Controller for new connectivity paradigms • Edge/Cloud computation orchestration
Trustworthiness	• Extended Endpoint Security: DLT, x/rApps • Identity and access Management: ZT access control, ZT policy enforcement gateways, ZT enabled SDP controllers • Security management platforms: collaborative XDR cluster managers, O-cloud security platform, federated SIEM. • Quantum-safe tools: DLT-based O-RAN forensics, cooperative PHY quantum safe security, post-quantum cryptography (PQC) algorithms • Threat intelligence and cyberdefence: honeypot managers, attack modelling repositories, CTI management engines, intrusion response systems, FL-ready Intrusion Detection System (IDS) engines
Communication and Sensing	• 6G-RAN system integrating sensing capabilities • Multiband ISAC, AI-enhanced ISAC receivers, ISAC-enabled RIS • Distributed MIMO • OTFS modulation-based sensing • Semantic communications solutions
Energy efficiency	• Energy Efficiency as a Service • RedCap-based energy optimisation • O-RAN energy reduction controllers • Energy harvesting solutions, predictive harvesting and energy-aware functionality placement, AI-based digital twins for sustainability. • Federated protocols for energy balancing,
Microelectronics and Hardware	• Microelectronics processes: SiGe, InP, 3D Integration • Network as Sensor • Q/V Band NTN • Private 6G networks • Reconfigurable antennas, D-Band and H-Band X-haul links
Others	• Data space toolkits • Interoperability interfaces and frameworks • Perception knowledge generation, privacy-perception exposure • Multi-sensor raw data fusion

With respect to TRLs, most KERs sit on the mid-range (TRL4-6), reflecting they are in the validation and demonstration stages, as shown in Figure 56 and Figure 57. KERs projected to reach TRL3 and TRL7 represent 8% and 5% of the total, respectively. Generally speaking, security, sustainability and ISAC-related KERs are expected to reach TRL4, for example, end-to-end security plane, sustainable network frameworks, energy-aware protocols, multi-band ISAC, or distributed MIMO. At TRL5, KERs mainly address deterministic communications, while those sitting at TRL6 target predictive intelligence, advanced orchestration and vertical integration, among others.

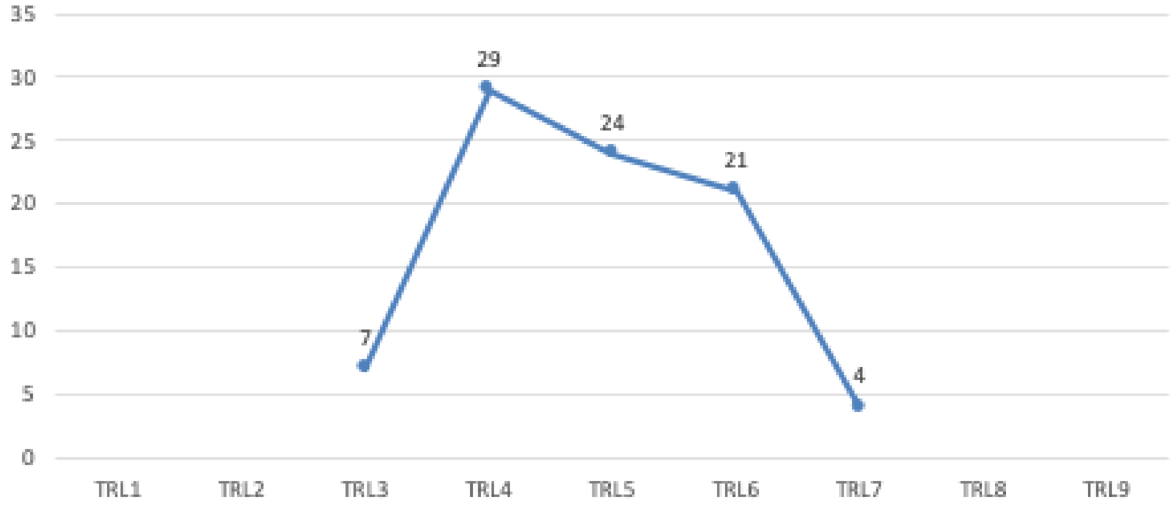

Figure 56: KERs and corresponding TRLs as reported by Call 3 projects.

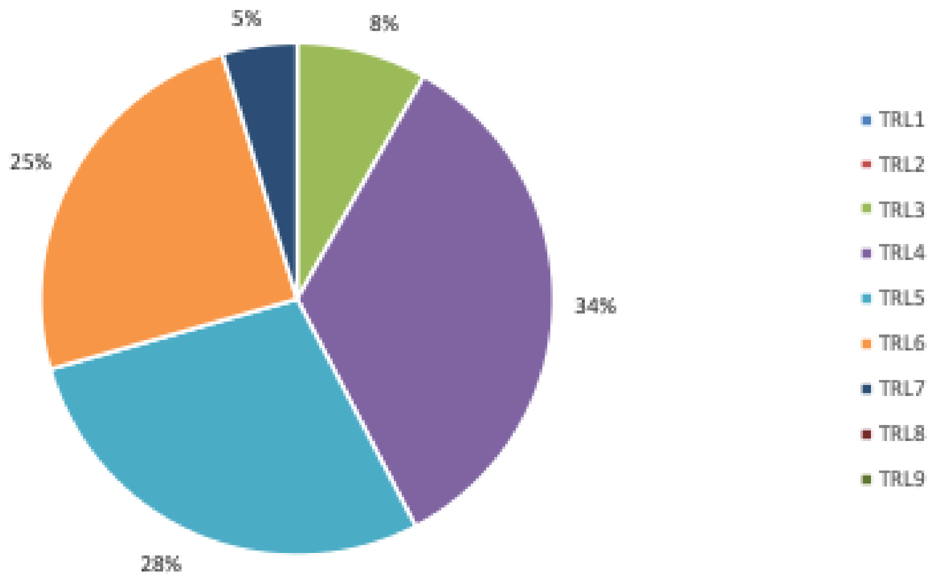

Figure 57: KERs and corresponding TRLs expressed as percentages as reported by Call 3 projects.

Projects also reported five KERs targeting TRL2-4, mainly related to various AI/ML solutions and functionalities; six KERs projected to reach TRL4-5 addressing advanced radio technologies, high-frequency connectivity and private 6G networks; five KERs anticipated to progress to TRL5-6 concerning digital twins, automation and spectrum efficiency; and, six KERs at TRL6-7, including communication, Compute-as-a-Service, IoT and AI enablers. Most of the latter correspond to one project.

There is a clear progression in the maturity of the results reported by Call 3 projects with respect to previous calls, as depicted in Figure 58. On average, Call 1 and Call 2 projects anticipated low to medium TRLs (TRL3-4) while in Call 3 most KERs are expected to reach TRL4-6.

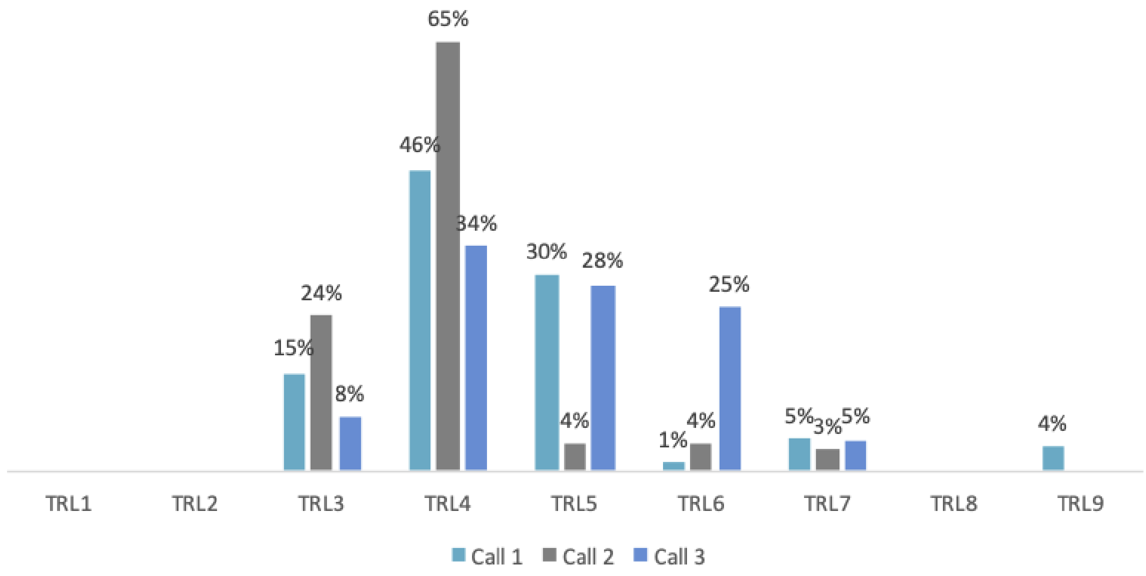

Figure 58: KERs and corresponding TRLs compared across calls.

Key insights

- KERs span a wide range of technological domains. Many are focused on achieving an autonomous and intelligent 6G network, but the numerous KERs addressing trust and resilience elements highlight this as a cornerstone of 6G.
- Most KERs sit in the mid-TRL range (TRL3-5). A certain progression by domain can be observed: AI/ML KERs are the least mature (TRL2-4), network management ones are in the mid-range (TRL4-5) and trustworthiness KERs are the most mature (TRL5-6).
- Vertical demonstrations are essential for pushing TRLs higher.
- No KERs are expected to reach deployment.
- The results in Call 3 are expected to reach higher TRLs than in previous calls, which indicates a clear progress in the maturity of the innovations being developed.

Question M9: *Does your project promote the participation of SMEs?*

In line with previous calls, the diverse initiatives devised to promote the participation of SMEs among Call 3 projects mainly focus on technology development and validation, collaboration and networking, and new business opportunities and market expansion.

Most projects involve more than one SME in the consortium, leveraging their expertise in areas such as AI, automation, cybersecurity, digital twins, LiFi, multi-connectivity, antennas, XR, and edge-cloud orchestration. SMEs are often essential in the development of new technologies and enhancement of existing solutions and services, as well as in their validation.

Call 3 projects mention SMEs' work in AI/ML, network automation, Reconfigurable Intelligent Surfaces (RIS), quantum-safe security tools, or predictive analytics, enabling novel network functions and services. Moreover, SMEs often participate in proofs-of concept (PoCs) and large-scale testbeds to validate new 6G applications, for example, immersive reality and optical communications, among others. These contributions are essential for the deployment and validation of the project innovations. In turn, it helps SMEs broadening and improving their product portfolio and enhancing their competitive edge.

Participating in SNS projects offers SMEs an opportunity to gain visibility and direct market engagement, as well as to enter new markets. SMEs cutting-edge technological insights and innovations that equips them to meet evolving market demands, staying ahead of the competition. In fact, SMEs are essential to develop market-oriented business models and ensure 6G adoption thanks to their focus on specialised requirements for verticals.

The collaborative approach of SNS projects, bringing together larger industrial stakeholders, academic institutions, and research communities, facilitates that SMEs build a robust network that supports mutual growth and knowledge sharing. Moreover, these collaborations are pivotal in the development of standards, favouring interoperability and promoting scalability of new technologies. As a result, SMEs are better positioned to integrate their solutions into broader ecosystems, enhancing their competitiveness and long-term sustainability.

Overall, the findings are very similar to those in previous calls. However, there is a strong emphasis in the SMEs expertise in niche domains as well as in their role in validating technology, bringing it closer to commercialisation.

Key insights

- SMEs are driving innovation in the 6G ecosystem, contributing to cutting-edge technologies, often in niche domains, and ensuring solutions are practical, scalable and aligned with the market demands.
- Participating in SNS projects offers a unique opportunity for SMEs to collaborate with large industrial players, academia and other actors, gain access to testing facilities, boost their visibility and growth, expand their capabilities, and access new business opportunities.

5 6G Landscape Analysis & Trends

5.1 Methodology for 2025 Analysis

The 6G Landscape and Trends analysis performed by the CSA projects serves as a “checkpoint” in time to investigate the R&I activities that other relevant regions, associations, verticals and general involved stakeholders are engaged in, providing also a view for their vision of the development of future 6G networks. The insights generated by such an analysis are extremely useful for the SNS JU community as they help in benchmarking the European and SNS vision and work against those of other relevant stakeholders and may lead to fine-tuning of the SNS JU activities and next steps, to ensure that Europe remains relevant and competitive in the 6G race. As the 6G standard cannot be prepared in isolation, awareness regarding the commonalities and differences in vision, objectives and targets with other major stakeholders becomes critically important.

Several rounds of landscape/trend analysis were performed by the predecessor CSA project SNS ICE, where a breakdown of the R&I activities and 6G vision of International [4], European [5] and Vertical [6] stakeholders was delivered, both for 2023 and 2024. The results of the trend analysis performed in SNS ICE were widely disseminated and assisted in verifying that the EU and SNS R&I roadmap is very well aligned with the rest of the world while no major gaps in expertise compared to other regions were detected. These outcomes and insights were also published as peer-reviewed papers at the EUCNC conference [7][8][9], attracting thousands of views and multiple citations.

As the trend analysis delivered by SNS ICE covers the 6G R&I landscape on international, European and vertical levels up until the beginning of 2025, and there have been very few new position or white papers by key stakeholders since then, an additional generic trend analysis at this stage was deemed redundant. As the global discussion has shifted towards specific technologies and features of 6G that stand to benefit key economic, societal and vertical sectors, it makes more sense to perform a targeted analysis on the work carried out and the vision of various relevant stakeholders regarding key technologies, features and aspects of 6G networks and the weight that each stakeholder places on them, directly translating their vision and expectations for future applications and use cases. Such a targeted study, will allow for a comparative analysis between the SNS JU research direction and vision on 6G with other stakeholders, revealing commonalities and differences, as well as alignment or divergence of expectations regarding specific technologies and their expected impact in future networks. It was also deemed necessary to look beyond technological aspects and to include non-technological areas in this analysis such as sustainability, sovereignty, monetization and business model evolution, as these aspects are key parts of the 6G discussion, expected to be significantly affected by the advent of future networks and services.

Based on the above-described methodology, SNS CO-OP partners have identified several ‘thematic areas’ (both technical and non-technical) that should be specifically targeted with this first SNS CO-OP landscape and trend analysis these thematic areas are:

- **Artificial Intelligence (AI)** (transversal theme)
- **Cloud/edge - 3CN**
- **Micro-electronics** (incl. Front-End Module, FEM)
- **Cyber-Security**
- **Sovereignty** (incl. Trustworthiness (security, trust, resilience, privacy) (inc. non-technical aspects)
- **Hardware/Devices**
- **Quantum**
- **Terrestrial Networks/Non-Terrestrial Networks** integration (TN/NTN)
- **Sustainability** (societal, environmental, economic) (transversal) (inc. non-tech)
- **Business model evolution/Monetization** (transversal theme)

The SNS CO-OP landscape analysis presented in this section, attempts to provide some first insights on how these thematic areas are approached by various key stakeholders from different relevant domains, what type of work is already ongoing or envisioned in these areas and what is the long-term vision. The analysis, further includes a direct comparison with the approach and priorities of the SNS JU ecosystem attempting to identify the commonalities and differences with these stakeholders per thematic area, thus allowing for convergence and alignment on common topics of interest. The targeted stakeholder groups for this landscape analysis are the ***European Industrial & Academic ecosystem*** (6G-IA), ***NetworldEurope***, relevant calls of the ***Horizon Europe*** programme, major ***international associations***, ***EU National Initiatives***, ***EU peer Associations***, key ***Vertical stakeholders***, ***Mobile Network Operators*** (GSMA, ConnectEurope) and major ***Standardization and pre-standardization*** groups. The views, priorities and vision of each of these stakeholders with regards to the above-identified thematic areas are analysed in the rest of this section and compared to the SNS JU work, vision and priorities as extrapolated from the ***SNS CO-OP annual questionnaire*** and the ***SNS JU Work Programme***.

5.2 SNS JU Landscape Analysis

5.2.1 SNS JU Priorities

The SNS Joint Undertaking (SNS JU) continues to refine its research and innovation agenda towards the realization of 6G networks that are intelligent, secure, sustainable, and inclusive. The following paragraphs outline the main SNS JU priorities across the key thematic areas identified in the European 6G landscape, based on the analysis of project questionnaire responses (Sections 4.1, 4.2 and 4.3 of this deliverable) and alignment with the SNS JU Roadmap and Work Programme.

Artificial Intelligence (AI)

AI is a pervasive enabler across the SNS JU portfolio, with approximately 94 % of projects integrating AI/ML mechanisms (Figure 18). Current activities focus on AI-driven network management and orchestration, RAN optimization, and intelligent resource allocation, complemented by early exploration of AI-native architectures (Section 4.1.4). Projects also investigate federated learning and explainable AI to ensure trustworthy automation. Going forward, the SNS JU vision is to establish AI as a built-in element of 6G networks—transforming operation from static configuration to self-learning, adaptive systems that enhance efficiency and sustainability.

Cloud/Edge – 3CN

The Cloud-Edge continuum and the broader 3C Network (Connected, Collaborative, Computing) paradigm remain central to SNS JU research project. Projects are developing mechanisms for distributed computing and orchestration across edge-cloud infrastructures (Figure 18), relying on frameworks such as O-RAN, Kubernetes, and Open-Source MANO. The vision for Call 3 is a unified 3CN framework integrating communication, computation, and storage into a single programmable fabric, delivering real-time intelligent processing at the edge while ensuring global connectivity and resilience.

Microelectronics (incl. FEM)

Microelectronics and front-end modules (FEM) underpin physical-layer advances in 6G. SNS JU projects target energy-efficient components, THz transceivers, and reconfigurable intelligent surfaces, often in collaboration with European semiconductor initiatives (Section 4.1.2). Current efforts address RF front-ends and antenna systems supporting massive MIMO and beam forming. The forward vision is to reinforce Europe’s strategic autonomy in enabling hardware, building on synergies with photonics and materials research to secure competitiveness in 6G SoC development.

Cyber-Security

Security is a transversal pillar across all SNS streams. Projects investigate network trust, identity management, and AI-driven threat detection (Sections 4.1.3 and 4.1.5), embedding security-by-design principles and post-quantum cryptography. The SNS JU vision is to achieve self-protecting networks capable of dynamic risk mitigation and resilience. This orientation supports Europe’s broader objective of digital sovereignty and secure infrastructure autonomy.

Sovereignty/Trustworthiness

Digital sovereignty and trustworthiness form horizontal priorities in the SNS JU agenda. Projects explore frameworks for data governance, transparency, and ethical AI (Section 4.2.2 and 4.2.3). Trustworthiness is achieved through verifiable AI, secure data exchange, and open architectures that reduce non-EU dependencies. The forward vision promotes "trust by design," positioning SNS JU as a key instrument for European technological sovereignty and standardization leadership.

Hardware/Devices

Device-level innovation remains a foundation for 6G use cases. Projects are developing new transceivers, sensors, and embedded systems supporting ultra-low latency and energy-efficiency (Section 4.1.6). Work also targets integration of sensing and communication, software-defined hardware, and circular design approaches. The vision is to realize adaptive, intelligent, and eco-efficient devices supporting ubiquitous connectivity and green ICT objectives.

Quantum Technologies

Quantum technologies are emerging at low TRLs in the SNS JU portfolio (Figure 17 and Figure 18) at early phases. Research explores quantum-secure key distribution, quantum sensing, and hybrid classical-quantum architectures. The vision for Call 3 and beyond is to leverage Europe's strong quantum ecosystem to enable ultra-secure and precise network operations through quantum-enhanced 6G infrastructures.

TN/NTN Integration

Integration between Terrestrial and Non-Terrestrial Networks (TN/NTN) remains a high priority for achieving ubiquitous coverage. SNS JU projects are developing architectures and protocols for seamless TN/NTN interworking (Section 4.1.6), including satellite and aerial connectivity. The vision aims for a unified service-oriented infrastructure providing resilient, global 6G coverage that supports critical communications and bridges digital divides.

Sustainability (social, environmental, economic)

Sustainability is one of the most consistently addressed priorities across the SNS JU projects (Figure 38). Activities span energy-efficiency experimentation, green ICT design, and integration of societal and ethical values (Section 4.2.5). Energy Efficiency is the most targeted KPI across all calls (Figure 16). Looking ahead, the SNS JU intends to quantify sustainability impacts via Key Value Indicators (KVIs) and embed circular economy principles throughout the 6G ecosystem.

Business Models/Monetization

SNS JU acknowledges that technological progress must be supported by viable business models (Section 4.3.1). Projects are investigating value-driven frameworks such as network-as-a-service, data marketplaces, and cross-vertical monetization schemes. The forward vision is to foster open, collaborative innovation ecosystems that enhance SME participation and translate network intelligence and trust into sustainable economic impact for Europe.

5.2.2 SNS JU Work Programme 2026

The orientations adopted for the SNS JU Work Programme (WP) 2026, is another source of valuable information regarding the position and vision of the SNS JU community, on major technological and horizontal issues. The discussions between 6G-IA Board, EC and SNSO Office and 6G-IA Work Programme Task Force/Core Team (TF/CT) rapidly led to the orientation to target one "small" WP2026 and one "large" WP2027, also considering the shift in timing for the Call 2025 implementation (deadline for Call 2025 proposals submission on 18.09.25 instead of initially targeted April 2025). The SNS JU R&I WP 2026 marks a critical transitional year for the SNS JU and the broader European 6G agenda. It comes at a time when the SNS JU Programme is moving from Call 2 into Call 3, consolidating the foundation laid in 2024–2025 and preparing for the final major SNS Call, under Horizon Europe, to be launched in 2027. Compared to previous Work Programmes, the SNS JU R&I WP 2026 is smaller and more targeted. This focused approach enables the SNS JU to sustain momentum and ensure high-impact investments, while strategically preparing for a broader and more ambitious R&I Work Programme in 2027.

The SNS Work Programme definition was relaying on the overall set of stakeholders and inputs summarized in Figure 59, repeated from SNS OPS deliverable D1.2 [10] to facilitate the understanding of the reader.

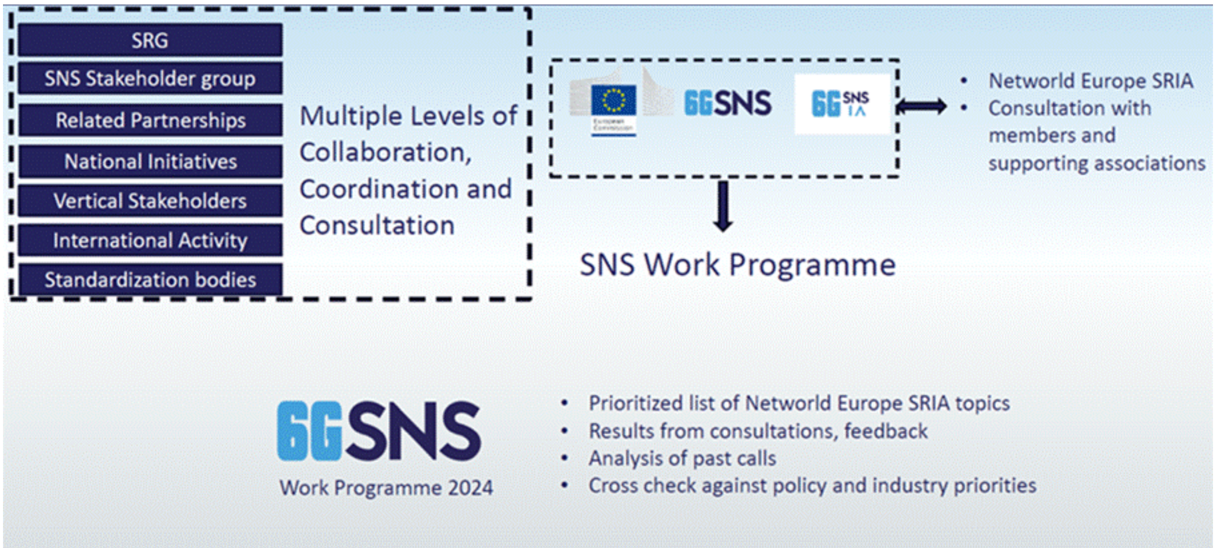

Figure 59: SNS Work Programme definition – Overall perspectives and stakeholders

The scope of the SNS JU R&I WP 2026 focusses on critical topics on 6G. Initially, it included five Strands, but finally it was structured along the following three:

- Stream B covers research for revolutionary and evolutionary technology advancements. In preparation for 6G and more specifically in the AI domain, the SNS JU R&I WP 2026 Stream B targets a Topic with high-level TRL leveraging also previous SNS programmatic results with the objective of delivering innovative solutions towards real-life networks in a short-term period. The target is to further explore the role of AI in network platforms, as a tool for 6G network optimisation and by ensuring the availability, curation and validation of high-quality real and synthetic data sets needed to train AI models in AI-native 6G systems. Development of data sets for AI solutions for 6G services and applications for verticals (AIaaS) are also included.
- Stream C focuses on further development of experimental infrastructure(s), in support of the various phases of the SNS JU. Stream C developments in the SNS JU R&I WP 2026 have a particular focus on the availability of an evolvable experimental infrastructure to engage the 6G community to run experimentations, by continue offering of EU-wide technology experimentation platforms to innovators (SMEs, start-ups, Researchers etc.) that can test and incorporate candidate 6G technologies in an E2E way for their further validation.
- Coordination and Support Actions (CSA): One of the actions targets an operational and output-optimisation CSA to facilitate the activities of the European SNS JU community and undertake various activities to maximise the impact of the SNS JU programme. Furthermore, a second CSA will support EU deep bilateral cooperation with India, towards identification of potential synergies and alignment of European and India's standardisation agendas. A third CSA will continue the previous SNS developments on massive IoT and device integration, targeting a shared European roadmap and a strategy for a renewed European industrial capability around simplified, lower-cost 6G-enabled devices, and ultimately rebuild European industrial capabilities in this critical sector.

The first draft of WP2026 was launched on 8th of August 2025, for consultation by 6G-IA Members. TF/CT Members analysed the overall set of 6G-IA Members inputs, indicating that there was clear acceptance of the proposed orientations in the draft WP 2026 with specific valuable feedback/perspectives, raised questions and proposed orientations. The second draft mature WP2026 definition was further progressed and converged in September-November 2025, enriched with new inputs and proposed up-dates/grades from TF/CT and EC-SNSO.

5.2.3 SNS JU Sustainability task force white paper

Another source consulted in order to understand the orientations of the SNS JU was the publications from the SNS JU Sustainability task Force [11], addressing the sustainability methodologies and approaches within the SNS JU. As also highlighted in in SNS OPS deliverable D1.4 [3], “Sustainability is not a peripheral concern but a foundational principle encompassing environmental, social, and economic dimensions, going beyond mere energy efficiency improvements.” The SNS JU Sustainability Task Force white paper presented findings from an extensive analysis of how 27 SNS JU-funded projects are addressing sustainability in the development of 6G technologies. The projects, primarily at low to mid Technology Readiness Levels (TRLs), show a strong emphasis on environmental sustainability, particularly energy efficiency, with widespread adoption of AI-driven resource management, dynamic power scaling, and architectural optimization. However, broader environmental concerns such as circularity, renewable energy integration, and lifecycle impacts remain relatively underexplored.

Economic sustainability is generally framed around cost-efficiency, industrial growth, and technological innovation, though few projects explicitly link these goals to environmental or social outcomes. Social sustainability is addressed by most projects, often through digital inclusion and ethical principles like privacy and trustworthiness but lacks consistent definitions and measurable indicators.

Four core themes structure the analysis:

1. **Sustainability Targets** – Projects face challenges in setting relevant and measurable targets due to the complexity of technologies and systems, and the early-stage nature of the research. There is a call for broader interdisciplinary engagement and clearer guidance on sustainability values.
2. **Methodologies** – Standardized sustainability frameworks and impact assessment methods are rarely used. While Key Value Indicators (KVIs) are referenced, their application is inconsistent and often lacks validation. Lifecycle and circularity approaches are minimally adopted.
3. **Trade-offs** – Projects acknowledge trade-offs between sustainability and performance, such as energy efficiency versus latency or complexity. Co-optimization strategies are emerging, and sustainability-by-design is gaining traction, though often focused narrowly on energy savings.
4. **Implementation Considerations** – Real-world deployment raises challenges in scalability, circularity, and ethical dimensions. Topics such as privacy, trust, and transparency are increasingly considered, but digital sobriety and end-of-life planning are largely absent.

The white paper concludes that while energy efficiency dominates current sustainability efforts, there is significant potential to expand the scope to include economic and societal dimensions, lifecycle thinking, and policy engagement. The SNS JU and broader 6G community are well-positioned to drive this evolution, provided future initiatives embed interdisciplinary expertise and value-driven design from the outset.

5.3 6G Landscape & Key Stakeholders Trend Analysis

5.3.1 European Industrial & Academic ecosystem (6G-IA)

The 6G Smart Networks and Services Industry Association (6G-IA[9]) is the official representative of the European industrial, academic and SME stakeholders with vested interest in 6G development and is also the private side of the SNS JU. In fulfilling its role as the representative of the European private side, the 6G-IA regularly hosts targeted thematic Workshops with industry and academia experts (from its members pool as well as external experts) to discuss the current state of things, the gaps detected in key technological areas and to shape the vision of 6G-IA for the next few years. The reports of these annual meetings constitute rich sources of information regarding the outlook and vision of the private sector in Europe and as such is very relevant for the entire SNS JU.

[9] https://6g-ia.eu

In 2024 and 2025 the 6G-IA held in person Workshops[10] with key stakeholders from the following domains: **microelectronics, photonics, NTN, Security, Wireless and Cloud services**. This section provides the findings of the analysis of these reports with regards to the selected thematic areas.

Artificial Intelligence (AI)

AI is positioned as a native feature of 6G, enabling cognitive, self-optimizing networks and intelligent service provisioning. 6G-IA emphasizes AI-driven automation across layers, from PHY/MAC resource optimization to semantic communication and predictive management. AI's role extends to *AI-as-a-Service* (AIaaS), MLOps, and distributed edge intelligence supporting low-latency applications and digital twins. The research focus lies on trustworthy, explainable, and energy-efficient AI integrated with communication functions. The long-term goal is a seamless, federated AI ecosystem embedded in the network fabric, delivering ubiquitous intelligence and supporting data sovereignty and secure federated learning.

Cloud/Edge – 3C Networks

Cloud-edge integration—or the "Connected, Collaborative, Computing" (3C) paradigm—is seen as foundational to the 6G architecture. The vision focuses on a European sovereign *cloud continuum* connecting devices, edge nodes, and centralized clouds through open interfaces and standardized APIs. The 6G-IA stresses minimizing dependency on hyperscalers by promoting open-source, interoperable, and secure telco-cloud solutions. Architectural priorities include AI-based orchestration, stateless and event-driven service architectures, multi-cloud federation, and dependable low-latency edge operations. The long-term aim is a distributed, secure, and sustainable service platform underpinning both network operations and new digital markets.

Microelectronics (incl. Front-End Module, FEM)

Microelectronics form the backbone of European 6G competitiveness. The 6G-IA prioritizes a coordinated R&I roadmap for *Front-End Module (FEM)* development—covering new FR3 spectrum (7–15 GHz) and advanced massive MIMO designs—with synergy between SNS and Chips JU. The focus includes GaN-, CMOS-, and FD-SOI-based integration, beamforming ICs, and RF/analog front-end innovations. Future efforts aim to reach TRL 7–8 through pilot lines (FAMES, APECS) and to expand FEM work to mmWave, NTN, and joint sensing/communication applications. This effort also links to European chiplet platforms and heterogeneous packaging for sovereignty and vertical market impact.

Cybersecurity

Cybersecurity and privacy are embedded into all 6G design dimensions—from telco-clouds to AI and hardware. The 6G-IA envisions an *end-to-end trusted architecture* emphasizing confidentiality, resilience, and local survivability. Topics include secure-by-design cloud frameworks, privacy-preserving sensing, and physical-layer security mechanisms. Federated learning, confidential computing, and distributed ledger technologies are considered key enablers for trust in multi-stakeholder environments. The long-term goal is to ensure Europe's digital autonomy through verifiable, standards-aligned trust mechanisms integrated in network and service layers.

Sovereignty and Trustworthiness

Sovereignty is a recurring horizontal theme. The reports call for *technological independence* via open-source cloud stacks, European chip design, and trusted supply chains. Trustworthiness encompasses security, resilience, privacy, and transparency in AI and data governance. The 6G-IA envisions a regulatory-aligned ecosystem (AI Act, Data Act, CRA) where data storage, compute, and network control remain in EU jurisdiction. Non-technical aspects—like governance, ethical AI, and fair data monetization—are considered essential to achieving digital trust and long-term competitiveness.

[10] https://6g-ia.eu/strategic-consultation-workshops/

Hardware and Devices

Hardware evolution underpins 6G's performance targets. Priorities include energy-efficient ASICs, flexible HW/SW co-design, and modular accelerators for the *6G compute continuum*. The reports emphasize the need for open, programmable hardware abstraction layers, photonic integration, and RAN silicon co-designs. Device innovation will also drive new sensing, positioning, and ultra-low power IoT capabilities. In the long term, a seamless hardware-software integration—agile, energy-aware, and multi-vendor—will enable 6G's adaptability and sustainability.

Quantum Technologies

Quantum aspects are emerging, mainly in the context of security, timing, and computation. 6G-IA positions quantum communication and computing as complementary enablers for enhanced cryptography, synchronization, and distributed computing efficiency. Integration into network management and secure communication frameworks is foreseen, though still exploratory. The long-term vision points to hybrid classical-quantum infrastructures for trusted and high-performance 6G services.

Terrestrial/Non-Terrestrial Network (TN/NTN) Integration

Integration of satellite (NTN) and terrestrial (TN) segments is a central architectural goal. Research priorities target seamless mobility, spectrum coordination, and unified service continuity across TN/NTN. The FEM expansion roadmap highlights programmable antennas and hybrid RF-optical links for inter-satellite and satellite-to-earth communication. The vision foresees a globally integrated, software-defined 6G network enabling ubiquitous coverage, reliability, and emergency resilience through space-air-ground convergence.

Sustainability (Societal, Environmental, Economic)

Sustainability is viewed as a *core cross-cutting objective*. 6G-IA promotes "6G for sustainability" and "sustainability for 6G," integrating environmental efficiency with socio-economic inclusion. Priorities include energy-optimized radio design, intelligent power management, and life-cycle-aware microelectronics. On the societal side, human-centric design, accessibility, and ethical governance are emphasized. Economically, sustainable business ecosystems are encouraged via open innovation and circular digital economy principles. The long-term ambition is climate-aligned, resource-efficient connectivity supporting digital and social resilience.

Business Model Evolution/Monetization

Current telecom revenue models are seen as unsustainable under rising data demands. The reports propose evolving towards *service-based monetization*, where operators expose APIs and network functions to verticals through open marketplaces. Cloud-based and AI-driven service orchestration will enable "network-as-a-platform" paradigms, while ensuring compliance with European sovereignty and competition policies. Long-term, 6G is envisioned as an *economic enabler*, with distributed, collaborative ecosystems built on fair value distribution and regulatory modernization.

Table 4 provides an overview of the key focus areas, their expected role in 6G, long-term vision of the 6G-IA, as well as an initial comparison with the respective views (work and vision based on their questionnaire responses) of the SNS JU projects so far.

Table 4: Overview of 6G-IA's key focus areas and vision on the selected thematic areas

Thematic Area	Key Focus Areas	Key Role in 6G	Long-term Vision	Differences // Commonalities with SNS JU
Artificial Intelligence (AI)	Native intelligence, MLOps, semantic comms.	Cognitive/autonomous network control	Federated, trustworthy AI ecosystem	**Commonalities:** AI pervasive; MLOps & AIaaS adoption. **Differences:** 6G-IA emphasises ethical/sovereign AI framing; SNS focuses on applied, TRL/testbed AI use in orchestration and vertical trials
Cloud/Edge – 3CN	Cloud continuum, open APIs, orchestration.	Foundation for distributed compute & services	Sovereign, interoperable telco cloud	**Commonalities:** Strong emphasis on cloud-edge continuum and open APIs as well as European sovereignty **Differences:** None in vision. SNS takes a more hands-on approach as projects are executing cloud continuum pilots and multi-provider orchestration;
Microelectronics (FEM)	FR3 FEM, GaN/FD-SOI, pilot lines (FAMES, APECS).	Hardware enabler for RAN performance	European FEM leadership & chip autonomy	**Commonalities:** Both identify FEM and RF/microelectronics as strategic. Focus on mmW and JCAS/ISAC **Differences:** None in vision. Still early for SNS projects to claim full FEM fabrication — SNS emphasizes integration/trials and calls for Chips JU follow-up.
Cyber-Security	Quantum-safe, privacy, secure cloud frameworks.	End-to-end trusted infrastructure	Built-in resilience & sovereignty	**Commonalities:** Cyber-Security viewed as critical components of 6G. **Differences:** 6G-IA emphasizes hardware supply-chain trust and quantum-safe optics as strategic priorities which have not been addressed yet in SNS.
Sovereignty/Trustworthiness	EU data jurisdiction, open source, supply chains.	Policy-aligned digital control	Ethical, sovereign digital ecosystem	**Commonalities:** Both stress sovereignty and trustworthiness as critical aspects of 6G **Differences:** 6G-IA articulates concrete industrial sovereignty actions (pilot lines, chiplets, FEM roadmap); SNS projects practice trust values in project KPIs and deployments but have limited budgets for full supply-chain sovereignty actions.
Hardware/Devices	Accelerators, photonics, low-power ASICs	Performance & flexibility enabler	Energy-aware, reconfigurable HW	**Commonalities:** HW co-design and accelerators appear across both. **Differences:**6G-IA pushes strategic pilot-lines and chiplet platforms; SNS work is oriented to integrating and trialling device prototypes within system projects.

Quantum	QKD/PQC, timing, quantum experiments	Trust & performance enhancement	Hybrid classical-quantum networking	**Commonalities:** Security-related quantum topics are acknowledged by both. **Differences:**6G-IA highlights photonics & QKD as strategic research lines; SNS Call-1 projects treat quantum as exploratory with limited concrete project coverage so far.
TN/NTN Integration	Seamless mobility, multi-orbit, hybrid RF-optical links.	Global coverage & continuity	Unified space-air-ground 6G	**Commonalities:** Strong alignment — both emphasize TN/NTN integration and NTN testbeds. **Differences:** SNS places more emphasis on trials and NTN use-case validation; 6G-IA adds broader roadmap and standards coordination (Open Labs, ESA links)
Sustainability (soc., env., econ.)	Energy efficiency, life-cycle, inclusion.	Cross-cutting design requirement	Climate-aligned, human-centric 6G	**Commonalities:** Top priority across SNS projects and 6G-IA (Energy Efficiency = #1 KPI in SNS). **Differences:** SNS projects have started from the implementation of concrete energy-saving algorithms, device/RAN measures and SDG mappings in projects, however the full sustainability considerations (beyond energy efficiency) have still to be addressed.
Business Models/Monetization	Open APIs, service marketplaces, AIaaS	New value chains & operator services	Platform-based, fair monetization	**Commonalities:** Both call for new operator revenue models, API exposure, vertical engagement. **Differences:** SNS projects are experimenting with vertical trials, requirement provisioning and SME engagement (applied testing); 6G-IA additionally stresses regulatory modernization and cloud sovereignty to enable market changes.

5.3.2 NetworldEurope (SRIA)

The NetworldEurope Strategic Research and Innovation Agenda (SRIA) is an exercise conducted every two years that refers to the overall activities of the European community. NetworldEurope have organized several events over time that help position very active areas, in particular over the last two years the following areas were identified that have made significant leaps: Non-Terrestrial Networks, Autonomous Networks, Connected Vehicles, and more. But regardless of these thematic initiatives, that address parts of the community, the Visions for Future Communications Summit (VFCS25) event verifies the overall existence of a sense of community. Following a call for proposals for VFCS25, a program is organized encompassing several relevant areas and will have a series of keynotes addressing different directions and perspectives for the community. The VFCS is thus the trigger for the new SRIA and from this point forward the community will structure itself to create a new version of SRIA, which will have as much impact as the previous SRIA versions and serve as a basis for discussions in FP10.

For the previous SRIA we identified the following areas:

- **System Architecture Considerations** – analysing the evolution of systems towards dynamically composed, multi-stakeholder environments, with an increasing softwarisation and intelligence of the whole system, and the accompanying challenges.
- **Fundamental Enablers for Future 6G Systems** – this chapter addressed network protocols and network services interfaces.
- **Network and System Security** – discussing the paths on the increasingly relevant aspects of security in our infrastructure.
- **Software and AI Technologies for Telecommunications** – addressing the software related challenges of the ongoing network softwarisation, the increasing system complexity, and the enabling of adaptive and customized services.
- **Radio Technology and Signal Processing** – where the challenges and potential solutions perceived for the future wireless (and mostly cellular) communications are discussed.
- **Optical Networks** – a critical component of the backbone (amongst other potentialities) and its perceived evolution.
- **Non-Terrestrial Networks and Systems** – discusses the upcoming closer integration of 3D networks into the overall communication system.
- **Opportunities for Devices and Components** – tackles the unavoidable challenges at the fundamental element level, which will constrain and limit all system developments.
- **Future Emerging Technologies** – discussing promising technologies that may bring structural changes across all the current communication concepts. Some of these technologies are already being researched but have not yet a clear path (if ever) to the transformational impact it is expected by their wide adoption.

However, some reorganization of these chapters is anticipated in order to simplify the communication of the message to the community at large. The trends that we see for the new SRIA will lead to the redesign of some chapters in order to promote a global cohesive system vision which is not so much technological structured but functionally structured. And as such things like Radio Technology, Non-Terrestrial Networks and Optical Networks will clearly be separated in architectural aspects and in technology aspects and will be probably repositioned in different chapters following these kinds of guidelines. The same will happen with Physical Layer Security and System Level Security which is how things are usually handled. Taking this in consideration the next SRIA chapters will address:

- System Architecture
- Network and System Intelligence
- Protocols and Interconnections
- Access Systems
- Future Emerging Technologies

Furthermore, future SRIA will provide a separate section on aspects such as: **Sustainability, Security and Privacy, Resilience and Reliability, Efficiency and Performance**.

This covers the uptake of several of the above identified thematic areas that can be summarized and mapped as follows:

Artificial Intelligence (AI)

Advances in native intelligence - where AI capabilities are embedded directly in network nodes - allow infrastructure to sense, reason, and act with minimal external guidance. Coupled with robust MLOps pipelines, these intelligent models can be reliably trained, deployed, monitored, and updated at scale, ensuring trustworthy performance in dynamic environments. Emerging semantic communications techniques further enhance efficiency by transmitting meaning rather than raw data, enabling AI-driven systems to coordinate using far fewer resources. Together, these innovations dramatically strengthen cognitive/autonomous network control, allowing networks to self-optimize, predict failures, allocate resources intelligently, and adapt in real time with unprecedented precision. This area will be included as part of a novel chapter in SRIA, cantered on Network and System Intelligence.

Cloud/Edge – 3C Networks

SRIA has included the Cloud Continuum for many years (in reality, was one of the first documents that advocated this, more than six years ago). This will continue to be a central tenant on the Cloud Continuum architecture concept, open/standardized APIs and Orchestration. By adopting open APIs, cloud providers promote transparency and portability, removing lock-in and enabling services to interoperate across different platforms. Modern orchestration frameworks unify diverse compute, storage, and networking resources, making it possible to manage heterogeneous cloud environments as a single, coherent system. Interoperable clouds - built on standards, open interfaces, and federated trust models - form the foundation of a resilient digital ecosystem where services can be composed, migrated, and audited across borders. These principles support a future in which organizations operate in a sovereign digital space while fully benefiting from the elasticity, automation, and openness of the broader cloud continuum.

Microelectronics (incl. Front-End Module FEM)

In this thematic area, a clear trend for a merger of microelectronics across different access technologies can be observed, which will be reflected in a new SRIA chapter called Access Systems.

Cybersecurity

Cybersecurity is essential for achieving an *end-to-end trusted infrastructure* capable of providing the required network resilience and confidentiality. An effective *end-to-end trusted infrastructure* relies on secure onboarding, continuous monitoring, and cryptographic assurance to guarantee data origin authenticity. Moreover, an *end-to-end trusted infrastructure* provides continuous authentication of devices and users, reducing the risk of impersonation and unauthorized access. Specific sections on security aspects are planned for all SRIA chapters.

Sovereignty and Trustworthiness

Policy-aligned digital control ensures that data governance, platform behaviour, and automated decision-making systems operate strictly within the boundaries of democratically established rules and societal expectations. It reinforces national and organizational sovereignty by guaranteeing that digital systems remain auditable, compliant, and resistant to unauthorized influence or opaque algorithmic manipulation. By embedding regulatory requirements directly into system design, policy-aligned digital control increases public trust and accountability, reducing the risk of misuse or misalignment. Specific sections on sovereignty and trustworthiness aspects are planned for all SRIA chapters.

Hardware and Devices

Some of the key areas include hardware accelerators (providing dedicated compute paths for tasks like beamforming, channel estimation, and massive-MIMO processing, reducing latency and power consumption), photonic components (enabling ultra-high bandwidth signal processing and low-latency optical interconnects, supporting data rates required for 6G fronthaul and backhaul) and low-power ASICs (that integrate specialized baseband and RF processing blocks that significantly cut energy use, enabling dense edge deployments and long-life IoT nodes). Together, they form the hardware foundation for next-generation technologies (e.g. 6G) by improving spectral efficiency, reducing end-to-end latency, and enabling real-time AI/ML at the edge. As networks move toward sub-THz bands and software-defined architectures, hardware technologies are critical to meet the extreme throughput and energy-efficiency targets of future technologies. NetworldEurope does not focus on devices.

Quantum Technologies

Quantum Technologies at this stage appear in a multitude of dimensions. In some fields they are entering the market, in specific applications, or only perceived as niche market situations, requiring specific device development, while in other they are in nascent state, with more R&I needed to determine their exact added value and potential for integration. Some clear trends can be found such as interconnection of quantum computers (R&D for 2030+), or handling of QKD, while their application and importance for future networks is still under debate.

Terrestrial/Non-Terrestrial Network (TN/NTN) Integration

6G aims to achieve truly global coverage and service continuity by seamlessly integrating TN with NTN - including satellites, high-altitude platforms, and UAV-based communication nodes. The convergence of TN/NTN enables resilient and ubiquitous service delivery, ensuring that mobility, harsh climates, and geographical barriers no longer degrade network performance. A unified space–air–ground 6G architecture represents the long-term vision of a planetary communication fabric where heterogeneous networks operate as a single intelligent system. This will be included as part of the Access Systems technologies in SRIA, to be merged with wireless access.

Sustainability (Societal, Environmental, Economic)

Some of the key sustainability areas include energy efficiency (by integrating smart technologies and optimized processes to reduce consumption while maintaining high performance standards), life-cycle approach (ensuring that resources are responsibly sourced, products are designed for durability, and end-of-life pathways maximize reuse and recycling) and social inclusion (ensuring that all stakeholders benefit equitably from environmental and economic progress). The long-term vision should be climate-aligned, aiming to achieve net-zero emissions through science-based targets and continuous innovation. This will be included in all SRIA chapters as an aspect to consider.

Finally, it has to be noted that NetworldEurope does not address Business model evolution or Monetization aspects.

5.3.3 Relevant Horizon Europe Initiatives

Under the umbrella of Horizon Europe, there are several activities that are relevant with the research topics of the SNS JU meaning they should also be investigated. The Horizon Europe Clusters 3 and 4 represent two complementary pillars driving Europe's technological and strategic autonomy. While Cluster 3 (Civil Security for Society) focuses on Security, resilience, disaster preparedness, and protection of critical infrastructures, Cluster 4 (Digital, Industry & Space) focuses on industrial competitiveness, digital transformation, and strategic technological autonomy and sovereignty.

While the two clusters overlap technically (e.g., both fund secure cloud/edge and AI) but differ in intent, requirements, and delivery paths, CL4 drives capabilities and industrial scale; CL3 drives secure, regulated, mission-critical use and resilience. The main considerations about the role of the above-mentioned thematic areas in CL3 and CL4 activities are as follows:

Artificial Intelligence (AI) is positioned as a transversal enabler across both clusters, advancing toward trustworthy, explainable, and energy-efficient systems that support industrial automation, cybersecurity, and the data economy. The long-term vision is to establish *human-centric, sovereign, and green AI* ecosystems integrated in cloud-edge and 6G infrastructures

The **Cloud/Edge continuum**, evolving into the **Connected Collaborative Computing Network (3CN)**, is a key technological driver. Current initiatives prioritize large-scale pilots, federated infrastructures, and interoperability through European data spaces. The vision is to create a seamless, sovereign, and AI-native continuum supporting industrial automation and digital services.

Microelectronics and hardware receive strategic support through the *Chips Joint Undertaking* initiative (CHIPS JU[11]), reinforcing Europe's capacity in semiconductor manufacturing, photonics, and energy-efficient devices. These advances directly underpin AI, quantum, and next-generation communication technologies, ensuring secure and sustainable supply chains.

Cybersecurity and **Sovereignty** remain cross-cutting imperatives. CL3 strengthens Europe's preparedness through advanced threat detection, post-quantum cryptography, and security-by-design frameworks, while CL4 integrates trustworthiness into digital and industrial ecosystems. The overarching goal is a unified European cybersecurity fabric and holistic digital sovereignty grounded in resilient supply chains and trustworthy certification.

Quantum technologies are being developed through initiatives like EuroQCI (among others) and pilot infrastructures for quantum computing and cryptography, aiming to converge with classical systems in hybrid architectures.

Terrestrial and Non-Terrestrial Networks (TN/NTN) research advances in CL4 and SNS JU collaborations to achieve resilient, AI-native 6G ecosystems linking ground and satellite communications.

Sustainability is embedded throughout, reflecting Europe's *Twin Transition* vision. Both clusters emphasize energy-efficient hardware, green data centers, and circular electronics, moving toward sustainability-by-design and net-zero ICT systems.

Business model innovation in Horizon Europe is evolving toward ecosystem-based, data-driven, and open-source approaches, leveraging public-private partnerships such as SNS, Chips, and AI-Data-Robotics JUs.

Sovereignty acts as the strategic backbone ensuring that these AI capabilities are developed, operated and governed under **European control, values and regulatory frameworks,** meaning strengthening Europe's capacity to design its own AI models, run them on European cloud–edge infrastructures, process sensitive data locally, and rely on secure, transparent and auditable systems aligned with the AI Act. This includes sovereignty in data (local processing, strong governance), sovereignty in infrastructure (European cloud-edge continuum, open and trusted platforms), and sovereignty in components (microelectronics, hardware accelerators).

Table 5 presents a trend analysis of Horizon Europe Clusters 3 and 4 (CL3 & CL4), highlighting current activities, priorities, and emerging visions across key technological and non-technological thematic areas and provides the key commonalities and differences with the approach and vision of the SNS JU (as presented in the previous sections).

[11] https://www.chips-ju.europa.eu

Table 5: Comparative table between SNS JU and Horizon Europe CL3 & CL4 vision and work

CL4	CL3	Differences // Commonalities with SNS JU
Artificial Intelligence (AI)		
Industrial-grade generative AI • Automated decision-making in factories & networks • AI that can be audited and certified (traceable decisions, quantifiable risks) – Trustworthy AI • AI embedded into products (cars, robots, telecom equipment) • AI assisting engineers (predictive maintenance, optimisation)	**AI for safety threat response** • Behaviour detection for civil applications (cyberattacks, anomalies, fraud) • Real-time event prioritization for first responders • AI for misinformation and hybrid threats • Forensic AI for analysing evidence	**Main differences** • SNS JU is network-centric: AI for 6G system optimization, orchestration and automation, not forensic/public-safety AI. • SNS JU does not focus on emergency-response AI (CL3). • SNS JU uses AI mainly to enable efficient, resilient network and service management. **Commonalities** • Strong alignment with trustworthy, explainable AI (CL4 + SNS JU). • AI embedded in networked systems (CL4 and SNS JU). • Need for privacy-preserving, secure AI models across all three.
Cloud-Edge – 3CN		
Cloud/Edge – 3CN • Distributed computing as infrastructure: • Move from central cloud to edge nodes near users • Automatic placement of workloads for latency/energy purposes • Telecom + cloud convergence, federation and network/compute integration. Continuum computing (device–edge–cloud) • Local processing for sensitive industrial data	**Resilient computing for emergencies**: • Cloud/Edge nodes that keep operating when networks fail (distributed resilience). • Local command systems in disaster zones • Secure data sharing • Rapid deployment of portable compute units	**Main differences** • SNS JU focuses on commercial-grade 6G cloud-edge architectures, not crisis/emergency compute (CL3). • SNS JU prioritizes integration with 6G experimental platforms; CL3 prioritizes resilience under extreme conditions. • Research on Edge-cloud convergence is covered by the SNS JU **Commonalities** • Edge-cloud convergence is a core element across CL4 and SNS JU. • Shared interest in decentralised computing, secure data flows & orchestration.
Micro-electronics/FEM		
Chips enabling European autonomy • Chips for AI, telecom and low-power processors for edge devices • Photonics for fast communication • Chiplet-based designs for flexibility	**Secure, trustworthy, robust sensors/electronics** • Tamper-proof components for critical assets and infrastructures protection • Sensors for hazardous environments • Wearable electronics for first responders	**Main differences** • SNS JU microelectronics work is oriented toward 6G network hardware enablers (RF, photonics, antennas), not the security-oriented sensors of CL3. • CL4 focuses on EU industrial chip leadership; SNS JU focuses on 6G-specific components **Commonalities** • Photonics, low-power compute, and advanced semiconductors are shared priorities (CL4 – SNS) • EU technological sovereignty in chips is a unifying theme.

<table>
<tr><th colspan="3">Cybersecurity</th></tr>
<tr><td>Securing digital industry
• Protecting cloud/edge AI-based pipelines
• Zero-trust embedded architectures in manufacturing & telecom
• Securing data spaces and digital twins
• Supply-chain cybersecurity for devices</td><td>National and societal cyber resilience
• Protection of hospitals, transport, utilities
• Early detection of cyberattacks on public services
• Tools for law enforcement and cyber forensics
• EU-wide crisis reaction platforms</td><td>Main differences
• SNS JU does not cover law-enforcement, national-security or forensic cyber tools (CL3).
• SNS JU focuses on network-level security, not sector-specific public services.

Commonalities
• Zero-trust, secure-by-design networks across CL4 & SNS JU.
• Strong alignment on protecting distributed cloud/edge and supply chains.</td></tr>
<tr><th colspan="3">Quantum</th></tr>
<tr><td>Long-term strategic technologies
• Quantum computing for material design & optimisation
• Quantum networking for ultra-secure links
• Quantum simulators integrated with HPC</td><td>Security-oriented quantum
• Quantum-safe communication and encryption
• Future-proof secure communication (QKD)
• Quantum sensors for surveillance or early warning</td><td>Main differences
• SNS JU focuses on 6G-ready quantum communication enablers, not broad HPC/industrial quantum computing.
• CL3's emphasis on quantum for public-safety and PQC is not central to SNS JU

Commonalities
• Alignment on quantum-secure communications and network trust.
• Interest in early quantum networking technologies.</td></tr>
<tr><th colspan="3">HW/Devices</th></tr>
<tr><td>Smart industrial devices
• Industrial robots, advanced IoT.
• High-reliability (edge network) devices for factories
• Scalable sensor networks for production and logistics</td><td>Mission-oriented devices
• Drones, autonomous rescue robots
• Body-worn tech for first-time responders (vital signs, location)
• Environmental sensors for floods, fires, chemical hazards</td><td>Main differences
• SNS JU prioritizes network equipment, radios, antennas, not ruggedized emergency hardware.
• Device requirements for emergency response (CL3) do not exist in SNS JU.

Commonalities
• Interest in energy-efficient, secure hardware for next-gen networks.
• AI-embedded hardware intersects with SNS JU device-layer innovation.</td></tr>
<tr><th colspan="3">TN - NTN</th></tr>
<tr><td>6G-ready integrated networks
• Seamless TN + NTN integration for global coverage and ubiquity.
• High-capacity links for industrial requirements (e.g., low latency applications)</td><td>Mission-critical communications
• Backup connectivity in disasters (portable base stations, satellite fallback)
• Inter-agency communication standards (PPDR/MCX)</td><td>Main differences
• SNS JU focuses on 6G NTN integration for commercial networks; CL3 focuses on NTN for emergency/disaster scenarios.
• SNS JU emphasizes experimentation platforms, not crisis operations

Commonalities
• Strong alignment on TN/NTN convergence (CL4 - SNS JU)
• Shared priority: integrated terrestrial + non-terrestrial networks.</td></tr>
</table>

Sustainability		
Green digital transformation • Energy-efficient data centres & networks • Circular and repairable hardware • Reducing emissions in manufacturing via automation	**Climate resilience and protection** • Systems to forecast floods, wildfires, heatwaves • Hardening infrastructures against climate stress • Tools for emergency environmental response	**Main differences** • SNS JU targets network/service sustainability, not industrial (CL4) nor civil-protection resilience (CL3). • SNS JU focuses on energy-efficient 6G architecture, spectrum use, hardware efficiency. **Commonalities** • Energy and resource efficiency. • Need for sustainable, low-footprint infrastructures.
Business models and industrialization		
Data economy + service economy • Marketplaces for edge services • Pay-per-use infrastructure models • Data spaces as industrial assets	**Public-sector capability models** • Interoperable tools for civil and safety applications (e.g., police, fire, health). • Vendor-independent architectures • Long-term sustainment instead of profit models	**Main differences** • SNS JU is ecosystem-oriented, focusing on 6G value chains and EU industrial leadership, not just monetisation (CL4) or operational continuity (CL3). • SNS JU emphasises open platforms, multi-stakeholder collaboration **Commonalities** • Cost-effective, interoperable solutions. • Scalable architectures reducing CAPEX/OPEX. • New service models enabled by 6G, edge, and AI
Sovereignty		
Digital autonomy • Control over European cloud, chips, AI, data • Open-source and open tech stacks • Trusted hardware supply chains	**Societal sovereignty** • Protecting citizens' data and rights • Reducing dependence on emergency management tools • Trusted technologies for national security forces and first-time responders	**Main differences** • SNS JU focuses narrowly on network & service sovereignty (6G architectures, platforms, standards). **Commonalities** • Trusted systems. • Local/s sovereign data processing. • Privacy, security, resilience as cross-cutting priorities.

5.3.4 International Associations

An important part of the mandate of SNS CO-OP is to liaise with other international R&I organizations working on 6G across the entire globe and to facilitate bi-directional communication both to communicate the vision, work and achievements of the SNS community to the rest of the world, as well as receive input on the work, vision and achievements of other global reasons and cross-checking the alignment towards a global 6G standard. To achieve this goal the vast global network and the long-standing connections of 6G-IA with other regional 6G associations have been utilized. The current geo-political climate that has driven some of the major global stakeholders to withdraw from global synergies and to focus on their own sovereignty, does not assist in the creation of international collaborations across the entire world, however several active links remain open with the international stakeholders that were willing to cooperate, as will be reported in the upcoming deliverable of WP2 (D2.2).

This section provides a targeted analysis of the five main global regions of the world with R&I activities on 6G based on their recent publications and position papers, namely. **U.S.A (5G Americas)** [12][13][14][15][16]**, Japan (XGMF)** [17][18][19][20]**, India (TSDSI)** [21][22]**, China (IMT-2030 PG)** [23][24][25][26] **and South Korea (<u>Korean 6G Forum</u>)** [27][28]. As in previous sections, the position of these regional associations with regards to the targeted thematic areas has been attempted to be deciphered and to produce a commonalities / differences table with regards to the approach taken by SNS JU and European stakeholders (see Table 6).

<u>U.S.A (5G AMERICAS)</u>

- **Artificial Intelligence (AI):** 5G Americas positions AI/ML as the foundational and "AI-native" element of 6G networks, essential for managing the complexity of future systems. The vision involves deep integration of AI at every network layer—from the physical layer (optimizing beamforming) to the application layer—to enable intent-based, self-configuring, self-healing, and self-optimizing autonomous networks. The goal is to move towards zero-touch automation, cutting fault detection time and reducing false alarms significantly, which lays the groundwork for the extreme reliability required for 6G use cases.

- **Cloud/edge:** The vision for 6G involves an infrastructure built on cloud-native principles to manage the demands of new services and use cases. Edge computing will be critical to process the massive amounts of data generated by 6G applications, especially those requiring low latency like ISAC (Integrated Sensing and Communication) and industrial automation. This cloud-native, edge-based architecture will support distributed intelligence and dynamic resource allocation, ensuring the scalability and agility needed for future network demands.

- **Micro-electronics (incl. Front-End Module, FEM):** While there is no specific focus on FEM from 5G Americas, continuous advancements in microelectronics to support the high-frequency spectrum bands being explored for 6G is mentioned as one of the priorities. These hardware advancements are necessary to achieve the extreme performance targets and energy efficiency goals that will define 6G, balancing coverage and capacity as network densification increases.

- **(Cyber) Security:** 5G Americas emphasizes the necessity for robust security and trust frameworks to be integrated into 6G design from the outset. The move to intent-based autonomous networks requires robust "observability frameworks" to provide real-time visibility and security. The complexity and integration of new technologies like AI and ISAC necessitate a proactive approach to security risks, including the development of new techniques to safeguard data integrity and privacy across the more diverse and dynamic attack surface of 6G networks.

- **Sovereignty (incl. Trustworthiness):** A core position of 5G Americas is the imperative for North American leadership in 6G development and standardization to ensure regional "sovereignty" in technology and policy. This involves driving global standards and regulatory alignment to position the region as a pioneer and benchmark for best practices. Trustworthiness is a cross-domain requirement, built on a foundation of secure and resilient infrastructure that avoids data silos and ensures robust governance and multi-vendor interoperability.

- **Hardware/Devices:** The 6G vision supports a massive increase in device connectivity, from immersive experience devices (XR) to battery-less ambient IoT technologies. This requires enhanced IoT scalability and the ability to support diverse hardware with varying performance and energy requirements. The 6G infrastructure will need to support the integration of these vast numbers of devices, facilitating use cases in smart cities, industrial automation, and healthcare.
- **Quantum:** 5G Americas publications do not explicitly detail a quantum strategy in their 2024/2025 white papers on 6G vision. While post-quantum cryptography is an industry-wide consideration, their materials focus on AI, ISAC, and spectrum as the primary technological drivers.
- **Terrestrial Networks/Non-Terrestrial Networks integration (TN/NTN):** Seamless and ubiquitous coverage is a 6G KPI, which 5G Americas addresses through the integration of Non-Terrestrial Networks (NTN) with existing terrestrial infrastructure. This hybrid approach, advanced in 5G-Advanced Release 18 and beyond, uses satellite-based coverage to extend high-performance connectivity to underserved regions and support applications like public safety and defence, where consistent connectivity is critical.
- **Sustainability:** Sustainability is a key business outcome and design principle for 6G. 5G Americas advocates for designing energy-efficient networks with features like cell sleep modes, antenna switching, and discontinuous transmission to reduce power consumption. The vision is that intent-based, AI-driven automation will lead to energy optimization, aligning with societal environmental goals and delivering economic benefits through cost savings and improved operational efficiency. However, further sustainability aspects (beyond energy efficiency) especially touching upon societal and environmental sustainability are not directly addressed.
- **Business model evolution/Monetization:** 6G will unlock new revenue channels beyond traditional connectivity. 5G Americas highlights "Sensing as a Service" as a new monetization model, where operators offer enterprises valuable data from ISAC capabilities (location, movement, object recognition) via API-based platforms. Furthermore, 6G is expected to drive economic value through high-value use cases in industrial automation, healthcare, and transportation that improve efficiency and enable new data-driven services.

Japan (XGMF)

- **Artificial Intelligence (AI):** XGMF envisions AI/ML playing a critical role in 6G, moving from simple automation to enabling a truly "cognitive" network. AI will be integrated throughout the system for efficient network operation, resource optimization, and enhanced radio performance (e.g., beam management in THz bands). A core aspect is using AI to create and manage highly precise digital twins, which requires the convergence of communication, computing, and data processing enabled by machine learning.
- **Cloud/edge:** The XGMF vision necessitates an evolution of the network architecture towards a more flexible, distributed system based on cloud-native principles. Cloud and edge computing will be integral to handle the massive data volumes and diverse processing requirements of 6G use cases. Edge computing will be specifically utilized to ensure low latency and real-time processing for applications like high-resolution wireless sensing and industrial automation, supporting an intelligent, resilient, and high-performance network infrastructure.
- **Micro-electronics (incl. Front-End Module, FEM):** Advancements in microelectronics are foundational to achieving 6G's performance goals. XGMF specifically highlights the need for new device technologies capable of supporting the use of terahertz (THz) frequency bands (100 GHz and above). This includes research into high-frequency front-end modules (FEMs) and high-speed data converters, as well as novel antenna technologies like intelligent reflective surfaces (IRS) and distributed MIMO to manage propagation challenges and enable ultra-narrow spot beam communication.
- **(Cyber) Security:** Security is a fundamental design principle for 6G in the XGMF vision, emphasizing trustworthiness, resilience, and privacy from inception. Given the pervasive nature of 6G and the integration of new services like ISAC, the attack surface expands significantly.

The vision calls for research into robust, privacy-preserving technologies and resilient network design that can withstand failures and cyber threats, ensuring the integrity of communication and data essential for critical societal infrastructure.

- **Sovereignty (incl. Trustworthiness):** XGMF aims to establish Japan as a leading player in the development and standardization of Beyond 5G/6G technologies. This involves fostering a strong domestic industry and building global partnerships to ensure supply chain resilience and strategic autonomy. The goal is to drive international standards that reflect Japanese technological strengths and values, building a reliable and trustworthy ecosystem that can be globally deployed.
- **Hardware/Devices:** The 6G hardware ecosystem will expand dramatically beyond smartphones to include a vast array of connected devices. XGMF's vision supports diverse hardware, including autonomous vehicles, sophisticated industrial sensors, AR/VR devices, and high-resolution wireless sensing equipment. This requires new radio access technologies and massive device connectivity, facilitating enhanced IoT scalability and new device-to-device communication capabilities crucial for pervasive digital twin applications.
- **Quantum:** XGMF's publicly available vision documents for 2024-2025 generally focus on AI, ISAC, and spectrum as primary drivers. While post-quantum cryptography is an acknowledged industry-wide security challenge for the 6G era, their key publications do not lay out a specific, detailed strategy for integrating quantum technology itself into the 6G network architecture.
- **Terrestrial Networks/Non-Terrestrial Networks integration (TN/NTN):** Ubiquitous connectivity is a key performance indicator for 6G. XGMF promotes the seamless integration of Non-Terrestrial Networks (NTN), primarily through satellite communication (LEO/MEO/GEO), with terrestrial infrastructure. This hybrid network approach aims to provide global coverage, ensuring communication in remote areas, during disasters, and for maritime/aeronautical use cases, thereby increasing the overall resilience and reach of the 6G system.
- **Sustainability (societal, environmental, economic):** Sustainability is a core philosophical tenet of the XGMF vision, aiming for a human-centric 6G that contributes to solving societal issues and achieving the SDGs (Sustainable Development Goals). This includes the development of energy-efficient network architectures, from radio access to core network, to minimize the environmental footprint. The economic sustainability is driven by creating new value/solving challenges in areas like disaster prevention, energy management, and healthcare.
- **Business model evolution/Monetization:** XGMF views 6G as a critical platform for creating new economic value, moving beyond traditional mobile service subscriptions. New business models will be driven by innovative industrial use cases, such as high-resolution wireless sensing for digital twins, remote medical operations, and advanced industrial automation. The monetization strategy focuses on providing reliable, high-value, B2B vertical solutions and data-driven services that address specific industry needs.

India (TSDSI)

- **Artificial Intelligence (AI):** TSDSI views AI and Machine Learning (ML) as essential, "native" components of the 6G network, critical for managing complexity and enabling advanced functionalities. AI will be utilized across the stack, from the radio access network (RAN) to core services, to enable intelligent resource allocation, predictive maintenance, network self-optimization, and highly personalized services tailored to individual or group needs, moving towards fully autonomous network operation.
- **Cloud/edge:** The TSDSI 6G vision emphasizes a distributed, cloud-native network architecture. It promotes the use of Mobile Edge Computing (MEC) to bring processing power closer to the end-users and devices, which is critical for meeting stringent low-latency requirements for applications like tactile internet, real-time analytics, and industrial automation. This cloud-edge convergence is designed to improve efficiency, resilience, and scalability of the future network.

- **Micro-electronics (incl. Front-End Module, FEM):** A key part of the Indian 6G vision is achieving self-reliance and fostering indigenous R&D in hardware and microelectronics. This includes developing affordable, energy-efficient chips and front-end modules (FEMs) capable of operating in new frequency bands (e.g., in the 7-15 GHz range and sub-THz bands). The aim is to create an indigenous supply chain and reduce reliance on foreign technology, a strategic priority for national sovereignty.
- **(Cyber) Security:** TSDSI emphasizes a robust and multi-layered security framework designed to address the increased attack surface of 6G systems. The vision calls for research into innovative security solutions that support fine-grained data ownership, secure communication across heterogeneous networks, and the integration of privacy-preserving mechanisms. Security is seen as a continuous process embedded in the network design, not an add-on feature.
- **Sovereignty (incl. Trustworthiness):** A major driving principle for TSDSI is "self-reliance" (Atmanirbhar Bharat), positioning India as a co-creator rather than just a consumer of 6G technology. This involves establishing indigenous R&D and manufacturing capabilities to ensure strategic autonomy, supply chain resilience, and the ability to define national security and privacy requirements in the global standards framework. This focus aims to build a trustworthy national digital infrastructure.
- **Hardware/Devices:** The TSDSI vision supports a massive and diverse ecosystem of hardware and devices. Beyond smartphones, 6G is expected to connect billions of low-cost IoT devices for smart agriculture and logistics, as well as high-performance hardware for immersive AR/VR, haptics, and autonomous vehicles. The network design must accommodate this vast range of capabilities, cost points, and energy consumption requirements.
- **Quantum:** TSDSI publications acknowledge the threat that quantum computing poses to current encryption standards. While not detailing specific quantum hardware integration strategies for the access network itself, they do highlight the importance of security research into post-quantum cryptography (PQC) and quantum-safe algorithms to ensure the long-term data integrity and confidentiality of the 6G infrastructure and its applications.
- **Terrestrial Networks/Non-Terrestrial Networks integration (TN/NTN):** Ubiquitous and affordable connectivity across India is a primary goal. TSDSI promotes the seamless integration of terrestrial networks with non-terrestrial networks (NTN), including satellites and high-altitude platforms (HAPS). This hybrid approach is essential for bridging the digital divide by providing coverage in remote, rural, and difficult-to-reach areas, and enhancing overall network resilience during natural disasters.
- **Sustainability:** Sustainability in the TSDSI vision is heavily focused on the economic and societal impact, driven by the need for affordable access. The goal is to design energy-efficient networks that are both environmentally conscious and economically viable for a broad population. By enabling services in healthcare, education, and agriculture, 6G aims to facilitate sustainable economic growth and societal inclusion across India.
- **Business model evolution/Monetization:** 6G is viewed as a platform for significant economic transformation, enabling new business models in high-value verticals. TSDSI expects a shift from consumer-centric services to B2B and B2B2X models in sectors like e-governance, logistics, and smart infrastructure. The vision is to generate new revenue streams by providing ultra-reliable, low-latency, and high-throughput services that transition India's digital economy to the next level.

China (IMT-2030 PG)

- **Artificial Intelligence (AI):** The IMT-2030 Promotion Group envisions AI as a natively integrated, pervasive component of 6G networks, enabling the "Intelligent Connectivity of Everything." AI will power autonomous network operation, from intelligent resource scheduling to self-optimization and predictive maintenance. This deep integration aims to achieve high levels of automation and support new intelligent applications like digital twins and integrated sensing.

- **Cloud/edge:** The vision for 6G architecture is a converged, cloud-native infrastructure that seamlessly integrates communication, computing, data storage, and AI. This distributed approach emphasizes the integration of mobile edge computing (MEC) to process vast amounts of data locally, ensuring ultra-low latency and high reliability required for industrial control, autonomous driving, and immersive extended reality (XR) applications.
- **Micro-electronics (incl. Front-End Module, FEM):** Advancements in microelectronics are considered crucial for enabling 6G's physical layer capabilities. The IMT-2030 group highlights R&D efforts in new hardware components to support higher frequency bands, such as terahertz (THz) communication, and the development of intelligent reconfigurable surfaces (IRS) and advanced antenna arrays. The goal is to develop highly efficient, high-performance hardware to meet the extreme performance targets of 6G.
- **(Cyber) Security:** The IMT-2030 Promotion Group emphasizes the need for a robust, "built-in" security system for 6G that addresses the holistic security requirements of a connected intelligent world. This involves research into security architectures that ensure data privacy, confidentiality, and integrity across the complex, heterogeneous network environment, protecting both national infrastructure and end-user data.
- **Sovereignty (incl. Trustworthiness):** A core objective is to position China as a global leader in 6G technology, driving international standards and fostering indigenous innovation to ensure technological "self-reliance" and national security. The vision promotes a trustworthy and resilient network infrastructure that adheres to national requirements, ensures supply chain stability, and establishes China's strategic autonomy in the future communications landscape.
- **Hardware/Devices:** The 6G hardware ecosystem is expected to be incredibly diverse. The IMT-2030 vision supports a vast array of devices beyond smartphones, including smart surfaces, autonomous vehicles, industrial robots, and immersive AR/VR gear. The network must be capable of supporting extreme device densities and a wide range of data rates and energy requirements across this heterogeneous landscape.
- **Quantum:** While specific network integration details are less emphasized in public vision papers, the IMT-2030 group acknowledges the future threat of quantum computing to current encryption standards. Research efforts in the broader Chinese technology sector include the development and integration of post-quantum cryptography (PQC) and exploring potential synergies between quantum information and classic communication systems for enhanced security.
- **Terrestrial Networks/Non-Terrestrial Networks integration (TN/NTN):** Ubiquitous global coverage is a key 6G requirement. The vision promotes the seamless integration of terrestrial networks with non-terrestrial networks (NTN), including low-earth orbit (LEO) satellites and high-altitude platforms (HAPS). This hybrid approach aims to provide continuous connectivity in rural and remote areas, enhance disaster relief communication, and support global maritime and aeronautical services.
- **Sustainability:** Sustainability is a fundamental principle, focusing on building an energy-efficient 6G network to support environmental goals and green applications. The IMT-2030 vision aims for reduced energy consumption per bit through architectural optimization, advanced hardware, and AI-driven efficiency. The economic sustainability is driven by the creation of new market opportunities and the digital transformation of various industries.
- **Business model evolution/Monetization:** 6G is expected to drive the evolution of business models by shifting towards integrated information services. Monetization will come not just from connectivity but from enabling high-value B2B services in verticals like intelligent manufacturing, smart cities, and autonomous transport. The vision focuses on providing tailored network capabilities as a service (NaaS) to industries, creating significant new economic value.

Korea (Korean 6G Forum)

- **Artificial Intelligence (AI):** Korean organizations envision an "AI-native" 6G network where machine learning is fundamental to all operations. AI will be deeply integrated into the entire network lifecycle, from resource management and beamforming optimization to zero-touch autonomous network operations. The goal is to create highly intelligent and self-sustaining systems that adapt to complex demands, ensuring efficiency and enabling new AI-services.
- **Cloud/edge:** The vision for 6G architecture is a fully cloud-native network with an emphasis on integrated edge computing. The goal is to create a distributed and flexible infrastructure that supports the demanding performance requirements of new 6G services, such as ultra-low latency for real-time control and high throughput for immersive applications. This architecture will facilitate the seamless integration of computing and communication resources.
- **Micro-electronics (incl. Front-End Module, FEM):** Advancements in microelectronics are a strategic priority to enable new frequency bands and performance targets. Korean R&D focuses on developing advanced hardware components, including high-efficiency power amplifiers and front-end modules (FEMs) for the sub-terahertz (sub-THz) bands (e.g., 70-300 GHz). The objective is to secure indigenous technology for these critical components to reduce reliance on foreign suppliers.
- **(Cyber) Security:** The Korean vision for 6G incorporates a holistic and robust cybersecurity framework integrated into the network design from the outset. Emphasis is placed on developing resilient architectures that protect against emerging threats across the expanded 6G attack surface. This includes research into advanced encryption, authentication mechanisms, and intrusion detection systems to ensure the trustworthiness and integrity of critical infrastructure.
- **Sovereignty (incl. Trustworthiness):** Korea's "K-Network 2030" strategy aims to secure a leading position in the global 6G market, ensuring technological sovereignty and strengthening the domestic supply chain. The goal is to develop indigenous core technologies and drive international standardization efforts to establish global leadership. This focus on self-reliance ensures security and trustworthy digital infrastructure, meeting regulatory requirements.
- **Hardware/Devices:** The 6G ecosystem is expected to support a vast range of diverse hardware beyond smartphones. The vision includes devices for immersive media (AR/VR), intelligent sensors for smart cities and factories, and advanced robotic systems. The network must be capable of supporting the massive increase in connected devices and provide the necessary performance metrics (high reliability, low latency, energy efficiency) tailored to each specific device type.
- **Quantum:** While quantum computing is acknowledged as a future threat to current cryptography, publicly available Korean 6G vision documents from 2024-2025 primarily focus on the development of post-quantum cryptography (PQC) and quantum-safe security measures to protect 6G communication. The vision for integrating actual quantum communication technology into the 6G access network architecture, is less defined in these documents.
- **Terrestrial Networks/Non-Terrestrial Networks integration (TN/NTN):** Ubiquitous and continuous connectivity is a key performance target. The Korean vision emphasizes the seamless integration of terrestrial networks with non-terrestrial networks (NTN), including LEO satellites and aerial platforms. This hybrid approach ensures coverage in difficult terrains (maritime, aerial, remote areas) and enhances network resilience in disaster scenarios, supporting a truly global connectivity infrastructure.
- **Sustainability:** Sustainability is a primary consideration in the K6GF vision, focusing on achieving energy efficiency and contributing to environmental goals. R&D efforts are directed towards "green" 6G technologies, network energy optimization strategies, and using 6G applications to enable a low-carbon society (e.g., smart grids, efficient logistics). The goal is to balance economic growth with environmental responsibility.
- **Business model evolution/Monetization:** 6G is seen as an engine for new economic growth, moving beyond traditional mobile service revenue. The Korean strategy focuses on enabling high-value vertical industries, such as smart factories, autonomous driving, immersive

entertainment, and digital healthcare. New business models will revolve around selling specialized network services and capabilities (NaaS) tailored to enterprise needs, generating significant new market value.

According to the above-presented findings, there seems to be significant alignment among international associations in most thematic areas, while some differences in approach and focus can also be detected in certain areas, depending on the exact expertise and socio-economic focus of each region. The ***thematic areas presenting the largest degree of alignment*** among international associations, with little to no variation in their vision seem to be:

- **Artificial Intelligence (AI):** This is globally treated as one of the critical building blocks of 6G networks with pervasive characteristics in all aspects of future networks. All international associations are placing AI at the top of the research priorities.
- **(Cyber) Security:** All associations mention that 6G networks will increase the potential area of attack, and novel secure by design architecture and mechanisms are of paramount importance to ensure the security, resilience and privacy of data.
- **Hardware/Devices:** All international associations are well-aware that the device/HW ecosystem of 6G networks will be significantly extended and that 6G should be able to handle large numbers of diverse devices simultaneously, including support for novel affiliated technologies and devices such as IoT.
- **TN/NTN integration:** This is another front where international associations unanimously agree that will be one of the key characteristics of 6G networks in order to ensure global, uninterrupted ubiquitous coverage.
- **Business model evolution/Monetization:** No specificities are provided by any of the associations, but they all count on 6G to be a force of significant market developments enabling a whole suite of new applications, use cases and markets, offering possibilities to capitalize on new technologies (such as ISAC) and broadly enabling aaS ecosystems.
- **Quantum:** Even though the role of quantum computing and related technologies in 6G networks is not specifically mentioned by any of the associations, they all mention that Post-Quantum Cryptography is an aspect than needs to be reckoned with, and seem to be keeping relevant quantum developments in their radar.

Besides these areas where there seems to be almost absolute alignment among the international associations, there is a second group of areas, where a significant degree of alignment is observed but some different approaches can also be detected. Those are:

- **Cloud/edge:** The need for network edgification and move of resources closer to the device is mentioned by all, however a difference in approach can be detected especially by Europe (and Japan) where the concept of 3CN is highlighted as the main way forward.
- **Micro-electronics**: This is another are where all associations are placing significant importance, however small differences in the exact spectrum targeted and/or devices can be detected per region. Moreover Europe, Japan, India and Korea seem to place special interest on FEM.
- **Sustainability**: This theme is also universal, however certain associations seem to focus mostly on sustainability from the energy efficiency perspective (U.S.A, China) while others are examining additional aspects such as societal and economic sustainability.

Finally, **Sovereignty** deserves a special mention, as it was interesting to observe that all associations refer to their "National" sovereignty and the industrial leadership from their side (based on leading relevant standardization processes) as a key goal going forward. On one hand this makes a lot of sense as the recent pandemic highlighted the dependency issues of the global supply chain, however, such approaches also stand to create silos and limit synergies and collaborations which should be avoided at all costs.

Table 6 provides an overview of the key focus are per international association for each thematic area.

Table 6: Overview of international associations views/vision on the selected thematic areas

Thematic Areas	5G Americas (North America)	Japan (XGMF)	India (TSDSI)	China (IMT-2030 PG)	Korea (K6GF)	Commonalities/Differences with SNS JU
Artificial Intelligence (AI)	AI-native network design, integrated across all layers for autonomous network management, zero-touch automation, and self-optimization.	AI/ML as core enablers for radio tech, network operation, and creating detailed "digital twins".	AI-native across RAN/Core for intelligent resource management and personalized services.	Pervasive AI for "Intelligent Connectivity of Everything," autonomous network operation, and enabling digital twins.	AI-native network for full lifecycle automation and resource optimization.	**Commonalities:** All regions prioritize AI as native to the network and essential for automation and efficiency. **Differences:** No major differences observed (SNS JU emphasizes European values, data governance, and AI explainability within its projects)
Cloud/edge	Cloud-native architecture with critical edge computing for low-latency services like ISAC.	Distributed, cloud-native architecture leveraging MEC for low-latency processing of wireless sensing data.	Distributed, cloud-native architecture with strong MEC emphasis for low-latency applications across India.	Converged cloud/edge architecture integrating compute and storage to support ultra-low latency and high reliability.	Fully cloud-native with integrated edge computing for real-time control, immersive apps, and enhanced resilience.	**Commonalities**: Universal focus on cloud-native and edge computing for latency and reliability. **Differences**: SNS JU explicitly promotes "Connected Collaborative Computing (3Cs) Networks" and an open-source European cloud framework (Project Sylva) to ensure interoperability and reduce reliance on non-EU hyper-scalers.
Micro-electronics	Focus on using the 7.125–8.400 GHz "Golden Band" for coverage/capacity balance.	Focus on new devices for Terahertz (THz) frequencies and Intelligent Reflecting Surfaces (IRS).	Focus on indigenous R&D and manufacturing of affordable chips/FEMs for new bands to achieve self-reliance.	R&D in new components for THz communication, IRS, and advanced antenna arrays.	R&D priority on advanced FEMs for sub-THz bands to secure indigenous supply chain.	**Commonalities**: Universally treated as a cornerstone of 6G to 'tap' into new spectrum. **Differences**: SNS JU R&I efforts place strong emphasis on integrated photonics and optical networks for energy efficiency and high capacity.

Cyber-Security	Robust, built-in security and observability frameworks to safeguard data integrity and privacy.	Fundamental design principle; research into privacy-preserving technologies and resilient network design.	Multi-layered security framework with focus on data ownership granularity and national compliance.	"Built-in" holistic security protecting privacy, confidentiality, and integrity across the network.	Holistic framework integrated from design stage, focusing on resilience and encryption.	**Commonalities**: All regions embed security as a fundamental design principle. **Differences**: Only minor scope differences, e.g., SNS JU emphasizes security under the umbrella of EU policies and regulations (e.g., GDPR),
Sovereignty	Drive North American leadership in standards; ensure strategic autonomy and avoid ceding ground to competitors.	Establish international leadership and domestic industry strengthening through collaboration.	Achieve "self-reliance" through indigenous R&D and standards co-creation.	Position China as global leader, drive standards, ensure technological "self-reliance" and supply chain stability.	"K-Network 2030" strategy to secure leadership and indigenous core technology.	**Commonalities**: Every region aims for supply chain independence and leadership position in standardisation for strategic autonomy. **Differences**: Each association is targeting their own sovereignty (which may oppose that of others).
Hardware/Devices	Support for diverse hardware (XR, industrial IoT, NTN); emphasis on new service models like ISAC.	Support for massive IoT, AR/VR, autonomous vehicles, industrial sensors; need for new radio access technologies.	Support vast, diverse ecosystem including low-cost IoT for agriculture and high-performance AR/VR gear.	Supports diverse devices from smart surfaces to industrial robots and AR/VR; enables massive device densities.	Supports immersive media, smart sensors, robotics; requires specific performance metrics tailored to each device type.	**Commonalities**: All visions support a massive increase and diversity of connected hardware beyond smartphones. **Difference**: SNS JU focuses on specific R&I to regain ground on core technologies for special-purpose end-devices and ensures their compliance with EU policies.
Quantum	Acknowledges future threat to crypto; no specific *network integration* plan in general papers.	No specific *network integration* plan mentioned; general acknowledgment of PQC necessity.	Research into post-quantum cryptography (PQC) is emphasized as a security requirement.	Acknowledges threat; PQC development and potential synergies with quantum information for security.	Focuses on PQC and quantum-safe security measures; no detailed *network integration* plan.	**Commonalities**: Superficially treated by all, simply mentioning PQC. **Differences**: No specific differences detected, as subject is superficially

						treated.6G-IA to host a dedicated WS on Quantum in Q1 2026.
TN/NTN integration	Hybrid approach using satellites for ubiquitous coverage, public safety, and defence applications.	Seamless global connectivity via integration of satellites (LEO/MEO/GEO) with terrestrial infrastructure.	Essential for bridging the digital divide across rural areas using satellites and HAPS; enhances resilience.	Deep integration of terrestrial with NTN (LEO, HAPS) for global, ubiquitous coverage and disaster relief.	Seamless integration of TN/NTN (LEO sats) for continuous connectivity in difficult terrains and disaster scenarios.	**Commonalities**: All regions view NTN integration as vital for achieving ubiquitous coverage, resilience, and bridging the digital divide. **Differences**: EC/SNS JU office teaming up with the European Space Agency (ESA) for coordinated R&I in this area.
Sustainability	Focus on energy-efficient technologies, AI-driven energy optimization, and alignment with environmental goals. No mention of other forms of sustainability (beyond energy efficiency)	Fundamental principle; human-centric, energy-efficient design contributing to societal challenges and SDGs.	Focus on economic and societal impact; affordability as key for widespread access and sustainable growth.	Fundamental principle; energy efficiency to support environmental goals and green applications.	Focuses on energy efficiency, "green" tech R&D, and using 6G apps to enable a low-carbon society.	**Commonalities**: All regions prioritize sustainability focusing on energy efficiency. **Differences**: SNS JU emphasizes both "Sustainable 6G" (making the network green) and "6G for Sustainability" (using 6G to enable green use cases in other sectors), often linking this explicitly to the European Green Deal. Societal and economic sustainability are also treated.
Business model	"Sensing as a Service" (SaaS) and high-value B2B verticals.	Creation of new value streams and monetization via wireless sensing for digital twins and industrial use cases.	Transition to B2B and B2B2X models; focus on providing NaaS (Network as a Service).	Shift towards integrated information services; monetization via NaaS and high-value verticals.	Focus on new growth engines via B2B verticals like smart factories, autonomous driving; provide NaaS.	**Commonalities**: All anticipate a significant shift to B2B/B2B2X and NaaS models. **Differences**: Specific focus on targeted sectors that are important per region.

5.3.5 EU National Initiatives

While there is significant funding available at the European level for research and innovation activities, SNS ICE identified that large funding has also been allocated at the National level in various member states towards the development of beyond 5G and 6G technologies. The cumulative funding of the national programmes outweighs the funding that was made available at the European level or through SNS, and this led to the identification of the European National Initiatives as an important contributor. SNS CO-OP now continues with the activities established in SNS ICE, including regular online collaboration meetings with the national initiative representatives of the identified member states; namely, **the Netherlands, Italy, Spain, Finland, Germany, Sweden, Ireland, France**, and the **UK**. Based on the discussions conducted with the NIs, the following can be said about the position of the national initiatives with regards to the targeted thematic areas.

Artificial Intelligence (AI)

The potential of AI is well recognized in the National initiatives, and several initiatives incorporate work on AI in some form. In Ireland, the CONNECT centre has a set of themes and a working group associated with each theme. One of these themes is 'AI-driven Network Customisation' which focuses on creating customised networks where resources can be sliced and stitched together to provide an end-to-end network substrate with an allocation and configuration of resources to suit niche operators. Within the national programme of the Netherlands, the program line 2 focuses on AI network automation and digital twins. Within the Italian national Initiative, Restart, work is organized in 8 spokes. Within Spoke 5 on 'Industrial and Digital Transition Networks' one of the areas of work is the design of AI-based network architectures and systems for industrial applications. Similarly, in Spoke 8 on 'Intelligent and Autonomous Systems', work is carried out on merging AI and communication technologies to enable intelligent services operating at the edge of the network.

In France, in the strategic priorities of the France 2030 programme, one of the identified points is to stimulate training, research and uses in artificial intelligence and its adoption by the whole of French society. Lastly, in the 6G Flagship in Finland, in the strategic area on 'Distributed Intelligence' work is being carried out on distributed AI. A co-creation session held with the national initiative representatives at Techritory 2024 identified AI / Intelligent agents as an area of work that needs more attention in Europe.

Cloud/edge - 3CN

Structured interviews were conducted with the national initiatives where they had the opportunity to indicate how much focus is put on a certain topic in their initiative. Most of them indicated that Edge and Ubiquitous computing is a primary focus area, while only three said that this topic receives moderate focus. None of the initiatives said this is a low priority or that they do not work on this. This was verified during the co-creation session with the national initiative representatives during Techritory 2024, where all participants indicated to be working actively on the cloud continuum and related activities.

Within the Dutch national initiative, program line 2 focuses on developments in the cloud and edge. Within spoke 6 of the Italian national initiative on 'Innovative Architectures and Extreme Environments', work is carried out on architectural components and interfaces that support inter-domain cloud continuum services. Simultaneously, spoke 8 on 'Intelligent and Autonomous Systems' is working on advanced edge-computing architecture. In Finland, the strategic area on 'Distributed Intelligence' is also focusing on computing on the edge-to-cloud continuum. In the France 2030 programme, one of the strategic priorities is to create a French and European technological alternative that makes France a sovereign economic power in the cloud. The PEPR programme has focus on cloud-based and mobile edge cloud based, among other things.

The topic of the Connected, Collaborative Computing Network or 3CN has also gained a lot of traction and is fast becoming an important topic of focus in many member states. Currently, discussions are ongoing with various NI representatives to see how they are working on these developments.

Micro-electronics (incl. Front-End Module, FEM)

Several national initiatives have indicated during interviews that microelectronics is one of the primary focus areas in the initiative. This includes Germany, Finland, Sweden, Ireland, France and the Netherlands. At the time of interviews, Italy had mentioned that it is a low focus area for them. Spain had indicated that they do not work on this in the 6G initiative but there a different program, PERTE Chip project (axis 11) that addresses Microelectronics.

Within Sweden, one of the Competence Centres, ACT, is focusing on advanced chip technology through new processes and methods. The research targets high-speed-electronics, opto-electronics and power electronics. The centre is hosted by Lund University and KTH, Royal Institute of Technology in Stockholm. Within the Netherlands, there is a dedicated program line of Intelligent Components which works on highly efficient transmitters, joint communication and sensing technology, over-the-air testing, and optical wireless communication. This programme line is mainly driven by the microelectronics industry in the Netherlands. Within France, this is topic is addressed in the national strategy of Electronics.

Cyber-Security

While all national initiatives indicated that they work on network and service security, only few have this as a low focus area. This includes the Netherlands and Italy. Finland, Germany, Sweden and Ireland have indicated that this a high focus area for them. However, at the co-creation session at Techritory in 2024 it was identified that security is one of the topics that is lagging behind in Europe and a recommendation for further strengthening of the R&I work on this was made. The recommendation included addressing security by design. It was noted that in the past rounds of SNS calls, there is only one call on Security which is a 'catch all' for all kinds of security techniques. But security is missing in the other calls. It was recommended that every call should have security integrated into it as one of the aspects in order to promote 'Security by Design'.

Within the currently active work on security, Sweden has a Competence Centre, NextG2Com, focused on advanced communication systems including radio-based communication and networks, as well as software, data, cyber security and applications. The centre is hosted by Lund University. Within France, this topic is addressed in the PEPR 'Network support to global security'. In Ireland, work on cybersecurity is one of the themes of the CONNECT centre and has a working group associated with it. The work is focused on the pivotal concept of trust in network connectivity.

Sovereignty (incl. Trustworthiness (security, trust, resilience, privacy)

The changing geopolitical climate has once again refreshed the discussion on the need for digital sovereignty, including aspects like resilience, trust, etc. This is also reflected in the current ongoing discussions with the national initiatives. A podcast[12] recently recorded with the national initiative representatives of France, Finland, Ireland and the Netherlands on the topic of Resilience goes into detail on the work being done by their initiatives on ensuring resilience in their societies through 6G. Finland has been especially insisting on this, and recently held the 6G Resilience Summit in Oulu, Finland (17-18 November, 2025).

Within the Dutch national initiative, digital autonomy, reliability, and sustainability are the core values that are driving the programme. Within program line 3 of the initiative, work is being done to ensure resilience of the energy grid. Within the UNICO 6G R&D in Spain, funding is available from Recovery and Resilience plan fund which holds the aim to achieve digital sovereignty for Europe. Within the German national programme, there is a dedicated working group (WG5) on Security, Resilience, and Trustworthiness. In addition, there are several 6G Projects on Resilience which focus on the resilience of communication infrastructure and digital systems, and system architecture, technologies and modules (hardware and software), and network management aspects are addressed. Within the Italian national initiative, trustworthiness is addressed in Spoke 4 on 'Programmable Networks for Future Services and Media'. Spoke 6 addresses 'Innovative Architectures and Extreme Environments', design and development of full-stack architectures, algorithms, and technologies fitting extreme environments in terms of KVI requirements like robustness, reliability, heterogeneity, and energy-efficiency.

Hardware/Devices

Work on devices and components is not as active in the national initiatives as the other topics. Some countries like Finland, Germany and Ireland have indicated that they focus on this heavily, while

[12] https://rss.com/podcasts/sns-co-op-podcasts/

countries like Spain have indicated that they have no work ongoing on this.

In terms of specific efforts that are active here, Italy's Spoke 3 on 'Wireless Networks and Technologies' is working on developing a new generation of high-frequency technology components (mixers, detectors, RF chips for highly integrated systems, radiating elements and arrays). In the Finnish 6G Flagship, the strategic area on 'Devices and Circuit technology' also focuses on Radio hardware. In the Swedish Competence Centre, WiTech, work is carried out on energy efficient semiconductors as well as advanced antennas and sensors.

Quantum

Quantum is a relatively new topic for most countries and does not feature prominently in most of the national initiatives on 6G. However, some of them have efforts active in this regard. Within Ireland, one of the themes and its associated working group on 'Quantum & Satellite Communications' is working on new technologies that are offering transformative solutions for secure and high-speed data transmission. France 2030 has a strategic priority that focuses on capitalizing on France's scientific excellence in the field of quantum technology to fulfil France's potential of becoming a leading technological and industrial player. Within the Netherlands while Quantum is not a topic in the 6G national initiative, a dedicated national programme funded by the Ministry of Economic Affairs and Climate Policy called Quantum Delta NL is working towards making the Netherlands a leading player in Quantum technology.

Terrestrial Networks/Non-Terrestrial Networks integration (TN/NTN)

Non-Terrestrial Networks is an important focus area in most national initiatives, such as, Italy, France, Spain, and Germany. On the other hand, Ireland and the Netherlands have indicated that they either do not focus on NTN technologies or the work is limited.

In Ireland, the theme and associated working group on 'Quantum & Satellite Communications' is working on new technologies that are offering transformative solutions for secure and high-speed data transmission. In Italy, in the Spoke 2 on 'Integration of Networks and Services', work is being done on designing a 3D multi-layered communication architecture for integrated TN/NTN networks, supporting novel 6G-oriented use cases with specific QoS and energy requirements. Alongside, work on conceiving and evaluating novel transmission techniques and advanced network and service orchestration frameworks for integrated T/NT networks is also done.

At the co-creation event at Techritory in 2024 it was noted that bilateral collaborations between national 6G Initiatives work very well in realising work on certain topics. One successful example of such bilateral collaboration is the work on 6G non-terrestrial networks for which a 6G-Sky consortium has been formed which is applying for Celtic funding from a number of national governments. However, it was also noted that Celtic funding is not available in all countries.

Sustainability (societal, environmental, economic)

Sustainability has been identified as an important theme in the national initiatives and is being worked on in at least some capacity by all NIs. In Sweden, a Competence Centre, SEDDIT, is focusing on sensor information and decision-making for digital transformation. Climate change and security is in focus by developing autonomous systems and mathematical methods. The centre is hosted by Linköping University. Additionally, the SweWIN - Swedish Wireless Innovation Network, also a Competence Centre, has focus on sustainability and energy efficiency in wireless communication, and applications based on sustainable materials. The centre is hosted by KTH, Royal Institute of Technology in Stockholm. In Ireland, a theme along with its associated working group on 'Network Ecologies' believes that telecommunication networks and the research that produces them exist within, and as part of, larger social and environmental networks. Network Ecologies brings research from broad disciplinary contexts into networks research. In addition, Sustainability is crucial aspect of the research conducted at CONNECT, and often embedded as a part of the research in projects.

In the Netherlands, sustainability is one of the core values driving the national programme. In Italy, Spoke 7 in focusing on 'Green and Smart Environments'. In Finland, 'Human centric wireless services' is working on Sustainability, business, and regulation. There is also a dedicated project (with its own funding) under the 6G Flagship umbrella, called the 6G-Enabled Sustainable Society (6GESS) program. Within Germany, the WG2 'Societal perspective' focuses on sustainability and participation. In France, the French national strategy also addresses sustainability issues, for example in the PEPR in 'Work Package 2: energy-efficiency of future network infrastructures' and 'WP3: sobriety of EMF exposure and of energy consumption'.

Business model evolution/Monetization

Many national initiatives work actively on supporting SMEs, creating patents, participating in standardisation, and creating paths to commercialisation, etc.

In Sweden, SMEs are an integral part of the program. One of the partners of the programme is SISP which focuses on start-ups. The goal of the organization is to develop the world's most effective innovation ecosystem by adding connectivity between its members and Sweden's leading universities, companies, public organizations, customer and exit markets. Additionally, 'CoDig Continuous Digitalization' is a Competence Centre with a vision of a substantial increase of enterprise competitiveness through transformation of software intensive industries to continuously deliver increased value based on next generation of data and communication infrastructure. Within the Netherlands there is a program line dedicated to 'Strengthening the Ecosystem'. It focuses on the overall 6G ecosystem through various activities, such as, setting up a national 6G testbed, technology-policy co-development, supporting start-ups and SMEs, standardization and international collaboration, etc. In Finland, the 'Human centric wireless services' strategic theme includes work on business and regulation.

In France, the 'Frame xG' is the result of the call for proposals 'Maturation and Pre-maturation'. It focuses on technology transfer from research to industry via the creation of a patent factory. This project focuses on the transfer of technologies and the creation of companies by research organisms and valorisation structures, on the one hand. On the other hand, Frame xG will provide guidance to national stakeholders with regards to the standardization of their IP assets. In Germany, WG3 on 'Maximizing impact' focuses on involving vertical industries, SMEs, and management of innovation; whereas WG4 on 'Building a global 6G vision' focuses on building the vision, use cases, and roadmaps for 6G.

In Ireland, SME-centred innovation is supported through a coordinated national ecosystem linking EDIHs, Technology Gateways, clusters, and regional research institutes. ENTIRE, Ireland's Seal of Excellence EDIH hosted by SETU, plays a central role by providing Test-Before-Invest services, skills development, investment-readiness support, and ecosystem brokerage for SMEs and public organisations. Working closely with Enterprise Ireland, regional clusters, and SETU's research centres, ENTIRE enables digital transformation, technology validation, and early-stage commercialisation, particularly in agrifood, advanced manufacturing, and rural enterprise. Ireland's model emphasises technology transfer, access to testbeds, regulatory and data expertise, and alignment with Smart Specialisation priorities, ensuring SMEs can adopt next-generation digital tools. ENTIRE also contributes to European-level coordination through thematic working groups, cross-border EDIH collaborations, and participation in EU digitalisation initiatives, reinforcing Ireland's position in the wider European innovation landscape.

5.3.6 EU Peer Associations

The success of Europe's digital future depends on effective collaboration, and Peer Associations and Joint Undertakings (JUs) are essential partners when shaping this future. Therefore, identifying the most relevant peer associations and JUs is the crucial first step for the SNS JU. This approach not only fosters collaboration and enriches the digital ecosystem but also helps harmonize objectives and prevent unnecessary duplication of efforts.

Building on the thematic areas outlined in Section 5.1, this section seeks to identify and list the most relevant actors in each area. The goal is to pinpoint potential Peer Associations and Joint Undertakings which the SNS JU can collaborate or has already established collaboration with, and their vision regarding the different topics analysing their publications.

Artificial Intelligence (AI)

The most recent and influential European association in the field of Artificial Intelligence is the **AI, Data and Robotics Association (Adra)**[13] which represents the private sector within the AI, Data and

[13] AI, Data and Robotics Association https://adr-association.eu/

Robotics Partnership under Horizon Europe and has among their founding members stand three major European associations in the field of AI: EurAI[14], CAIRNE[15], and ELLIS[16]. Adra has released three position papers worth mentioning in the last years:

- **Strategic Research, Innovation, and Deployment Agenda (SRIDA)** [29]: the agenda advocates for a responsible, green digital transformation powered by AI, Data, and Robotics while fostering a sustainable, secure, and prosperous society grounded in European values (e.g., sovereignty). The document emphasizes Europe's potential to scale up and actively participate in the development of large AI models, addressing current limitations in size and complexity compared to global competitors. While generative AI has advanced rapidly in text and image generation, future opportunities lie in sound, video, and full multimedia production, as well as neuro-symbolic AI for trustworthy systems and generative AI for robotics. Achieving this vision requires aligning regulation with innovation and investing strategically to ensure compliance and competitiveness. Europe must take calculated risks to leverage its resources and capabilities, positioning itself for global impact and delivering significant benefits for both society and the climate.
- **Policy Paper and Technology Roadmap: GenAI and Robotics 4EU** [30]: This policy paper underscores Europe's opportunity to lead in the convergence of Generative AI and robotics, combining cognitive adaptability with physical capabilities to transform sectors such as manufacturing, healthcare, agriculture, and security. It advocates for a "Blue Ocean" strategy to drive innovation, supported by robust data and computational infrastructure and advancements in mechatronics. Open-source technologies are highlighted as essential for creating digital commons and reinforcing technological sovereignty. Rather than replicating U.S. or Chinese models, Europe is urged to pursue a distinctive path aligned with its cultural and societal values. Trustworthiness, ethics, and frugality are positioned as core principles to ensure sustainable and responsible leadership. Overall, the roadmap envisions Europe as a global leader in GenAI and robotics through strategic investment, collaboration, and value-driven innovation.
- **AI-powered robotics Strategy for Europe** [31]: The paper outlines a vision of a European digital future where AI-powered robotics revolutionize industry, infrastructure, and the economy by merging advanced software and hardware technologies without compromising safety, security, or privacy. These robotics solutions will serve critical sectors such as manufacturing, healthcare, agriculture, mobility, and social applications, acting as versatile tools that enhance human activities. Built on frugal and sovereign technologies, they aim to protect strategic independence while upholding European values. The resulting paradigm will prioritize robustness, trustworthiness, and ethical design, ensuring systems are both valuable and secure. A dynamic European robotics ecosystem, supported by international partnerships, will deploy these innovations globally.

The **Confederation of Laboratories for Artificial Intelligence in Europe** (**CAIRNE**[17] or formerly CLAIRE) is formed by more than 500 members labs, institutions and companies that form the Research and Innovation Networks. Three papers summarize the vision from CAIRNE regarding AI for Europe, and their vision on the steps needed to regain the position of worldwide front runners in AI:

- **Statement on Future of AI in Europe: "AI made in Europe"** [32]: The statement warns that Europe is rapidly losing ground in AI, becoming dependent on technologies developed outside the region, which threatens its economic, strategic, and cultural sovereignty. Current investments in European AI have been insufficient and fragmented, leaving Europe without the massive, unified computational infrastructure needed for global competitiveness. CLAIRE argues that regulation alone cannot solve this problem; instead, Europe must urgently launch a large-scale, coordinated initiative to ensure leadership in trustworthy, human-cantered AI.

[14] European Association for Artificial Intelligence https://www.eurai.org/

[15] Confederation of Laboratories for Artificial Intelligence Research in Europe https://cairne.eu/#down

[16] European Laboratory for Learning and Intelligent Systems https://ellis.eu/

[17] https://cairne.eu/

Without decisive action, Europe risks long-term technological dependence, economic decline, and diminished resilience across all sectors.

- **Moonshot in Artificial Intelligence: Trustworthy, Multicultural Generative AI Systems for Safe Physical Interaction with the Real World** [33]: Developed together with euRobotics, this moonshot aims for a large-scale, pan-European initiative to establish Europe as a global leader in trustworthy, multicultural AI by 2030. It responds to growing concerns over Europe's dependence on non-European tech giants and the risk of losing strategic sovereignty. The plan envisions creating European alternatives to generative AI systems, backed by an estimated €100 billion investment over six years, pooling talent and resources across the continent. Success would ensure AI systems aligned with European values, strengthen competitiveness, and address major societal challenges such as climate change, health, and inequality, while bringing critical technology under democratic control.
- **Open Letter: "Now is the time to create a CERN for AI"** [34]**:** This open letter calls for the creation of a "CERN for AI" - a large-scale, pan-European research hub dedicated to artificial intelligence - to secure Europe's technological sovereignty, cultural values, and economic competitiveness. It warns that Europe is falling behind the U.S. and China in AI innovation, risking dependency on foreign technologies and losing control over ethical standards. The proposal advocates for a centralized institution modelled after CERN, equipped with world-class infrastructure, fostering cross-border collaboration, attracting top talent, and driving trustworthy AI development aligned with European principles.

Other European AI associations/partnerships this report analysed are **European Association for Artificial Intelligence (EurAI)**[18] **(**composed by the AI national societies of the different State Members), and **European Laboratory for Learning and Intelligent Systems (ELLIS)**[19] (Pan-European AI network of excellence). These two societies are more related to academic endeavours and research (e.g., organizing conference on AI such as ECAI-2025, connecting top researchers on AI). During the analysis, no trends, roadmap or position papers from these associations were found.

Cloud/edge - 3CN

In the area of cloud and edge technologies, there are two main associations/organizations of interest for the SNS JU. First, the **European Alliance for Industrial Data, Edge and Cloud**[20] which brings together businesses, Member States representatives and relevant experts on data, cloud and edge technologies. Some of the most current activities are the publication of the *Thematic Roadmap on Telco Cloud* and the publication of *Thematic roadmap on open source and of the inputs on common trust principles*[21].

- **Thematic Roadmap on Telco Cloud** [35]: This roadmap outlines a vision for a highly secure, distributed, interoperable, and resource-efficient telco cloud that underpins Europe's digital transformation and sovereignty. The roadmap identifies the telco cloud as a critical enabler for next-generation edge and cloud services, supporting both internal telecom functions and external customer applications. Key pillars include: (1) *defining comprehensive requirements for technology*, infrastructure, and application lifecycle management; (2) *mapping current initiatives and solutions* (such as OpenNebula, Sylva, Nephio, CAMARA, and ETSI standards); (3) *identifying persistent gaps and challenges especially in multi-cloud orchestration, edge service orchestration, mobility management, federation, capability exposure, security, and hardware acceleration*; and (4) providing actionable *recommendations*. These recommendations call for the development of open-source orchestration and federation tools, intelligent resource matching algorithms, policy-driven orchestration, standard APIs, compliance monitoring, and closer collaboration between cloud and hardware initiatives. The roadmap concludes that addressing these challenges will not only strengthen Europe's position

[18] https://www.eurai.org/

[19] https://ellis.eu/

[20] https://digital-strategy.ec.europa.eu/en/policies/cloud-alliance

[21] https://digital-strategy.ec.europa.eu/en/news/thematic-roadmap-open-source-and-inputs-common-trust-principles

in global telecommunications but also foster innovation, economic growth, and digital sovereignty, urging continued policy and financial support for rapid implementation of these recommendations.

Following the publication of this Roadmap, the Alliance published a new deliverable, called the *Telco Cloud Reference Architecture (TCRA)* [36] which sets a reference for the constitutive elements of Telco Cloud solutions. The Telco Cloud Reference Architecture sets out a modular, open, and interoperable blueprint for deploying and managing complex telecom services across distributed, multi-provider edge and cloud environments. Its key message is that seamless orchestration, connectivity, and lifecycle management - enabled by components like the Multi-Cloud Orchestrator and Telco Connectivity Manager - are essential for flexibility, scalability, and digital sovereignty in next-generation networks. The architecture stresses the importance of interoperability and vendor neutrality, and highlights that future development should focus on integration, exposure, and streamlined blueprints to accelerate adoption and innovation across different industries.

- **The roadmap "The Open-Source Way to EU Digital Sovereignty & Competitiveness"** [37]: This roadmap provides a strategic blueprint for Europe to achieve digital sovereignty, economic resilience, and environmental sustainability by prioritizing the development, adoption, and governance of open-source cloud, edge, and IoT technologies in Europe. It highlights the need to reduce dependence on non-EU technology providers, especially in cloud, edge, and IoT sectors, and identifies four key motivators: sovereignty, data security and compliance, innovation and economic resilience, and environmental sustainability. The roadmap proposes actions across five pillars—technological development, skills development, procurement practices, growth and investment, and governance—emphasizing open standards, dedicated funding, targeted training, reformed public procurement, and strong European leadership. Sector-specific benefits include enhanced security and compliance for public administration, increased competitiveness and sustainability in manufacturing, improved healthcare data management, and optimized energy systems. The document also addresses challenges such as lack of open standards, funding constraints, skills shortages, market hesitancy, and fragmented governance, calling for unified action among policymakers, industry, and the open-source ecosystem to secure Europe's digital future.

In addition, in the association **Gaia-X**[22] plays a pivotal role in shaping the current European cloud ecosystem. The initiative promotes a federated architecture that interconnects multiple cloud service providers and users in a transparent framework, driving the development of Europe's future data economy. According to Gaia-X, this federated model lays the foundation for a competitive alternative to proprietary platforms that enforce vendor lock-in and operate under opaque conditions regarding data privacy, extraterritorial regulations, and security. Among the different specifications and documents published, the following white paper shows the opportunities in Europe for Data Spaces:

- **White-Paper: The-Role-of-Data-Spaces-in-the-Digital-Economy** [38]: How data spaces (secure, federated environments for sharing and accessing data) are essential for Europe's digital sovereignty, economic competitiveness, and AI innovation. Data spaces enable trusted, interoperable data exchange among businesses, governments, and research institutions, supporting new business models, efficient public policies, and ecological transition. They help ensure compliance with European regulations, protect data ownership, and reduce reliance on non-European technology providers. The paper highlights the role of Gaia-X in providing a harmonized framework for secure data sharing, and describes how data spaces foster collaboration, drive innovation, and support sustainable development across sectors. Ultimately, it calls for joint efforts from policymakers, industry, and research to scale up adoption and make data spaces a cornerstone of Europe's digital future.

<u>Micro-electronics</u>

The SNS JU has a stable collaboration with the **Chips Joint Undertaking (Chips JU)**[23]. The Chips JU

[22] https://gaia-x.eu/

[23] https://www.chips-ju.europa.eu/

aims to strengthen Europe's position in the semiconductor market and contribute to securing its long-term technological independence and leadership. The JU brings together the European Commission, the Member states and the private sector with three important partners: Aenas, EPoSS, and Inside. It is important to remark the importance of the Chips Act delivered 2023. The EU **Chips Act** [39] aims to strengthen Europe's semiconductor ecosystem by boosting research, innovation, and manufacturing capacity, reducing dependency on external suppliers, and doubling the EU's global chip market share to 20% by 2030 through €43 billion in investments. Its three pillars are: Chips for Europe Initiative (funding R&D and pilot lines for advanced technologies), Security of Supply (attracting investments to build large-scale production facilities), and Monitoring and Crisis Response (creating mechanisms to anticipate and mitigate chip shortages).

Notably, it is expected that the EC will deliver the Chips Act 2.0 in the summer 2026. Semiconductors associations such a European Semiconductor Regions Alliance (ESRA) and European Semiconductor Industry Association (ESIA) has published both position papers with the recommendations towards this **Chips Act 2.0**. The **ESIA Position Paper** [40] (European Semiconductor Industry Association) advocates for a revised EU Chips Act focused on industrial deployment, innovation across the entire value chain, and strategic support for AI and next-generation technologies, emphasizing streamlined funding, broader inclusion of stakeholders, and simplified administrative procedures to boost Europe's global competitiveness. In contrast, the **ESRA Position Paper** [41] (European Semiconductor Regions Alliance) calls for a place-based strategy that leverages regional strengths, enhances interregional collaboration, and prioritizes skills development, workforce mobility, and SME access, arguing that regional ecosystems are key to building resilience and sustaining Europe's semiconductor leadership. Both associations agree on the need for improved funding mechanisms, value chain integration, and revising the "first-of-a-kind" criterion but differ in their emphasis on centralized versus regional approaches to innovation and policy implementation.

Cyber-Security

In the field of cybersecurity, the **European Cyber Security Organisation (ECSO)**[24] plays a pivotal role. Established in 2016 as the contractual counterpart to the European Commission, ECSO was created to implement Europe's Public-Private Partnership in Cybersecurity (cPPP, 2016–2020). ECSO brings together more than 300 members, including large enterprises, SMEs, start-ups, research centres, universities, end-users, operators of essential services, clusters, associations, and public administrations at local, regional, and national levels across EU Member States and the European Free Trade Association (EFTA). ECSO's mission is to build a resilient and strategically autonomous digital Europe by empowering communities and shaping the cybersecurity ecosystem. This year they published their vision or European cybersecurity for the 2030:

- **ECSO's Strategic Vision: European cybersecurity 2030** [42]: sets out a roadmap to strengthen Europe's cybersecurity competitiveness, resilience, and global influence by 2030. The vision is built on five core values: European strength, public-private collaboration, community empowerment, a proactive approach, and human-centric cybersecurity. It is structured around three main strategic objectives: (1) making Europe a hallmark of competitiveness by reinforcing its cybersecurity industry, driving research and innovation, and supporting businesses; (2) building Europe as a resilient stronghold by protecting critical infrastructure, securing supply chains, and enhancing civil-military cooperation; and (3) positioning Europe as a global shaper by projecting its values, standards, and technologies internationally. The document calls for unified action across all stakeholders to overcome fragmentation and ensure Europe's leadership and trust in the secure digital economy by 2030.

Quantum

The largest European quantum technology industry association is the **European Quantum Industry Consortium (QuIC)**[25]. QuIC is a not-for-profit organization committed to fostering the growth of the quantum technology sector and positioning Europe as a global market leader. Its members include large enterprises, SMEs, start-ups, investors, research and technology organizations, and other associations

[24] https://ecs-org.eu/

[25] https://www.euroquic.org/

from all European states and associated countries. Within their publications the reader can find from reviews to *Quantum European strategy,* to their own roadmap:

- **Strategic Industry Roadmap (SIR)** [43]: provides a comprehensive vision for the development and commercialization of quantum technologies (QTs) in Europe over the next decade. It covers five main pillars: quantum computing, quantum simulation, quantum communication, quantum sensing and metrology, and enabling technologies. The roadmap highlights Europe's strong research base but notes the need for greater investment, industrial capacity, and talent development to compete globally, especially against the US and China. It details the current state and future goals for various quantum hardware platforms (such as superconducting, spin, trapped ion, neutral atom, photonic, and NV centre qubits), software, algorithms, and integration with high-performance computing. Key messages include the importance of building robust supply chains, standardization, and intellectual property strategies, as well as increasing funding and fostering education to address the growing talent gap. The roadmap stresses the need for supportive policy frameworks, international collaboration, and ethical governance to ensure Europe's technological sovereignty and leadership in quantum technologies. It also emphasizes sustainability, inclusivity, and alignment with societal goals, noting that quantum technologies will impact sectors such as medicine, communications, energy, finance, and national security. The document calls for urgent action to fill gaps in enabling technologies, support start-ups and scale-ups, and ensure that Europe's quantum industry can thrive and compete on the global stage.
- **QuIC Position Paper on the Quantum Europe Strategy** [44]: The QuIC welcomes the European Commission's Quantum Europe Strategy as a pivotal step to position Europe as a global leader in quantum technologies by 2030. QuIC's review highlights Europe's strengths in scientific excellence and a vibrant startup ecosystem, but warns of critical gaps: fragmented efforts, limited industrial uptake, and insufficient private investment. QuIC's vision calls for a balanced approach that combines top-down coordination with bottom-up innovation, ensuring inclusive policies, access to specialized infrastructure, and strong support for startups and SMEs. The paper emphasizes the need for strategic investment in quantum hardware, software, and enabling technologies, robust IP protection, harmonized standards, and resilient supply chains. QuIC advocates for industry involvement in governance, agile public procurement, and targeted education to build a skilled workforce. The consortium urges Europe to act decisively, crowd-in private capital, and foster international cooperation, so that scientific excellence translates into industrial leadership, technological sovereignty, and societal benefit. QuIC stands ready to support the implementation of the strategy, stressing that only fast, coordinated, and ambitious action will secure Europe's competitiveness and autonomy in the quantum era.

Quantum technology is inseparable from computing, and in this domain, a key role is played by the **European High-Performance Computing Joint Undertaking (EuroHPC JU)**[26]. EuroHPC JU coordinates efforts and resources from both the public and private sectors to establish Europe as a world leader in supercomputing. This Joint Undertaking brings together the European Commission, EU Member States, and three strategic private partners: the European Technology Platform for High-Performance Computing (ETP4HPC), the Big Data Value Association (BDVA), and the European Quantum Industry Consortium (QuIC). Quantum computing is one of the key pillars for the association in their different publications:

- **Infographic on EuroHPC Quantum Computers** [45]: Ten quantum EuroHPC quantum computers are being developed by European companies, and will help scientists break unsolvable problems, boosting EU competitiveness, strategic autonomy and sustainable prosperity.
- **Leading the way in European supercomputing** [46]: The document highlights quantum computing as a crucial next step for Europe's supercomputing ecosystem, emphasizing that certain computational challenges exceed the capabilities of classical supercomputers. The EU-funded HPCQS (High Performance Computer and Quantum Simulator hybrid) project is central to this vision, aiming to integrate quantum computing with classical high-performance

[26] https://www.eurohpc-ju.europa.eu/index_en

computing (HPC) and prepare European research, industry, and society for this future. HPCQS is building a federated quantum infrastructure using quantum simulators, which are more feasible than full quantum computers and already address complex problems in fields like chemistry and physics. The overarching goal is to position Europe as a leader in quantum computing, enabling innovative solutions to previously intractable problems and making quantum computing a future priority for European HPC Competence Centres.

Finally, quantum internet is expected to play a significant role in Europe's digital future. The **Quantum Internet Alliance (QIA)**[27] is a European platform dedicated to building a global quantum internet "made in Europe." QIA is working on the world's first full-stack quantum internet prototype network while driving the European quantum internet ecosystem to new heights. Its members include leading quantum research institutes and industry players from nine EU Member States. All documents published by the Alliance are technically relevance, but they expand the vision of the Alliance or present any roadmap.

Other Thematic Areas

To the best of SNS CO-OP's knowledge, there is no European association or partnership specifically focused on **hardware and devices** or **Terrestrial Networks/Non-Terrestrial Networks integration**. However, in the latter area, the SNS Joint Undertaking (SNS JU) has consistently collaborated with the European Space Agency (ESA), which is actively engaged in TN/NTN integration among other initiatives. In the ESA white paper "**6G and satellites**" [47], the agency outlines the European Space Agency's vision to make satellites a core part of the future 6G ecosystem, ensuring seamless integration between terrestrial and non-terrestrial networks. ESA aims to unify data architectures so that satellite connectivity becomes as versatile and resilient as possible, supporting ubiquitous, intelligent, and sustainable global communications. Through initiatives like ARTES 4.0 and the Space for 5G/6G Strategic Programme Line, ESA is driving the development of 6G-enabling satellites, including plans for a 6G laboratory in space to accelerate research and industry collaboration. This integration will enable advanced applications—such as AI-driven networks, immersive XR, digital twins, and real-time edge computing—while supporting sustainability, inclusivity, and security.

In the context of environmental sustainability, the **European Green Digital Coalition (EGDC)**[28] represents an initiative of leading European ICT companies, supported by the European Commission and the European Parliament. Its overarching aim is to exploit the enabling potential of digital technologies to reduce emissions and accelerate the Green and Digital Transformation of the European Union. The coalition have published some **EGDC Deployment Guidelines** [48] offer practical recommendations to help developers, users, investors, and policymakers maximize the climate and sustainability benefits of digital solutions across six priority sectors: Energy, Transport, Construction, Manufacturing, Agriculture, and Smart Cities. The guidelines focus on enabling digital technologies that reduce carbon emissions and resource use, while minimizing any negative environmental impacts. They emphasize the importance of defining and tracking metrics to measure energy and carbon savings, considering broader sustainability impacts such as health and social factors, and tailoring advice for different audiences to ensure optimal deployment and adoption. Developed through stakeholder consultation, these guidelines aim to support the creation, selection, and implementation of digital solutions that deliver measurable benefits for the economy, environment, and society. To the best of the author's knowledge, no comparable European association currently addresses the social and economic dimensions of sustainability as defined by SNS projects.

Other transversal thematic area such as **sovereignty** and **business model evolution/monetization** are addressed by nearly all the associations in some of the applications presented in this section.

5.3.7 Vertical Sector Trends

Tracking the evolution of industrial sectors—their needs, obstacles, and target applications—is crucial for shaping next-generation systems like 6G. As automation and sustainability accelerate digital transformation, expectations for connectivity performance and reliability also evolve, creating a

[27] https://quantuminternetalliance.org/

[28] https://www.greendigitalcoalition.eu/

continuous feedback loop between vertical industries and SNS JU research. Identifying sector-specific priorities and gaps helps steer research toward solutions that address real bottlenecks, enable advanced applications, and meet industry-driven requirements.

In this section, a different approach is taken with regards to the structure followed in previous sections as the defined *thematic* areas (i.e., AI, Cloud/edge, NTN, cyber-security, etc.) stated in Section 5.1 are not followed as such. The reason why is that vertical sectors along with mobile network operators (Section 5.3.8) are primarily concerned about the identification and definition of relevant use cases rather than in the underlying technologies supporting them. Consequently, the public information they generate (white papers, reports, etc.) is mostly focused on use cases, challenges, or high-level application requirements and needs (e.g., security, privacy, latency, interoperability, ubiquitous coverage, etc); rather than on how specific *technologies* can be exploited today or should evolve in the coming years. An exception to this rule is the introduction of disruptive technologies which are perceived as game-changers by a specific vertical. This is for example the case of ISAC or deterministic networking for e.g. industrial manufacturing or transportation. In this case, their engagement significantly increases, both at the level of publications and organization of events and, consequently, it is timely reported in this section. A more detailed analysis/exhaustive taxonomy would require the realization of interviews and surveys to key players from enough vertical companies/ associations, duly complemented with representatives from mobile network operators, to validate e.g., monetization aspects of those technologies and use cases.

In the light of all the above, this section provides a structured analysis of vertical-sector trends shaping the evolution toward 6G. It begins by establishing a consolidated baseline of cross-vertical insights drawn from the consultation run by the predecessor project SNS-ICE, followed by focused 2025 updates for a selected set of key industries. The core subsections then explore trend developments across major verticals—including Industry and Manufacturing, Media & Entertainment, Automotive, Railway, Agriculture, and Health—highlighting how their technological priorities and constraints are shifting. This analysis is complemented with an overview of emerging 6G use cases under study in 3GPP and how this relates to spectrum needs as analyzed by the RSPG. The section concludes by linking these insights to the upcoming SNS CO-OP vertical workshops, ensuring that evolving sector needs feed directly into future SNS R&I Work Programme planning.

5.3.7.1 Starting point: vertical trend analysis from SNS-ICE

To support a trends assessment, the SNS-ICE project created a questionnaire in July 2024 and distributed it to major vertical associations. The consultation targeted sectors such as automotive/transport/logistics, industry 4.0/manufacturing, education and Security/PPDR, smart energy, media/xR, and smart Health. The results, as presented in deliverable D3.3 [6] of SNS ICE, offered a comprehensive view of how these domains are using 5G today and what they expect from 6G, outlining priorities for future use cases and emerging technological needs.

The responses showed growing reliance on 5G to fuel applications ranging from autonomous driving and smart-city platforms to immersive interaction and connected healthcare. Looking ahead, participants expect 6G to resolve current technological bottlenecks, pointing to capabilities such as integrated sensing and communication, satellite–terrestrial convergence, and highly automated network intelligence. These shifts are linked to advanced scenarios like real-time monitoring, large-scale automation, and seamless global connectivity. At the same time, the survey highlighted persistent hurdles—standardization gaps, spectrum constraints, and infrastructure limitations—as well as the importance of enabling technologies. Cloud/Edge Computing, AI/ML, and cybersecurity emerged as cross-sector priorities, while areas like digital twins and immersive communications were recognized as promising but still maturing.

The findings also revealed uneven progress in 5G uptake across industries. Automotive/Transport/Logistics and Industry 4.0/Manufacturing are comparatively advanced due to their need for fast, dependable networks supporting applications such as autonomous vehicles, AGVs, and predictive maintenance. By contrast, Smart Energy and Smart Health still face higher deployment barriers, from investment constraints to limited infrastructure readiness. Regulatory and standardization challenges—such as delayed spectrum allocation and the lack of harmonized frameworks for technologies like Open RAN and NTN—remain major obstacles, especially for sectors dependent on global interoperability. Cross-industry collaboration was repeatedly identified as essential, whether for building smart-city infrastructures requiring cooperation between municipalities, technology providers, and telecom operators; or enabling healthcare use cases like remote treatment and real-time monitoring, which mandate collaborations between medical device manufacturers, hospitals, and connectivity providers. Ensuring adequate investment in AI/ML, Cloud/Edge Computing, and cybersecurity was likewise viewed as critical to scaling next-generation connectivity across verticals.

In summary, the analysis compiled by the SNS-ICE project (see Table 7, from SNS-ICE deliverable D3.4) [49]) underscores the need to synchronize connectivity evolution with sector-specific priorities. It provides a consolidated view of the main trends, challenges, and use cases across vertical domains, helping to chart a coherent path toward 5G, 6G, and future network technologies.

Table 7: Vertical trends, challenges and main use cases across industry domains [49].

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, adoption of AI, IoT, and robotics	Interoperability, system integration, skilled workforce shortage, delays in device commercialization	Digital twins, autonomous machines, mass sensorisation for real-time operations
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

5.3.7.2 Strategic update on key vertical trends

Building on the broad vertical landscape assessment presented in the previous section, this subsection provides a focused update on selected vertical sectors, highlighting how their priorities and expectations have evolved in recent times. While the previous section synthesized cross-industry trends drawn from the SNS-ICE consultation, here the analysis is refined by examining concrete developments in key domains where technological needs are evolving most rapidly. The aim is to capture sector-specific updates that reflect emerging use cases, shifting requirements, and early signals of 6G readiness. Together, these insights help align SNS research directions with the evolving demands of leading verticals.

Industry and Manufacturing

5G-ACIA has shown a rapidly growing interest in Integrated Sensing and Communication (ISAC), recognizing it as a key enabler for new industrial capabilities. ISAC is increasingly viewed as a technology that unlocks entirely new classes of use cases and requirements—particularly for advanced interaction, real-time awareness, and improved safety in industrial environments. This momentum is clear in 5G-ACIA's intensified work on use-case specification and standardization, as well as in the joint 6G-IA–5G-ACIA webinar[29] held on 10 October 2025, where both organizations underscored ISAC/JCAS as a strategic pillar for future 6G systems. The publication of a recent 5G-ACIA white paper[30] further reflects this growing attention.

For smart manufacturing and industrial automation, ISAC provides a unified framework that integrates sensing and communication in a single network infrastructure, reducing deployment complexity and operational costs. Its multi-node and multi-modality sensing capabilities enable robust detection, tracking, and environmental understanding—even in harsh industrial conditions. ISAC also enhances privacy and security by relying on RF-based sensing instead of more intrusive optical technologies. Beyond robustness, it supports applications such as predictive maintenance, environmental mapping, collision avoidance, and communication-enhanced localization—driving improvements in efficiency, safety, and digital-twin fidelity. These combined benefits position ISAC as a foundational driver in the evolution toward more intelligent, adaptive, and resilient industrial systems.

In addition to ISAC, 5G-ACIA also highlights several other technologies of high relevance for industrial automation, including deterministic networking, reduced-capability (RedCap) devices, and non-public networks (NPN). These topics are covered in dedicated white papers available for download on the 5G-ACIA website.

Media & Entertainment

Media and Entertainment (M&E) is a very wide sector which covers a number of services such as Books, TV, Cinema, Film production, Advertising, Radio, Gaming, Gambling, Music, social media, etc., that have been using communication channels since a long time. The main commonality between these sub-sectors is that they all need high bandwidth and low latency. However, new network functions could also bring new opportunities to develop innovative use cases.

In 2025, experiential entertainment moves into the spotlight, AI goes mainstream, streaming profitability accelerates and M&E executives recalibrate portfolios as linear TV fades [50]. This shift is disrupting

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[29] https://smart-networks.europa.eu/event/6g-ia-5g-acia-joint-online-webinars-isac-jcas-online-webinar/

[30] "Use Cases and Requirements for Integrated Sensing and Communication (ISAC) in Connected Industries and Automation". 5G ACIA whitepaper, Dec. 2024- Available from: https://5g-acia.org/whitepapers/use-cases-and-requirements-for-integrated-sensing-and-communication-isac-in-connected-industries-and-automation-2/

the entire linear TV market. According to statistics, the majority of linear TV viewers fall into the category of older audiences, typically aged 35 or older. Younger audiences are using mostly on demand TV provided by Over-the-Top (OTT).

Overall, the long-term impact of 6G on the M&E sector will be characterized by enhanced user experiences, new opportunities for content creation and distribution, economic sustainability, and significant social and cultural transformations. Ultimately, 6G's long term impact will hinge not only on technological breakthroughs, but on Europe's ability to translate them into sustainable M&E ecosystems - bridging seamlessly interaction and immersion, connectivity and inclusivity. In line with this, a scouting workshop with the Virtual Worlds Association[31] is planned for 2026. This association is aimed at improving and promoting immersive technologies, extended reality, digital twins, virtual collaborative spaces, interoperability, and digital skills.

Automotive

Innovation in the automotive sector extends far beyond electrification to encompass a comprehensive expansion of vehicular intelligence. Advancements in driver assistance, vehicle observability, and EV powertrain management are increasingly intertwined with the evolution of connectivity. Cloud connectivity, infotainment platforms, and enhanced V2X capabilities remain central, but the emergence of 6G introduces a transformative leap. Integrated sensing—enabled by sub-THz frequencies, wide RF bandwidths, and the beamforming/MIMO mechanisms inherent to 6G—provides radar-like environmental awareness with centimeter-level resolution. Supported by dense small-cell deployments and new high-bandwidth spectrum, 6G networks will combine sensing, localization, and communication into unified operating frameworks. This convergence delivers high-data-rate connectivity for ML-driven applications, significantly improving safety while opening the door to entirely new automotive services.

Compared to the trends in Table 7—centered on CCAM, the proliferation of C-V2X, digital roads, and diversified mobility services—the outlook adds three key advancements. First, it moves beyond pure connectivity to integrate high-resolution radio-based sensing directly into the communication interface, enabling vehicles not only to communicate but also to perceive their environment with unprecedented precision. Second, it introduces a tighter coupling of sensing, localization, and V2X, evolving CCAM into a more mature form where network-supported positioning and perception elevate automation and safety. Third, it expands digital-road and mobility-service concepts through 6G-enabled data rates and cloud/AI processing, fostering new operational models and richer cooperative services that were not feasible under earlier connectivity ecosystems.

Railway

As per its Strategic Deployment Agenda (SDA)[32], the railway sector, known for long innovation cycles, is advancing two major developments that future communication systems must support. Digital Rail Operations (DRO) aim to boost passenger and freight capacity without proportional new infrastructure by migrating from GSM-R to the 5G-based FRMCS, enabling higher train-to-track communication, greater automation, shorter headways, and improved performance applications. In parallel, the Gigabit Train concept targets home-like broadband connectivity for high-speed, cross-border travel, with projected demand of 3–5 Gbps for trains with around 1,000 passengers. Achieving this requires better trackside coverage and onboard systems to meet the increasing digital needs of passengers, staff, and equipment, making connectivity central to rail transport attractiveness.

To assess the latest trends and expectations for future communication systems, SNS CO-OP organized the "Joint EIM–6G IA Workshop — FRMCS & 6G Discussion" in September 2025, bringing together EIM railway stakeholders and 6G experts. Discussions focused on the evolution from GSM-R to FRMCS and eventually to 6G, with consensus on ensuring a smooth, software-driven migration that avoids the disruption and cost of previous technology transitions. Railway representatives highlighted needs such as ultra-reliable, low-latency communications for higher automation levels (notably GoA4), cost-efficient coverage through a mix of terrestrial, satellite, and private networks, and strict safety, security, and interoperability compliance inherent to rail operations. The workshop also explored 6G opportunities, including deterministic networking for predictable signaling, ISAC for obstacle and track

[31] https://www.virtualworldsassociation.eu

[32] https://eimrail.org/2024/09/24/strategic-deployment-agenda-5g-connectivity-and-spectrum-for-rail/

monitoring, and data-driven services. A network-of-networks approach and the 3C (Cloud–Computing–Communications) continuum were seen as promising, reinforcing that the sector seeks an evolutionary path integrating 6G capabilities into FRMCS with a focus on coverage, reliability, and long-term compatibility.

Agriculture

Recent works (e.g., [51]) indicate that the agriculture vertical is progressing beyond the IoT-centric smart farming trends toward a more intelligent and autonomous model. With 6G enabling high-speed, low-latency, and more reliable rural connectivity, AI and machine learning operate directly at the edge, supporting real-time analysis and continuous environmental sensing. Precision agriculture is elevated through ISAC, high-accuracy positioning, and broader use of autonomous drones and vehicles capable of monitoring and acting with minimal human intervention.

Agriculture also adopts new digitally driven approaches. Digital twins increasingly guide predictive planning and resource optimization, while private 6G networks ensure dependable connectivity for mission-critical robotic and drone operations. Indoor and controlled-environment farming gains relevance, relying on dense sensing and automation to optimize production. Overall, 2025 marks a transition from connected farming to AI-enhanced, sensing-rich, and increasingly autonomous agriculture.

Health

Compared with Table 7, the recently published whitepaper from the SNS JU Technology Board [52] reveals a substantial evolution towards *validated, clinically deployable* 6G-ready systems. A major trend at the level of trials and pilots is the integration of advanced sensing modalities and edge-native intelligence, enabling continuous, high-fidelity physiological monitoring (e.g., wearable ultrasound patches, implantable-device telemetry, contactless respiration sensing). The shift from intermittent to *continuous, anticipatory care* is enabled by pervasive edge AI, and integrated sensing-and-communication (ISAC) capabilities.

Another key trend is the rise of immersive and autonomous healthcare operations. XR-based telepresence, mixed-reality rehabilitation, remote surgical proctoring, and robotic emergency response are now validated in real-world pilots. Mobility support is also becoming a differentiator, with UAV-assisted health monitoring and nomadic micro-networks enabling care delivery in rural, mobile, or disaster environments. Finally, governance, data interoperability, and cybersecurity-by-design are increasingly becoming embedded features: systems are now designed for GDPR and EHDS compliance, secure slicing, and FHIR-based (Fast Healthcare Interoperability Resources) interoperability across health providers.

5.3.7.3 Coming up next: strategic vertical workshops towards SNS R&I WP 2027

SNS CO-OP is committed to tracking evolving trends across key vertical sectors to keep research and innovation aligned with emerging industrial needs. In close collaboration with the 6G-IA, the project will organize targeted vertical workshops to anticipate sector priorities. These focused, face-to-face meetings aim to clarify the current status and future needs of major industries as they move toward 6G adoption, while engaging stakeholders likely to contribute to SNS WP2027 proposals and later FP10-oriented initiatives. This work is timely, as a significant share of the ~200 M€ WP2027 budget will support large-scale vertical trials and pilots (Stream D). Insights from the workshops will feed into a formal report informing 6G-IA orientations for WP2027.

Workshops will be held in February–March 2026 organized by SNS CO-OP, and with participation from SNSO and DG-CNECT officers. Each session focuses on a specific vertical and is led by an experienced industry or association partner: Railway (Telecom Italia Mobile, 6G-IA), Smart Industry (Ericsson), Public Safety (PSCE Forum), and Automotive/CCAM (Telecom Italia Mobile, 6G-IA). A related Media & Entertainment workshop took place in May 2025. Participation is kept intentionally small (10–20 experts) to ensure meaningful, representative discussion.

5.3.7.4 Update of work on relevant 6G use cases at 3GPP and developments at RSPG

6G use cases are currently under active analysis in standardization bodies. In particular, 3GPP TR 22.870 [53] (under completion and expected to be approved by March 2026) provides a structured overview of candidate 6G use cases across multiple vertical sectors, as summarized in Table 8. It is worth recalling that SNS-ICE, the predecessor to SNS CO-OP, made substantial contributions to shaping this work by coordinating European input ahead of the 3GPP SA1 Workshop in May 2024. (as reported in [54]). SNS-ICE consolidated perspectives from SNS projects, national initiatives, the SNS JU Office, and the SB/TB/WGs, ensuring a coherent European position and supporting the presentation of the common European 6G use-case priorities at the SA1 workshop.

Table 8: Relevant 6G use cases being currently analysed at 3GPP.

Vertical sector	6G use cases
Industry & Manufacturing	• **Real-time Digital Twins** for monitoring and simulation of industrial processes. • **Cooperative mobile robots** and **AR-guided tasks** for smart factories. • **Predictive and corrective maintenance** powered by AI and integrated sensing. • **Autonomous local networks** for factories (NPN) with dynamic slicing.
Energy & Utilities	• **Decentralized contracts for smart grids** and Distributed Energy Resources (DER) management. • **Dynamic monitoring of transmission grids** and **Direct Transfer Trip (DTT)** for protection. • **End-to-end energy optimization** (network + UE) and **slice-level energy control**.
Transportation & Mobility	• **Autonomous vehicles** with distributed AI and integrated sensing (ISAC). • **Airspace management for UAM/UAV** and **intelligent drone swarms**. • **Smart logistics** with AGV and container tracking. • **Network-assisted smart transportation** and resilience in critical scenarios.
Healthcare & Communities	• **Personalized health monitoring** using AI. • **Child health management assistants** and **immersive services for aging populations**. • **Holographic telepresence** for telemedicine and remote surgery
Construction, Agriculture & Mining	• **Remote and automated construction** with collaborative robots. • **Dynamic material management** enabled by spatial computing. • **Cooperative networking in extreme conditions** (mining, agriculture).
Smart Cities & Public Safety	• **Disaster response** with resilient networks and rapid provisioning. • **Collaborative awareness** for real-time decision-making. • **Localized networks for verticals** and **mission-critical services**
Media, XR & Entertainment	• **XR rendering offload** and **immersive gaming**. • **Holographic and mixed reality experiences** for live events. • **Interactive guided tours** and **metaverse-based experiences**.

In 2025, 3GPP advanced its first systematic analysis of 6G requirements through SA1. Work during the year focused on refining cross-vertical 6G use cases—Industry 4.0, Energy, Transportation, Healthcare, Construction/Mining, Public Safety, and Media/XR—and identifying the associated service characteristics needed for early 6G design. Key scenarios such as real-time digital twins, autonomous mobility with ISAC, holographic telepresence, smart-grid protection, and immersive XR media were progressively detailed in successive revisions of TR 22.870, together with their demands on latency, reliability, uplink capacity, positioning accuracy, and deterministic networking.

Throughout 2025, SA1 consolidated global contributions to map these use cases to preliminary Release-2 requirements, emphasizing AI-native operation, semantic communication, UAV/robotic fleet support, massive sensing, and mission-critical service continuity. By March 2026, TR 22.870 will become the reference baseline inside 3GPP for vertical-sector expectations toward 6G, setting the foundation for the shift from exploratory study to formal requirement definition.

A proper evaluation of coverage and capacity needs for 6G use cases and usage scenarios is an essential element towards their eventual realization. This is intimately related to the identification of the spectrum needs underpinning them. Based on the ITU-R analysis for the IMT-2030 framework, the Radio

Spectrum Policy Group (RSPG) published in 2025 its Report on 6G strategic Vision. [55]. This document focuses on the following usage scenarios aimed at identifying spectrum needs:

- Usage scenarios based on **immersive communication** to provide a rich and interactive video (immersive) experience to users, including the interactions with machine interfaces and the use of virtual and extended reality.
- Usage scenarios based on **massive communication** to connect a very large amount of IoT devices, including those with very low power consumption, requiring low or moderate bit rates in a large coverage area.
- Usage scenarios based on **hyper-reliable and Low-Latency Communications** involving use cases based on communications in an industrial environment for full automation, control and operation. This usage scenario is expected to be served by extreme performance specialized networks with first network implementations expected to be local and tailored e.g., for industry.
- Usage scenarios based on **ubiquitous connectivity,** expected to provide affordable connectivity and, at minimum, basic broadband services with extended coverage, including sparsely populated areas. Typical use cases include, but not limited to, IoT and mobile broadband communication. Connectivity could be enhanced through interworking with other systems, e.g., non-terrestrial networks.
- Usage scenarios based on **AI and communication** to support high area traffic capacity and user experienced data rates, as well as low latency and high reliability, depending on the specific use case. Typical use cases include assisted automated driving, autonomous collaboration between devices for medical assistance applications and creation of and prediction with digital twins.
- Usage scenarios based on **Integrated Sensing and Communication** (ISAC) to provide spatial information about unconnected objects as well as connected devices and their movements and surroundings.

Discussions on spectrum for 6G continue in several RSPG work streams—including WRC preparation, the long-term vision for the upper 6 GHz band, evaluation of the 470–694 MHz range, and broader strategic spectrum matters. In the above-mentioned RSPG Report on 6G strategic vision the stakeholders' view on 6G spectrum is taken into consideration and outlined. Stakeholders broadly agree that low-band spectrum below 1 GHz will remain essential for wide-area, reliable coverage (potentially complemented by NTN), while sub-7 GHz bands, including the upper 6 GHz range and new 7–15 GHz allocations, will be needed to deliver higher capacity for dense urban and suburban environments. For confined-area or high-data-rate use cases—such as cooperative robots or human-centric immersive services—small-cell, millimetre-wave, and potentially sub-THz deployments are seen as viable options despite their limited coverage.

Several stakeholders highlight the need for at least 200 MHz of mid-band spectrum per MNO under conditions suitable for macro-cell operation, arguing that this is necessary to support 6G capacity increases beyond 5G while maintaining practical deployment costs. At the same time, researchers emphasise that spectrum sharing mechanisms—both with incumbents and between MNOs and local/private networks—should be built into 6G spectrum planning from the outset.

5.3.8 MNO Trends

According to GSMA Intelligence [56], 5G is the mobile technology with fastest adoption in the worldwide market. By 2030, more than 50% of mobile lines will be 5G, in Europe 5G lines will be more than 80% of mobile lines. Nevertheless, 5G monetization remains an issue for operators, especially in Europe. Notably, the B2B segment will grow at a higher pace than the B2C segment, driven by beyond connectivity offering focused on IT services such as cloud, edge cloud, AI and cybersecurity which meet digital transformation needs of big industries.

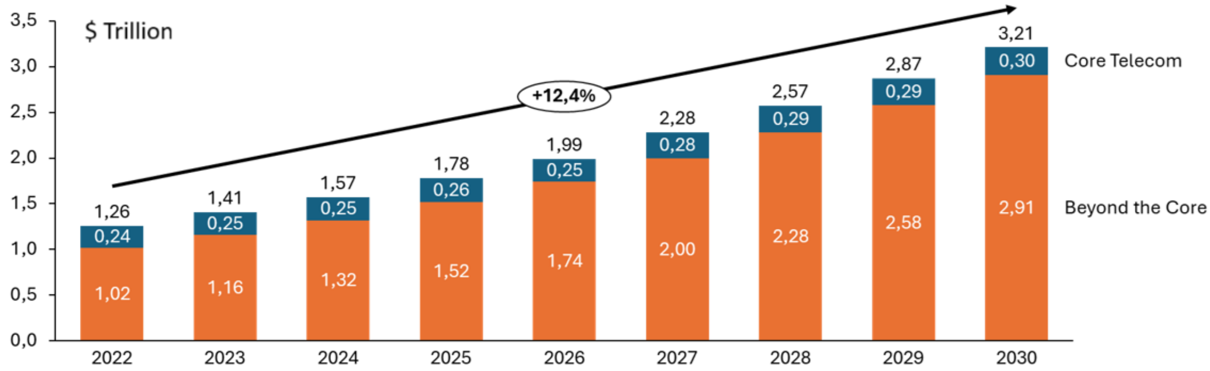

Figure 60: Global B2B revenue opportunity for core (i.e., connectivity) and beyond core services [56]

As Figure 60 illustrates, beyond connectivity services will be the main opportunity for mobile operators worldwide but will need efficient connectivity that can be offered in bundle. The addressable market is huge, with operators in good position to intercept 34% of this value by 2030 (see Figure 61 below).

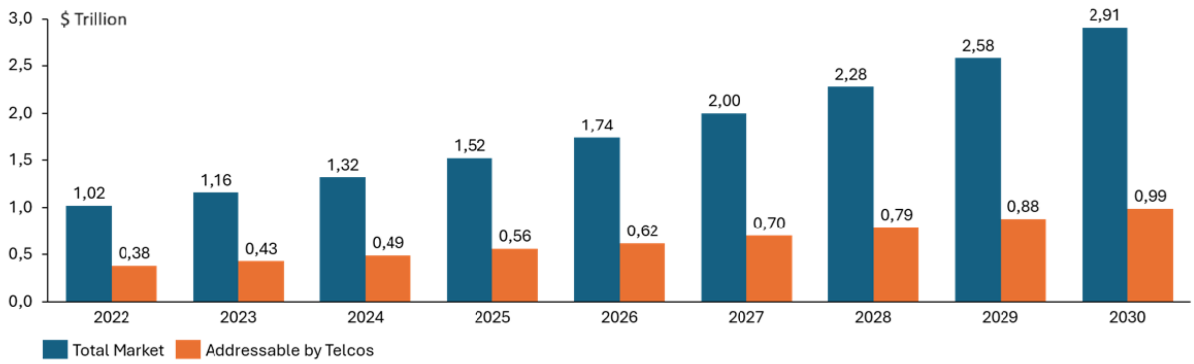

Figure 61: Global revenue opportunity for B2B technology services beyond core [56]

Cloud, Cybersecurity and IoT will be key drivers of this new value beyond the traditional B2B business model. And, interestingly, four verticals account for 37% of the total value produced by IT services [56], namely, Manufacturing, Financial Services, Automotive and Aviation. This is reflected in Figure 62, where the category 'Others' includes healthcare, public sector, retail, transportation & logistics, energy, smart cities agriculture, media etc.

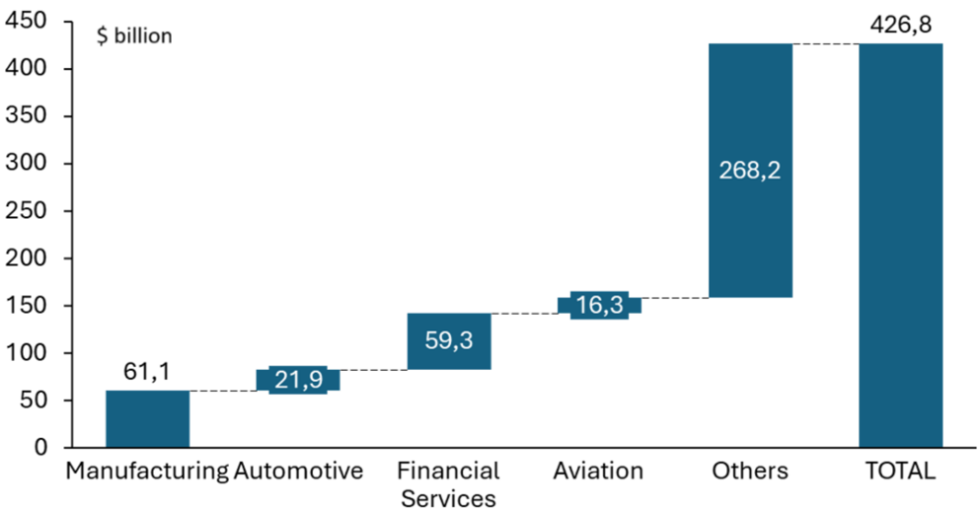

Figure 62: Global revenue opportunity for B2B technology services beyond core addressable by operators by selected verticals, 2023 [56]

Further adoption in vertical industries is driven mostly by private networks. There is increased demand for private networks from the defense and critical infrastructure sectors such as ports, airports and energy grids. New verticals are emerging as key consumers of private 5G including oil and gas, defence, broadcasting/media, healthcare. Feedback from early enterprise customers is positive for 65% of operators. Some 24% of operators claim their customers have already achieved expected benefits and significant financial returns, while 41% claim customers have achieved expected benefits and need more time to validate whether they have achieved significant financial returns

Mission critical connectivity and uplink bandwidth are key to private networks success. Mission-critical connectivity is needed across a range of verticals, including defense, oil & gas, energy, manufacturing and transport & logistics. There is also strong demand from segments that need to cater to surges in traffic. For example, live entertainment is driving demand for reliable connectivity, with operators looking to address this through private 5G. In the media sector, live TV broadcasting requires reliable and fast uplink from various locations. Large events such as the recent Paris Olympic Games have included live deployments of private wireless networks. Smart cities also need reliable uplink due to large deployments of CCTV and computer vision devices. Figure 63 summarizes which verticals are key adopters of private networks.

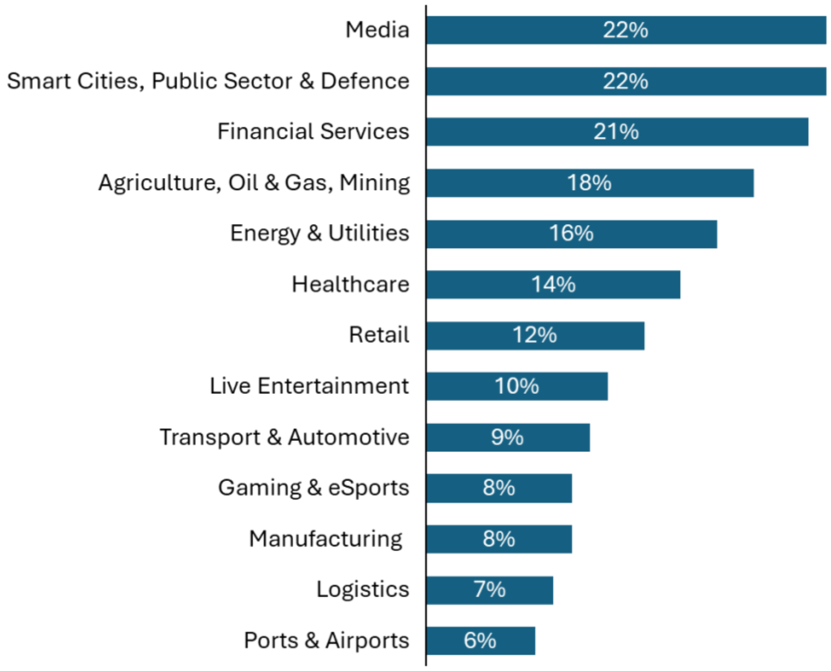

Figure 63: Key adopters of private networks among verticals [56]

However, almost 40% of operators find private network monetization challenging or relatively challenging. Monetization options include one-off fees from integration services; recurring revenues from managed network services and spectrum management; bundled service offerings with MEC and IoT; and revenue sharing with equipment partners.

Finally, network APIs is a hot bet for operators. Nearly 80% of operators in the GSMA Intelligence Network Transformation Survey 2024 claim to have exposed network APIs on a commercial basis. While it has long been possible to expose network APIs, operators have struggled to adopt a standardized approach that achieves scale. Recent initiatives by the mobile industry to develop a common set of network APIs have provided fresh momentum. Collaboration between the GSMA, TM Forum and the CAMARA Project on the GSMA's Open Gateway API ecosystem is important for increasing interoperability. Around 75% of the mobile sector, by market share is participating in GSMA Open Gateway.

5.4 (Pre) Standardisation trends & roadmap

5.4.1 Major SDOs Roadmaps

This section provides an overview of the roadmap and currently considered timelines of the 3 major Standards Developing Organizations (SDOs), namely 3GPP[33], ETSI[34] and IETF[35], and an estimation of how these roadmaps match with the identified thematic areas.

3GPP

3GPP is the main SDO responsible of the standardization of the next Mobile Network Technology 6G. 3GPP work is based on releases and their roadmap and timelines for the first 6G release is divided in two phases, as depicted in Figure 64: Release-20 for studies and Release-21 for normative work.

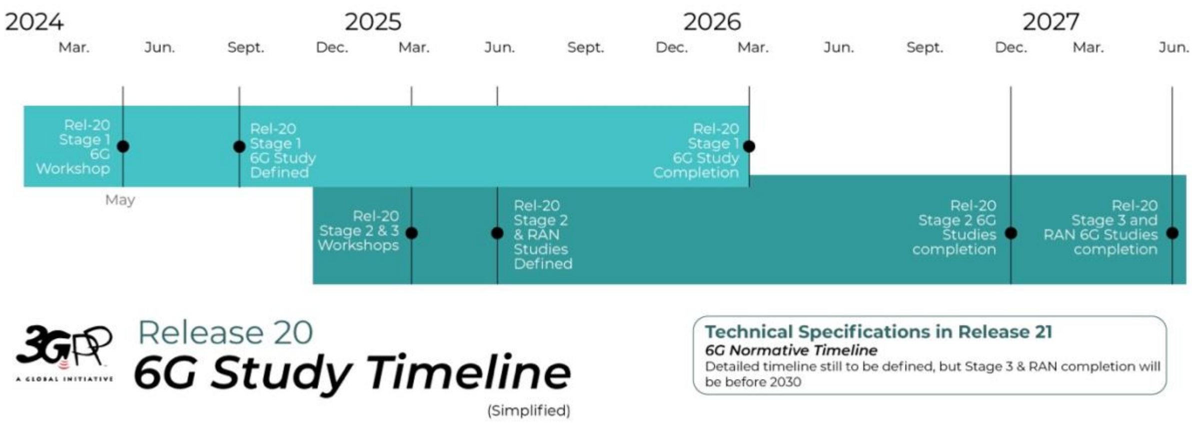

Figure 64: 3GPP timeline for the first 6G release.

At the time of writing of this report, the Stage-1 studies have entered their final phase: *Study on 6G Use Cases and Service Requirements* (TR 22.870) [53] performed by SA1 working group and focusing on the services and requirements for the future 6G system and cover a broad range of anticipated 6G capabilities (e.g., immersive communication, ubiquitous connectivity, AI-native networking, and enhanced trustworthiness). Study on 6G Scenarios and Requirements (TR 38.914) [57] developed by RAN plenary and focusing on the new 6G radio aspects requirements and KPIs. Stage-2 work, which contain more architecture work, has already started in the core groups like SA2 (developing the architecture of the future 6G) and SA3 (discussion about the security challenges that 6G will introduce). In the radio side, we have the different groups (e.g. RAN1,2,3) working on non-backward compatible radio access technology (hereafter “6G Radio”) addressing the full radio stack and spectrum of future use cases, operational constraints, and deployment realities while enabling of key existing and new services.

The 3GPP 5G/6G standards address some of thematic areas proposed in this section. In the area of **Artificial Intelligence**, support AI/ML have been already covered for 5G where the 3GPP standards define the Network Data Analytics Function (NWDAF) function which oversees training ML models based on data collected from other functions in the 5G architecture, and providing data analytics (TS 23.288). For 6G, where AI becomes a native component of the system, 3GPP is working on both AI for 6G and 6G for AI aspects, with particular attention to AI agents and intent management. **Cloud** standardization is out of scope for 3GPP. On the other hand, there is already support in 5G for Edge Computing including capabilities such as traffic routing to Edge local data networks, session and service continuity to enable UE and Application mobility, among others. **Cyber-Security** and new **Quantum computer threats and Quantum safe algorithms** are part of the objectives of the new study of 6G

[33] https://www.3gpp.org/

[34] https://www.etsi.org/

[35] https://www.ietf.org/

security which just started in SA3. In the case of **Terrestrial Networks/Non-Terrestrial Networks** integration, satellite access aims to be an integral part of 6G, being satellite one of the Radio Access Technologies offers by the 6G system.

Finally, it is still not clear how **sustainability** will be addressed by 3GPP beyond energy efficiency. In the 6G, Stage-1 *Study on 6G Use Cases and Service Requirements* (TR 22.870) there are references to the sustainability values in many of the use cases. However, there is no conclusion at the moment this report is written of how those values will be used and if the work will be continued in Stage 2 and 3.

ETSI

The European Telecommunication Standards Institute (ETSI) is the Institute responsible for standards in Europe. Besides being behind the support of all 3GPP activities through the Mobile Competence Centre (MCC) department, ETSI has created along the years different technical groups such as Technical Committees (TC), Industry Specification Group (ISG) and Software Development Groups (SDG), among others, which contributes to the standards activities in Europe in many different areas, some of them analysed in this section.

In the area of **Artificial Intelligence,** the *ISG ETSI Zero Touch network and Service Management (ZSM)* is active, working in Native AI network and service automation among other topics. The *ISG Experiential Networked Intelligence (ENI) is another relevant ISG*, which develops specifications for a Cognitive Network Management system that takes advantage of AI and enables the system to adjust the offered services based on changes in user needs, environmental conditions and business goals. In particular, *ETSI ENI* explores the integration of agentic AI into 6G systems. And finally, in relation with **cyber-security**, the *Securing AI (SAI) TC* focuses on developing standards for ensuring the security and trustworthiness of AI systems covering security requirements for AI models and systems, threat analysis, and explainability.

In the area of **cloud/edge**, ETSI has developed several frameworks through multiple ISGs to support service deployments on cloud and edge environments. Specifications and standards have been released to support *Network Function Virtualization (ETSI NFV)* and deployment on virtualized infrastructures, as well as *Virtual Network Function Management and Orchestration (ETSI MANO)* to support the lifecycle management of Virtual Network Functions and Network Services. Further, specific standards have been developed to support *Multi-Access Edge Computing (ETSI MEC)* to provide cloud-computing capabilities at the edge of mobile networks.

Regarding **Quantum technologies**, ETSI has recently approved the creation of a new TC on Quantum Technologies (TC QT) to advance on the underlying framework of standards for quantum technologies across numerous quantum-related domains, such as, *Quantum Communications, Quantum Networking, Quantum Sensing, Satellite Quantum Communications, Quantum Random Number Generators* and *Quantum Security*. This TC will also play a key role in supporting the European Quantum Communication Infrastructure (EuroQCI). In relation with cyber-security, the working group on Cyber Quantum Safe Cryptography (QSC) aiming to assess and provide recommendations for quantum-safe cryptographic primitives protocols and implementation considerations, should also be mentioned.

Finally, regarding **sustainability**, there are different TC and ISG addressing aspects such as energy efficiency. Moreover, ETSI has organized several summits and workshops over the recent years on **sustainability and ICT**.

IETF

The **Internet Engineering Task Force (IETF)** is the leading standards development organization (SDO) for the Internet, addressing a wide range of thematic areas critical to its evolution. One emerging focus is the **Quantum** Internet, which aims to enhance application functionality by integrating quantum technologies into Internet infrastructure, enabling innovations such as quantum cryptography, quantum sensing, and quantum computing. **Cybersecurity** remains a cornerstone of IETF's work, with a dedicated "Security" IETF area responsible for ensuring integrity, authentication, non-repudiation, confidentiality, and access control—capabilities that intersect all other IETF domains. In the realm of **cloud and edge computing**, IETF has initiated work on a *Unified Network and Cloud Orchestration Framework*, targeting management and orchestration for 5G environments. Additionally, the newly formed **AI** Preferences (AIPREF) Working Group focuses on defining mechanisms for websites to express preferences on how their content is used for AI training, search, and inference, covering both generative and non-generative models. Finally, **sustainability** is addressed through the Green Working Group, which aims to deliver foundational building blocks for energy-efficient Internet operations, supporting strategies that reduce environmental impact while maintaining performance.

5.4.2 SNS JU contributions to (pre)-standardisation

A sustained coordination between SNS JU projects and global standardisation bodies is essential to secure Europe's leadership position in shaping interoperable, secure, and energy-efficient communication systems that align with the digital and green transition goals. The Standards Tracker[36] is an online platform developed to provide a unified access point for SNS JU R&I projects, enabling their active participation in pre-standardisation processes. It also serves as a repository of selected telecommunication standards, helping researchers navigate the evolving landscape and stay informed about developments from standardisation committees. As of the date this deliverable was written, the Standards Tracker includes data only from Call 1 and Call 2 projects. Standards data from Call 3 projects is presented in Section 4.1.5 and will be incorporated into the tool in Q1 2026.

The platform also supports the creation of a European standardisation roadmap, offering insights into the timing, methodology, and rationale of contributions to ensure they are strategically aligned for maximum impact. By integrating the latest updates from SDOs and the SNS JU community, the tool facilitates gap analyses and impact reports, in line with the objectives of the SNS JU and the European Commission, while also benefiting vertical industries and 5G/6G associations.

The latest analysis of standardisation activities among SNS JU projects, as depicted in Figure 65 highlights a significant increase of contributions across major international bodies, demonstrating Europe's strengthened role in defining the technological underpinnings of next-generation communication networks.

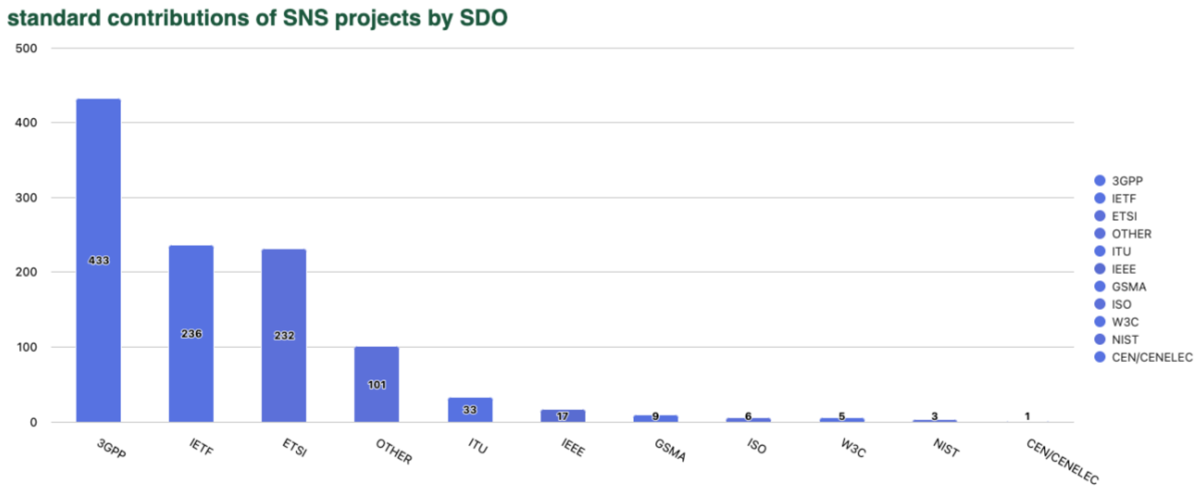

Figure 65: Analysis of SNS JU projects' standard contributions (November 2025) according to Standards Tracker data.

Over the past year, a remarkable expansion in participation has been observed, with projects collectively contributing to a wide range of standardisation organisations. The majority of inputs were directed toward **3GPP (433 contributions)** on critical topics such as enhanced radio access technologies, intelligent network management, and system architecture optimisation. Substantial engagement was also noted with **ETSI (232 contributions)** and **IETF (236 contributions)**, underscoring the growing importance of European research in areas such as AI-driven automation, edge computing, network security, and transport protocol refinement. These efforts support the interoperability and scalability objectives crucial for the deployment of complex, distributed network systems.

Beyond these primary bodies, projects have increasingly extended their influence to a broader set of (pre)standardisation fora, including **ITU (33 contributions)**, **GSMA (9), IEEE (17)**, **ISO (6)**, **NIST (3)**, **W3C (5)**, and **CEN/CENELEC (1)**. This diversification indicates a more holistic approach to

[36] https://sns-trackers.sns-ju.eu/standards-tracker

standardisation, engaging not only in telecommunications but also in adjacent domains such as cybersecurity, data management, and sustainable ICT practices.

5.5 Key Insights and Recommendations based on Stakeholders' Approach & Vision

The 6G Research and Innovation Landscape Analysis provides a comprehensive, structured and comparative view of global stakeholder perspectives on the technologies, enablers and strategic priorities that will shape the evolution of 6G networks. By systematically examining the positions of the SNS Joint Undertaking, European industry associations, national programmes, verticals, and leading international organisations, the analysis offers an integrated understanding of how the next generation of connectivity is expected to develop and where Europe stands in relation to competing global visions. This assessment is not only descriptive; it serves as a critical strategic instrument for identifying converging priorities, recognising emerging gaps, and directing future research and innovation activities under the SNS JU and across the wider European 6G ecosystem.

Across the nine thematic areas investigated, there is a pronounced coherence in the global understanding of the core technological pillars required for 6G. Stakeholders consistently position **artificial intelligence** as the defining enabler of autonomous, intent-driven and self-optimising networks, while **cloud–edge convergence** is viewed as the foundational architectural paradigm supporting distributed intelligence, high-performance services and advanced orchestration capabilities. **Microelectronics** and **device innovation** emerge as indispensable components for achieving the performance, **energy efficiency** and frequency capabilities envisaged for 6G. At the same time, **cybersecurity**, **trustworthiness** and **sovereignty** are recognised not as peripheral concerns but as central architectural principles that will fundamentally determine the viability and acceptance of future networks.

The analysis also reveals slight differences in emphasis across stakeholder groups. The SNS JU demonstrates a strongly operational and experimentally driven approach, focusing on demonstrators, testbeds and practical validation of early 6G technologies. In contrast, several industry associations and national initiatives expand the discourse to include large-scale industrialisation measures, supply-chain resilience, and capacity building—particularly in relation to microelectronics, cloud sovereignty and secure digital infrastructure (areas where the SNS JU is building towards). These differences are not contradictory; rather, they highlight complementary roles within the broader European and international ecosystem. SNS JU efforts accelerate technological readiness and experimental evidence, while industrial and national programmes emphasise production capabilities, long-term competitiveness and strategic autonomy.

The findings underscore the importance of treating **sustainability** as a horizontal requirement for 6G, encompassing not only energy efficiency but also lifecycle impacts, circularity and socio-economic value generation. Similarly, **quantum technologies**, though still emerging, are widely recognised as strategically important, particularly in relation to post-quantum security, high-precision sensing and timing. **TN/NTN integration** is universally regarded as a transformative feature of 6G, enabling global coverage, resilience and new service capabilities through unified terrestrial and non-terrestrial infrastructures. Finally, the evolution of **business models** is identified as a central determinant of 6G's future value creation, with network-as-a-service, AI-as-a-service and data-driven marketplaces expected to shape the economic landscape of next-generation connectivity.

SNS CO-OP partners have attempted to provide an overall overview of the 6G Landscape analysis across the different thematic areas, based on the reviewed stakeholder views. Table 9 provides the most critical information extracted from this study in a concise manner. Based on this aggregated view the following key recommendations can be provided:

- **Maintain SNS's experimental focus while strengthening industrial linkages:** Continue TRL-focused pilots and connect outputs to Chips JU/national pilot lines to accelerate microelectronics sovereignty.
- **Harmonise sustainability metrics:** Adopt validated KVIs and lifecycle/circularity methodologies across projects to expand beyond energy KPIs.
- **Operationalise trustworthy AI and data governance:** Prioritise explainability, federated

techniques and alignment with AI/Data Acts in SNS outputs.

- **Amplify TN/NTN trials and standards engagement:** SNS experimental platforms should be leveraged to inform standardisation and ESA/NTN coordination.

Overall, this landscape analysis offers a strategic foundation for shaping future 6G research and innovation priorities. It provides clear evidence of where Europe is aligned with global trends, where it holds unique leadership, and where further investment, coordination or policy action may be required. By mapping convergences and divergences across the ecosystem, it equips the SNS JU and its stakeholders with the insights necessary to target high-impact research areas, reinforce European competitiveness, and ensure that future 6G systems embody the values of trustworthiness, sustainability, openness and technological excellence that underpin the European approach to digital innovation.

Table 9: Overview of key insights per thematic area according to global stakeholder views.

Thematic Area	Envisioned Role in 6G	Key Insights Based on Stakeholder Views	Main Commonalities/Differences with SNS JU
Artificial Intelligence (AI)	Core enabler for autonomous, adaptive and self-optimising networks; foundation for intent-based management, real-time optimisation, semantic communication and pervasive automation across the architecture.	Stakeholders widely agree that 6G will be intrinsically AI-native, with emphasis on large-scale learning frameworks, explainable and trustworthy AI, and distributed/federated intelligence. Advanced MLOps, data governance, and energy-efficient models are recurrent priorities.	Strong alignment with SNS JU's focus on AI-enabled orchestration and automation. SNS JU is more experiment-driven, while other actors more heavily emphasise ecosystem-scale AI governance, ethical frameworks and global data-sharing federations.
Cloud/Edge Continuum (3CN)	Acts as the programmable substrate of 6G, combining connectivity, compute and storage into a unified service platform enabling distributed intelligence, near-real-time processing, and dynamic service placement.	Stakeholders highlight the need for sovereign, interoperable edge–cloud ecosystems, federated multi-cloud orchestration, and open interfaces enabling portability and resilience. The continuum is seen as essential for low-latency services like XR, digital twins and network automation.	High convergence with SNS JU's 3CN direction, especially on cloud–edge orchestration and open interfaces. Other groups put additional emphasis on sovereignty and reducing dependency on hyperscalers, whereas SNS JU centres more on trial-based architectural validation.
Microelectronics (incl. FEM)	Foundational to achieving higher frequencies, improved energy efficiency and advanced RF performance. Key to enabling THz/sub-THz communications, integrated sensing and high-directionality systems.	Global actors identify microelectronics as a strategic domain, stressing chiplet-based design, photonics, RF front ends and European/national pilot-line development. Energy-efficient silicon and heterogeneous integration are viewed as competitive imperatives.	Shared recognition of microelectronics' strategic relevance. SNS JU prioritises integration, prototyping and system-level experimentation, while other stakeholders emphasise scaling production capabilities, supply-chain autonomy, and deeper coordination with Chips JU and industrial pilot lines.
Cybersecurity	Ensures trustworthiness and resilience across all layers of 6G, including secure-by-design infrastructures, post-quantum readiness, continuous threat detection and robust identity and privacy management.	Stakeholders agree that security must be native, pervasive and automated. Growing interest appears in AI-driven anomaly detection, zero-trust architectures, PQC adoption, and supply-chain verifiability. Some national initiatives emphasise public-safety and critical-infrastructure resilience.	Broad alignment with SNS JU, which foregrounds built-in, self-protecting network capabilities. Differences mostly relate to scope: SNS JU maintains an architectural/system focus, whereas other programmes additionally prioritise sector-specific security solutions and national sovereignty requirements.
Sovereignty & Trustworthiness	Serves as a guiding principle shaping architecture, supply chains, data governance and infrastructure deployment, ensuring openness,	European and international stakeholders emphasise transparent architectures, trustworthy AI, data sovereignty, secure supply chains and open-source components. Sovereignty is seen as	SNS JU champions trust-by-design, open architectures and policy alignment (AI Act, Data Act). Other actors additionally highlight economic instruments—such as sovereign cloud stacks and chip production capacity—

Thematic Area	Envisioned Role in 6G	Key Insights Based on Stakeholder Views	Main Commonalities/Differences with SNS JU
	reliability and strategic autonomy across the 6G ecosystem.	both a technological and industrial-policy challenge.	creating a broader industrialisation agenda beyond SNS JU's remit.
Hardware & Devices	Enables differentiated service classes through specialised sensors, energy-efficient IoT, reconfigurable radios and high-performance user devices supporting sensing, localisation, XR and advanced mobility.	Stakeholders highlight the need for low-power ASICs, photonics-enabled devices, multi-sensor capabilities and platform-level device interoperability. Vertical-specific devices (industry, healthcare, transportation) are viewed as critical for 6G value creation.	SNS JU aligns strongly on innovation needs but focuses on device–network integration through experimentation. Other stakeholders emphasise large-scale device ecosystems, manufacturing capacity and harmonisation of device standards.
Quantum Technologies	Supports long-term 6G vision through post-quantum security, advanced sensing, high-precision timing and potential quantum-enhanced networking capabilities.	Global perspectives see quantum primarily as a strategic security topic (PQC and QKD), with additional interest in quantum sensing and photonics-enabled components. TRL remains low but strategic value is high.	SNS JU treats quantum as exploratory but necessary, particularly in relation to PQC integration. Other stakeholders, including some industry groups, place stronger emphasis on investing in quantum-enabled infrastructure and photonic technologies earlier in the research cycle.
TN/NTN Integration	Enables seamless, global and resilient connectivity by unifying terrestrial, satellite, aerial and high-altitude systems for service continuity and ubiquitous coverage.	Stakeholders consistently highlight the importance of NTN for bridging digital divides, ensuring resilience and supporting new edge/distributed services. Multi-orbit architectures, hybrid RF/optical links and standards alignment are key topics.	Strong convergence: SNS JU funds architectural frameworks and early NTN trials. Some international and national programmes place additional emphasis on industrial NTN roadmaps, cross-agency cooperation (e.g., ESA) and standardisation leadership.
Sustainability (cross-cutting)	Acts as a core requirement influencing design choices, technology selection, deployment models and KPIs, aiming for significant reductions in energy, emissions and resource use, while enabling positive societal impact.	Stakeholders agree on the urgency of energy efficiency but increasingly stress lifecycle assessment, circularity, and socio-economic sustainability. 6G is expected to contribute to greener vertical sectors via digitalisation.	SNS JU is fully aligned on sustainability as a pillar, with strong emphasis on measurable energy KPIs and KVIs. Differences arise in the breadth of coverage: SNS JU is more advanced in formalising sustainability metrics, while others increasingly highlight circularity and lifecycle models.
Business Models/Monetisation	Shapes the economic viability of 6G through platform-based value creation, service marketplaces, NaaS, AI-as-a-Service and new vertical-oriented offerings.	Stakeholders anticipate a transition from connectivity revenue models toward platform, data and compute-driven business structures. Openness, fair competition and interoperability are viewed as essential for innovation.	SNS JU aligns closely but emphasises experimental validation with verticals and SMEs. Industry associations place additional weight on regulatory reform, market structure evolution and reducing dependency on hyperscalers to enable sustainable monetisation.

6 SNS Vision & Roadmap

This section is the first step towards an SNS Vision update. The approach taken is first to provide an overview and recap of the SNS vision work by SNS OPS which discusses the trends towards 6G including smart networks and services beyond connectivity provision in Europe. Based on this and the observations drawn in Section 5, we provide complementary overarching perspectives and ideas believed to be important for the SNS community and the ability to create a stronger impact. An early summary of the Fifth Visions for Future Communications Summit (VFCS)[37], held in Lisbon 25-26 November 2025 is also provided, highlighting some of the key vision aspects addressed, which serve as inspiration for the further directions and SNS Vision update

Moreover, early considerations towards SNS JU Phase 3 (shorter term) and FP10 (longer term) are provided. With this approach this section provides a preliminary and high-level vision impact analysis and also complements the trend analysis in Section 5. At this stage, it is highlighted that the overview provided through Section 5 shows the depth and width of the technological opportunity space. This landscape analysis which emphasises stakeholder and industry status and to some extent also vision perspectives is highly valuable for the overarching and continued work on assessing and setting directions for the last phase of SNS JU and towards FP10.

The Vision discussion in this report is simply providing the initial discussion and analysis directions, based on the current 'pulse' of the community as recorded by the trend analysis (Section 5). Further, more detailed analysis towards an updated SNS Vision will be delivered in a dedicated Vision SNS CO-OP deliverable (D1.2), which is due in September 2026.

6.1 Recap of the SNS OPS Vision work

SNS OPS project legacy

In SNS OPS D1.3 [58] and D1.4 [3], a comprehensive overview and analysis of the SNS JU process towards a European Vision for 6G was given. SNS-OPS highlighted several areas to drive the SNS vision forward toward the last phase of SNS JU, and even for FP10. At this point, the 6G-IA 6G SNS Vision whitepaper should also be highlighted as an important output [2]. It provides a baseline and sets out a strategic roadmap for the development and deployment of sixth-generation smart networks and services in Europe. It emphasises the need for a collaborative, sovereign, and sustainable approach to 6G, highlighting key technological pillars such as AI-native networks, cloud-edge integration, advanced microelectronics, and robust cybersecurity. The document advocates for open standards and interoperable solutions, suggesting the reduction of reliance on global hyperscalers and the fostering of European leadership in digital infrastructure.

A smooth migration from 5G to 6G implies *that 6G should be based on an evolved 5G core network* (5G CN) and multi-RAT spectrum sharing for efficient interworking. Further a *simplified yet flexible and modular 6G architecture* is needed to adapt to future evolution and deployment cases. Ubiquitous network connectivity must be ensured through integration of diverse connectivity options, e.g., TN, NTN, mesh, etc. Enabling native AI support in 6G networks implies developing frameworks to support full network automation and provide AI as a service solution. An *end-to-end security and privacy preservation framework* is essential and must be aligned with the European principles and policies. Solutions supporting *vertical industries* must be aiming at common denominators applicable for various sectors.

Sustainable 6G and 6G for sustainability implies developing sustainable solutions and services for the 6G system as well as the use of 6G for sustainable solutions for the verticals and society (in terms of environmental, social and economic perspectives).

EU stakeholders need to address *societal needs* and provide reflections on how they will drive priorities and roadmap towards 6G from the public telco operator's perspectives.

[37] https://futurecomresearch.eu

European capabilities must be improved. This can be done by developing pan-European experimental platforms (test and validation of technical performance, validation of innovative business models, supporting agility and fast developments close to market solutions etc.).

Further, the SNS OPS project points to several *6G technological enablers*, like supporting beyond communication services, enabling the cloud continuum by providing edge cloud solutions. In this context defining *open interfaces* towards hyperscalers and service providers are necessary. 6G needs to provide exposure and network programmability through APIs, considering *interoperability* in both on-net and off-net service and device endpoints. *Network disaggregation* should be supported through open lower-layer split (LLS). On the spectrum side, it is recommended that mainly *focus on low and mid-band frequencies* and consider higher frequencies only for specific solutions, like e.g. backhauling.

SNS JU Project Vision analysis

The **SNS JU project Vision analysis** questionnaire is comprehensively analysed in Section 4.2. The survey is a snapshot of the focus of the Call 3 projects which started in January 2025. It shows that many important visions aspects, as recommended by the SNS OPS project and discussed above, are being emphasized by the projects. Many projects are focusing on the *transition from 5G* to sustain and enhance 5G innovations, however, the integration of new service capabilities is also important. We also see an increased emphasis on *privacy, security and human safety*. Sustainability is focused on *sustainable 6G and energy efficiency*, and significant support for the UN SDGs targeted by the SNS JU. There seems to be consensus that 6G must be based on *societal needs with a European perspective* and that major 6G societal challenges are to enable the creation of *new business models and market segments*, and to ensure a strong European impact on standardization.

6.2 Towards SNS Phase 3 and FP10

6.2.1 Ideas for strengthening impact creation

This section addresses how SNS JU can strengthen impact and deliver on the overall SNS JU programme level objectives. While recognizing the vast technological opportunity space presented above and at the same time observing the state of our industry and the slower than expected adoption, use, and growth by 5G and related services, it is important to consider potential ideas and steps for strengthening impact.

- **Overarching perspectives:** Overarching and cross-sector perspectives are needed for the European research and innovation landscape, such as strengthening industry advancement, digital and green transitions, sustainability, sovereignty, resilience, and societal progress. Moreover, stronger coordination, harmonization, and collaboration across SNS projects is essential, while strengthening the alignment and interaction with business development activities. This has the potential of better understanding the customer problems to be solved and provision of solutions and services addressing this.
- **Complex ecosystem – mobilize all stakeholders**: The telecom sector is a complex interconnected and interoperable multi-stakeholder platform ecosystem, and coordination and co-creation is challenging. It is important to identify and resolve barriers that prevent progress, which is the intended goal of the recommendations and mechanisms provided by the Impact Assessment and Facilitation Action (IAFA) as set out by the European Partnership for SNS Proposal [59]. This will ensure that the process from research to market is effective and inclusive for every stakeholder involved.
- **Cross-disciplinary research**: Research is essential to support the IAFA targeted actions, providing evidence for technological trends, anticipating customer and market needs, and spotting barriers early. Strong research enables IAFA to assess new solutions, harmonise standards, guiding strategic priorities and policy decisions, and turn insight into practical applications. The SNS community activities related to key values (KVs), key value indicators (KVIs) and evolving related frameworks and methodology are essential as part of this. With cross-disciplinary approaches, IAFA activities become effective in driving Europe’s smart networks and services leadership.

- **Pan-European experimental platform**: The potential of a stronger pan-European experimental platform should be addressed. Interoperable and harmonized experimental platforms across Europe can create the needed multi-stakeholder platform for technology research and development, while experimenting and co-crating with and across the various stakeholder for greater scale, efficiency, and innovation outcomes. It is essential for instance for AI, 3CN, and related API exposure ambitions, to address opportunities in adaptive and scalable solutions and architectures, their interoperability, and support of intelligent automation. This will allow for improved customer centricity, platform and service maturity, to strengthen and drive user experience.
- **Business model evolution and innovation**: 6G reinforces a service approach which is already part of 5G and beyond business model evolution. With 6G's interoperability and AI-enabled self-optimising, an ever-increasing number of technical functions and rights-to-use can be continuously recombined for new services at a high pace. The SNS-JU programme and community should attend to how this will impact the 6G business model buildings blocks. While the vision is new revenues and economic growth, the business models may require customer channels that handle dynamic negotiations of prices and cost sharing, and re-allocation of key activities, resources and partners across the 6G ecosystem. Moreover, how to build sufficient trustworthiness for new 6G business models is a major challenge in the European contexts.
- **Sustainability**: Climate changes and geo-political challenges call for increased attention on sustainability. The overall SNS JU programme needs further rethinking and strengthening in this direction. Rightly, the European SNS JU community's way of addressing the KVs/KVIs are globally unique and should be further strengthened. This requires smarter and stronger cross-sectorial collaboration. SNS JU and smart networks and services can play a stronger role when NGOs, Public sector, business and industries need tools and services for such collaboration and co-creations. Also, citizen engagement can be further facilitated.

The above overarching perspectives are all together aimed to set ambitions for the forthcoming SNS vision roadmap, strengthening of SNS Phase 3 and the forthcoming preparations for FP10.

6.2.2 Summary and ideas from VFCS 2025

The VFCS25[37] closing discussion highlighted a set of converging technical, architectural, and societal challenges that will shape future communications systems.

On the technology side, several areas emerged as particularly strategic. **Optical** was recognized as more central than initially anticipated, with significant challenges at the device level and promising developments such as hollow-core and other fibre types that could improve capabilities. At the device level aspects as improved network synchronization. Underwater communications were also discussed as a niche where, for certain applications, traditional undersea constraints may be less dominant and where unique advantages could be realized for specific applications. In parallel, **satellite–terrestrial convergence**, including in spectrum usage, was seen as a key frontier. The rapid progress of satellite systems—illustrated by the now-real notion of direct connectivity from regular phones—raises concerns that commercial deployments may outpace research, particularly in areas such as GNSS resilience and the use of terrestrial networks as large-scale sensors.

Edge computing and **energy efficiency** were recurring themes. The group stressed that the main challenge for the edge is not only latency, but also the complexity and jitter arising from the aggregation of highly heterogeneous traffic. Future edge architectures may need to be designed explicitly around controlling time variability, not just propagation delay. On energy, participants called for a clear understanding of who consumes energy and how costs are propagated from infrastructure to users. There was a strong message that systems can no longer be designed "without thinking about power," especially given the dramatic increase in consumption caused by high-throughput wireless use cases. Ideas such as dynamically switching overlapping cells on and off according to traffic demand were cited as examples of more energy-sensitive network design.

Resilience, dual use, and federation formed another major cluster of discussion. Participants identified the need for frameworks that can guide the design of infrastructures serving both commercial and broader resilience roles, particularly where multiple networks or services are federated. Today, there is no well-defined methodology to link high-level resilience objectives to concrete technical architectures. The concept of graceful degradation was highlighted as an area where current networks fall short, with past attempts at ultra-fast handover architectures having failed due to correlated failure risks. Understanding the fundamental limits of network architectures, and how to avoid cascading failures, remains an open research problem.

A substantial portion of the debate focused on the emerging "**Internet of Agents**" and **AI-centric networks**. Participants considered scenarios where customers are AI agents rather than humans, raising questions around protocols, identification, skill and capability registration, and the orchestration of dynamic swarms of digital and physical agents. This led to broader reflections on AI delivery networks and the data/compute continuum, including the possibility of treating the network as a unified compute-communication fabric with AI services offered from the edge (an AI-CDN model) rather than from devices themselves. How these concepts interact with telco edge offerings and with large-scale sensing capabilities was identified as a strategic question for future work.

Finally, **security and privacy** were recognized as foundational concerns that cut across all these topics. While many enabling technologies are already standardized, deployment in real environments often lags behind. The rise of AI agents challenges traditional authentication, authorization and accounting models, especially as agents become adaptive or self-modifying. New security models will be needed to manage these entities safely. Overall, the concluding tone was both realistic and ambitious: technology, particularly AI and satellite systems, is moving faster than expected, while legal, economic and operational frameworks struggle to keep pace. The discussions clearly delineated a rich agenda for future research on resilient, energy-aware, AI-enabled communication networks.

6.2.3 Towards SNS Phase 3

Following the SNS WP2026 (addressed in Section 5.2.2) the final SNS Work Programme will be released in 2027. This will be a very important WP, strategically completing the SNS programme and overall SNS projects portfolio and also ensuring the best transition from Horizon Europe to the forthcoming Framework Programme in the next Multi-year Financial Framework (MFF) covering the 2028-2034 period. It is expected to include (among others) both "FP10" and the European Competitiveness Fund (ECF). The SNS WP2027 is targeting an overall EC funded budget of 220+ M€. Its definition will start in January 2026 and it is expected to run full speed from February to November 2026 with EC-SNSO - TF/CT leadership, as in previous occasions. It will allow targeted actions of technology research, development, experimentation and validation addressing many (if not most) of the thematic areas highlighted in Section 5. The WP2027 will build from previous work and lessons learned and it will allow the strengthening of global impact.

The WP2027 definition will also include further specific 6G-IA focused Workshops (to be organized in January-February 2026 see also Section 5.3.7.3), two 6G-IA Members Consultations (expected to be launched in May and July 2026) and several interactions with SRG/MSs Representatives. The WP2027 definition will also clearly leverage the up-to-date SNS portfolio analysis (including also the gaps analysis related to SNS Call 2025 selected Projects) and the latest important mega-trends and trends discussed during the latest Networld Europe VFCS 2025 and to be addressed in detailed technical content in the Networld Europe SRIA 2026 (to be developed in parallel to the WP2027 during the time period January to June 2026). The development of the WP2027 will be described in detail in deliverable D1.2 (due September 2026).

6.2.4 Towards FP10

The upcoming multi-annual financial framework for European R&I, FP10, is targeted for 2028 – 2034, which means that there will be an overlap of early phase FP10 projects with the last SNS JU projects running until 2030. The European Commission proposes to invest € 175 billion over the period 2028-2034[38]. The programme is proposed to build on 4 pillars: *Excellent Science*, *Competitiveness and Society*, *Innovation*, and *European Research Area*.

[38] https://research-and-innovation.ec.europa.eu/news/all-research-and-innovation-news/horizon-europe-2028-2034-twice-bigger-simpler-faster-and-more-impactful-2025-07-16_en

According to the legislative proposal, European Partnerships will remain an important element of the new Horizon Europe. Some substantial changes are proposed concerning the partnership formats. The Co-funded partnerships shall be discontinued and replaced by a different, MoU-based system[39].

Several organizations and associations (at European and National levels) have provided and continue to provide their inputs and recommendation on FP10 definition. The 6G Smart Networks and Services Industry Association (6G-IA) has also provided an initial position paper[40], and key points will be provided below. The Austrian ERA portal is maintaining a resource site where many of the position papers can be found[41].

The starting point and driving objectives to be developed for FP10 should build from those of the SNS JU (the need to maintain European leadership in telecommunications, support the digital transformation of industries, achieve sustainability and societal goals, and ensure strategic security and sovereignty in critical technologies). While the UN SDGs were among the strong drivers for the SNS JU, we expect both the Draghi report[42] and the Heitor report[43] to provide key complementary inputs and context for the development of overarching and driving objectives for the FP10 partnership proposal.

The Draghi report recognizes challenges in Europe including slowing growth, a widening GDP gap with the US, and the need for increased productivity and competitiveness. The report proposes three main areas for action.

1. **Closing the Innovation Gap**: Europe needs to focus on technological and scientific innovation, improve the pipeline from innovation to commercialization, and remove barriers that prevent innovative companies from growing.

2. **Decarbonization and Competitiveness**: The plan calls for a joint approach to decarbonization, ensuring that Europe's ambitious climate targets are matched by leadership in clean technologies.

3. **Increasing Security and Reducing Dependencies**: The strategy includes developing a foreign economic policy to secure critical resources and reduce dependencies on non-EU countries.

The Heitor report titled **"Align, Act, Accelerate: Research, Technology and Innovation to boost European Competitiveness"** highlights the European added value of the EU framework programme for research and innovation (R&I). It is a comprehensive report prepared for the European Commission by the Directorate-General for Research and Innovation. The report aims to enhance European competitiveness through research, technology, and innovation, and puts forward twelve recommendations. The recommendations have been drafted by an independent group of 15 leading experts chaired by Manuel Heitor, former secretary of state for science, technology and higher education of Portugal. The "whole-of-government approach" is highlighted as a key recommendation for creating momentum through transformative research and innovation policies. It involves aligning these policies with the EU strategic agenda and recent high-level policy recommendations to boost Europe's competitiveness and position in the global economy.

The 6G-IA "SNS in FP10" position paper recognizes the above context and the European Strategic Policy Goals. It argues for sustained European Research & Development & Innovation (R&D&I) in the SNS sector, building on a 30-year track record of leadership in mobile network generations (from GSM to 6G). The rationale is threefold: i) Why: Europe needs an extended R&D&I perspective to maintain competitiveness, sovereignty, and leadership in SNS; ii) What: FP10 should cover activities that address evolving technological, economic, and policy challenges; and iii) Implementation should maximize

[39] https://www.era-learn.eu/partnerships-in-a-nutshell/european-partnerships/next-framework-programme-fp10#legislative-proposal-for-the-10th-framework-programme-by-the-european-commission

[40] https://6g-ia.eu/wp-content/uploads/2025/05/sns-in-fp10-position-papervfinal.pdf

[41] https://era.gv.at/fp10/position-papers/

[42] https://commission.europa.eu/topics/competitiveness/draghi-report_en

[43] https://european-research-area.ec.europa.eu/news/align-act-accelerate-high-level-group-presents-recommendations-future-framework-programme

impact through public-private partnerships, leveraging Europe's strong ecosystem of industry, academia, and SMEs.

In recognizing the above and the previous sections (addressing technology, ecosystem, and societal topics) it becomes obvious that the SNS community and the industry will develop the technological areas and complementary ambitions as needed to drive and progress Europe beyond SNS JU. The 6G-IA and the NetworldEurope ETP will collaborate to develop the next Strategic Research and Innovation Agenda (SRIA) documents where the various SNS technologies, including telecommunication, internetworking, and complementary beyond connectivity technologies and related themes are positioned for further enhancements and radical innovations through FP10.

While the SNS JU community is coming from a strong technology orientation the challenge is to broaden the orientation to further strengthen the ecosystem evolution and innovation. This can be achieved along with extending the large-scale trials and pilots, ensuring effective continuity, longer-term duration, and stronger momentum, while building on the emerging Key Value and KVI orientation and methodologies of SNS JU. Ensuring improved efficiency and scale in early deployments of emerging technologies and solutions will be critical, along with higher ambitions for a strong pan-European experimental platform (exact format to be determined). Such interoperable, continuously evolving, and harmonized experimental platforms across Europe can bring together the stakeholders needed for technology research, development, and innovation with greater and stronger outcomes and impacts. To achieve a growing and broader service provisioning ecosystem, it will be essential to go beyond today’s 5G-6G orientation to address the wider opportunities from AI, cloud, and virtualization (3CN, API exposure, etc).

As indicated above, the funding schemes and the partnership structure and governance will change for FP10. It will be important to deliver on the expectations of the various sectors in demand of the evolved SNS technologies, solutions, and services. The expectations towards effective support of the twin transition (digital and green) will demand new ways of collaboration and co-development. We anticipate a need for further strengthening the collaboration with the various sectors (including vertical sectors) and their associations and partnerships as they also evolve and adapt to the opportunities from FP10. The further continuation of the Digital Europe Programme is important in this respect. This programme as evolved for FP10 can be better and mutually aligned with the community and might represent an innovative funding scheme for early solution deployments, technical and business model experimentation, in alignment with the just mentioned and anticipated ambitions for a strong Pan-European experimental platform.

As a concluding remark, the SNS JU Phase 3 can build early capacity and capabilities for entering into FP10 with a strong European momentum. It will be critical to ensure this momentum will only be further strengthened for FP10, as for instance indicated by section 6.2.1. Recognizing and building from the unique European positions of strengths the FP10 vision and roadmap should ensure a strong link between the supply side and the demand side ensuring the demand side requirements are targeted in effective ways. The unique European multi-stakeholder platform ecosystem as currently manifested by and centred around the major European Telcos must be strengthened and broadened to extend the current 5G-6G oriented SNS into a wider scope of interconnected and collaborative resilient future networks and services delivering upon the European policy objectives.

7 Conclusions & Way Forward

As discussed in the Introduction, the two main objectives of the SNS CO-OP CSA are (i) to support a continual monitoring and improvement process based on regular assessments of SNS KPIs; and (ii) to provide support for the identification of strategic R&I orientations at global, European and Member State level. The results achieved by SNS CO-OP in its first year on these topics have been reported in this Deliverable.

With the start of its activities, SNS CO-OP took over the ownership of Monitoring & Analysis Framework from SNS OPS, taking care of its maintenance and the update of the projects' questionnaire. Several changes have been made, aiming at reducing the workload of SNS projects for completing the questionnaire, reducing, as much as possible, duplication with other reporting mechanisms, improving clarity of the responses and to implement requests from the SNS Office e.g. to strengthen the KVIs section, offering more concrete insights.

The processing and analysing of the SNS project responses to the questionnaire has been a major activity for monitoring the progress in SNS JU as well as for performing a gap analysis, directly inputting the results in the generation of future SNS Work programmes. The aggregated view of the achievements shows that the SNS projects have delivered substantial measurable results during the first two years of their operation (Jan 2023 - Dec 2024), underscoring a successful commitment to both academic excellence and industrial relevance with e.g. 1,439 publications, 1,135 contributions to standards and 91 patent applications that were filed. The responses from the newly started Call 3 projects about their planned activities underline that there is a good coverage of all major technical topics, targeted SDOs with ETSI and 3GPP being steadily the most popular SDOs, but also regarding societal challenges underlining that sustainability is in focus in 6G SNS R&I activities. Not surprisingly and consistent with that, energy efficiency is the most often mentioned societal values addressed. All of those insights underline that activities in SNS JU make excellent progress and achieve the desired results in all envisioned dimensions.

Another major element of the work performed has been the analysis of the 6G landscape and the current trends. As explained in Section 5, a targeted analysis on the work carried out and the vision of various relevant stakeholders regarding a set of ten key thematic areas (both technical and non-technical) has been performed. This included naturally the SNS JU priorities and its Work Programme 2026 and took an outward look to EU National and International activities, Associations and SDOs. As such, it provides an excellent overview of the views of all these initiatives on the selected ten topics. The analysis of key trends from vertical sectors complements the analysis, bringing in the view of the current and prospect users of 5G/6G technologies. In Industry and Manufacturing e.g. it has shown that there is a rapidly growing interest in Integrated Sensing and Communication (ISAC), recognizing it as a key enabler for new industrial capabilities. For Media & Entertainment, the long-term impact of 6G will be characterized by enhanced user experiences and new opportunities for content creation and distribution, and for Agriculture recent works indicate that it is progressing beyond the IoT-centric smart farming trends toward a more intelligent and autonomous model. 6G research in SNS needs to keep such developments in mind in order to foster defining and developing a 6G that will be attractive to vertical users as an important target group for network operators, in particular in view of tapping into new sources of revenue.

This deliverable also provides a foundational stepping stone toward updating the SNS Vision by consolidating insights from prior work (SNS OPS analysis), early reflections from critical stakeholder events, and emerging considerations for SNS Phase 3 and FP10. Together, these elements provide initial insights and potential directions of the ever-evolving vision for 6G and paint a picture of a rapidly evolving technological and societal landscape—one in which Europe must simultaneously navigate complex ecosystem dynamics, leverage cross-disciplinary innovation, and reinforce strategic autonomy. The themes highlighted here underscore the importance of aligning research, experimentation, and policy with overarching goals of sustainability, resilience, and impact creation. As the community advances toward a fully updated SNS Vision in 2026, the preliminary perspectives presented in this report will serve as critical inputs, ensuring that future directions remain both ambitious and grounded in the real needs, opportunities, and challenges facing Europe's smart networks and services ecosystem.

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