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SNS OPS – Supporting the SNS JU Operations

D1.4: Second Period Assessment and Planning Report

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Abstract

This document is the final deliverable of SNS OPS WP1 and presents the final findings and insights gained within WP1, based on the WP activities. It presents the detailed analysis of the SNS OPS Questionnaire 2024 results, based on the survey conducted on the 63 active SNS Call 1 and Call 2 projects, and provides insights regarding the Programme level KPIs of the SNS JU (2023 accomplishments). Moreover, the process of absorbing the results of the questionnaire and turning them into useful information that in turn shaped the SNS Work Programme 25 is presented, along with the efforts to create additional momentum for 6G SNS. Finally, an overview of the current status of 6G vision in Europe is presented, based on various sources and stakeholders, offering suggestions for the way forward in order to maximize the impact of the SNS JU on the global stage.

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Disclaimer

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Executive Summary

This document presents the final deliverable of SNS OPS WP1, providing a comprehensive assessment of progress and insights gained through the SNS OPS Monitoring and Analysis Framework. It consolidates the analysis of the 2024 SNS OPS Questionnaire results, offering key findings from 63 active SNS Call 1 and Call 2 projects. The report evaluates Programme Level Key Performance Indicators (KPIs) for 2023, identifies research gaps, and refines the strategic vision for an SNS roadmap to shape the 2024/25 SNS Work Programme.

The most significant insights gained from the analysis of the 2024 SNS OPS Questionnaire can be distilled to the following:

- **Technical Assessment**:
  - Strong focus on AI/ML integration, system architecture, energy efficiency, and novel radio technologies.
  - Alignment with SNS Work Programme objectives, ensuring broad coverage of key areas.
  - KPIs emphasize energy efficiency, reliability, latency, and spectrum efficiency.
- **Vision Analysis**:
  - Strong emphasis on sustainability, affordability, and accessibility.
  - The European value-based approach and cybersecurity remain key priorities.
  - Stakeholder input highlights the need for continued alignment with global 6G advancements.
- **Market Insights**:
  - I4.0, automotive, smart cities, and media/xR are the primary vertical sectors targeted.
  - AI-driven automation and sustainable solutions drive market interest and innovation.
  - SME participation remains crucial for fostering diverse technological contributions.
- S**tandardization and Trials:**
  - ETSI, 3GPP, and O-RAN are the most targeted standardization bodies.
  - Validation efforts span across 19 EU countries, ensuring broad experimental coverage.
  - Lab testing and real-world trials drive 6G technology validation and scalability.
- **SNS JU Achieved Impact (Programme Level KPIs)**
  - Significant scientific impact was achieved during 2023 by Call 1 projects, delivering 129 peer-reviewed articles, 230 conference publications and 14 white papers.
  - Significant impact was also achieved in international standardization bodies with 308 standards contributions and 29 open-source contributions.
  - Great start in the capitalization and commercialization of SNS JU solutions, with 32 patent applications already being filed in the first year.
  - Impressive effort by the call 1 projects to disseminate and promote their work through the organization of 100 events and participation in another 314 events.

Moreover, this deliverable reports on the activities to advance the momentum of the SNS initiative and focuses on refining the strategic vision for 6G in Europe, by providing an in-depth analysis of gaps identified in previous research, proposing a refined SNS roadmap, and aligning the European 6G strategy with global developments. More specifically, it was identified that sustainability, security, and digital sovereignty remain central pillars of the evolving European 6G vision, hoping to ensure a strong European leadership role in next-generation networks. The importance of trust, inclusivity, and affordability in the development of future network architectures was also highlighted, while input from stakeholders has indicated that a balance of technological advancements with societal and economic impacts is required.

Finally, concrete recommendations towards all involved stakeholders are offered for the way forward. **Policymakers** are invited to establish regulatory frameworks that foster innovation while ensuring security, interoperability, and ethical AI integration in 6G networks. **Industry and Researchers** should focus on strengthening collaboration across European and international initiatives to accelerate the standardization and commercialization of 6G technologies, while **Investors and Public Institutions** should develop long-term funding strategies to support large-scale 6G trials, ensuring Europe remains competitive in the global market. Finally, **Vertical Industries** are invited to foster cross-sector engagement to co-develop solutions that maximize the economic and societal benefits of 6G.

Table of Contents

List of Figures

List of Tables

Abbreviations

3CN	3C Network – Connected, Collaborative Computing
3GPP	Third Generation Partnership Project
5G ACIA	5G for Connected Industries and Automation
6GF	6G Forum
6G-IA	6G Industry Association
AI	Artificial Intelligence
AIOTI	Alliance for IoT and Edge Computing Innovation
API	Application Programming Interface
AR	Augmented Reality
ASIC	Application Specific Integrated Circuit
ATIS	Alliance for Telecommunications Industry Solutions
B2B	Business to Business
B2C	Business to Customer
B5PC	Beyond 5G Promotion Consortium
B6GA	Bharat 6G Alliance
CCSA	China Communications Standards Association
CHIPS-JU	Chips Joint Understanding
CMOS	Complementary Metal-Oxide-Semiconductor
CN	Core Network
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
E2E	End to End
EC	European Commission
ECCC	European Cybersecurity Competence Centre
ECS	Edge Computing System
ECSO	European Cyber Security Organisation
eMBB	enhanced Mobile Broadband
ESA	European Space Agency
ETP	European Technology Platform
ETSI	European Telecommunication Standards Institute
FEM	Front-End Module
FSTP	Financial Support to Third Party
GA	Grant Agreement

HE	Horizon Europe
HPC	High Performance Computing
HW	Hardware
IAFA	Impact Assessment and Facilitation Action
ICT	Information and Communication Technology
IDPS	Intrusion Detection and Prevention System
IETF	Internet Engineering Task Force
IMT-2030	International Mobile Telecommunications - 2030
IO	International Organization
IoT	Internet of Things
IPCEI	Important Project of Common European Interest
IPR	Intellectual Property Rights
ISAC	Integrated Sensing and Communications
ITU-R	International Telecommunication Union – Radiocommunication Sector
KDT	Key Digital Technologies
KER	Key Exploitable Results
KPI	Key Performance Indicator
KSI	Key Sustainability Indicator
KSO	Key Strategic Orientation
KVI	Key Value Indicator
M2H	Machine-to-Human
M2M	Machine-to-Machine
MIMO	Multiple Input – Multiple Output
ML	Machine Learning
MNO	Mobile Network Operator
MR	Mixed Reality
NDT	Network Digital Twin
NESSI	Networked European Software and Services Initiative
NGA	Next G Alliance
NGMN	Next Generation Mobile Networks Alliance
NGO	Non-Governmental Organization
NRT	Non-Real Time
NTN	Non-Terrestrial Network
NWE	NetworldEurope
OAI	Open Air Interface
PSCE	Public Safety Communications Europe
RAN	Radio Access Network

RIS	Reconfigurable Intelligent Surface
RoI	Return on Investment
RT	Real Time
RTO	Research and Technology Organisations
SB	Steering Board
SBA	Service Based Architecture
SDG	Sustainable Development Goals
SDO	Standards Developing Organization
SIEM	Security Information and Event Management
SME	Small or Medium sized Enterprise
SNO	Satellite Network Operator
SNS JU	Smart Network and Services Joint Understanding
SNSO	SNS Office
SNVC WG	Societal Needs and Value Creation WG
SO	Specific Objective
SoC	System on a Chip
SRIA	Strategic Research and Innovation Agenda
TAM	Technology Acceptance Model
TB	Technology Board
TF	Task Force
TinyML	Tiny Machine Learning
TMV WG	Test Measurement and Validation WG
TN	Terrestrial Network
TRL	Technology Readiness Level
TSDSI	Telecommunications Standards Development Society
UAV	Unmanned Aerial Vehicle
UE	User Equipment
UN	United Nations
URLLC	Ultra Reliable Low Latency Communication
V2X	Vehicle to Everything
VET	Vertical Engagement Tracker
VR	Virtual Reality
VSC WG	Vision and Societal Challenges Working Group
WP	Work Programme or Work Package

1 Introduction

This document constitutes the final deliverable of the SNS OPS Work Package 1 "Assessment and Planning", and as such reports on all the developments, results and insights gained by the partners' work in the various WP1 Tasks. Moreover, as this is the final output of WP1, the key overall outcomes and major insights gained by WP1 are highlighted, while the hand-over of work to the follow up CSA project (SNS CO-OP), to ensure the legacy of SNS OPS, is also discussed.

1.1 Purpose and scope of the deliverable

The main purpose of this deliverable is to report on all the activities of WP1 in the past year, to officially document the results of all WP1 tasks and to ensure the legacy of the SNS OPS Monitoring and Analysis Framework (developed within WP1), which will be used and further evolved by the follow-up CSA project, (SNS CO-OP) by providing all the necessary information for a successful handover.

One of the key items reported in this deliverable is the detailed analysis of the 2024 SNS OPS Questionnaire to all active SNS JU projects, as part of the SNS OPS Monitoring and Analysis Framework. Section 2 presents the full analysis of the collected input from Call 2 SNS projects, broken down into three main categories i.e., technical, vision and market, comprising detailed graphs and extracted insights. An overview of the results of the 2024 Questionnaire was presented to the SNS community via a webinar[2] on June 27th, 2024, but the full detailed analysis of the collected input is provided in this deliverable. The analysis also includes the first insights regarding the programme level KPIs achieved by the Call 1 SNS projects during 2023, while the necessary updates implemented on the Questionnaire for the 2025 release, based on the community feedback are also presented.

The other key item addressed in this deliverable is the use of the gained insights from the questionnaire, to perform a gap analysis between the SNS JU research direction and the roadmaps of other associations, national initiatives and stakeholders, which resulted in an updated SNS Roadmap, and provided critical input for the design of the 2025 SNS JU Work Programme. The same input was also used to determine potential necessary updates to the overall SNS vision (as expressed by the projects), which acted as input to significant documents such as the updated NetworldEurope Strategic Research & Innovation Agenda (SRIA) and the 6G-IA Vision White paper. The SNS OPS partners have documented how their work has comprised a critical part of the input that the various EU stakeholders use, to determine the future steps in R&I endeavours.

The deliverable concludes by providing suggestions and recommendations regarding next steps for major EU stakeholders, and advice on the direction that the follow up CSA project should follow, highlighting attention points and potential pitfalls. This deliverable should be used by the follow-up CSA, as the "manual of operations" for all WP1 activities and for the handover of the Monitor & Analysis Framework and the annual questionnaire.

1.2 Context and background

The five tasks comprising WP1were focused on establishing an accurate picture of the status of the SNS projects and their adherence to the overall goals of the SNS via the definition, circulation, data collection and analysis of the SNS OPS "Monitoring and Analysis Framework". The data and insights offered by the annual circulation of this framework were used to assist the promotion of SNS JU work and to align and re-calibrate the SNS vision in order to keep up with global developments. The various WP1 tasks played their own important role towards this overall goal, as follows:

- ***T1.1 SNS progress assessment***, was responsible for the development of the Monitoring & Analysis framework and the corresponding questionnaire circulated to the new SNS projects on an annual basis. This task was also responsible for updating and circulating the questionnaire

[2] https://smart-networks.europa.eu/event/sns-ops-questionnaire-results-webinar/

every year and processing the results and producing relevant insights, which enabled the work of the rest of the Tasks of WP1 and other SNS OPS WPs.

- ***T1.2 SNS Road mapping,*** was responsible for performing a gap analysis based on the results of the annual project questionnaire and information on the overall trends in 6G research by other key stakeholders, such as Associations, National Initiatives, etc., and to create a roadmap for the further evolution of the SNS JU, which would ensure that SNS researchers would build their expertise in all critical 6G technological domains and would maximize their impact in global standardization bodies.
- ***T1.3 SNS Vision,*** was responsible for analysing the data from the SNS projects in order to establish the current vision of SNS researchers and benchmarking it with the 6G vision communicated by other global stakeholders. Through this comparative analysis, this task has presented the European view to the rest of the world and has provided suggestions for an updated SNS vision and the way forward in 6G research in Europe.
- ***T1.4 Building 6G SNS Momentum,*** was responsible for collecting the output of the previous tasks (project insights, gap analysis, vision update suggestions) and transforming them into concrete recommendations towards the SNS JU Work Programme core team, which would shape the future calls of the SNS JU. The task was also responsible to communicate these insights to future proponents and SNS JU call participants.
- ***T1.5 JU Metrics Methodologies Data Collection,*** was responsible for developing the methodology to collect all the necessary JU metrics (programme level KPIs) and to calculate and report them to the SNS JU on an annual basis. Metrics such as the In-Kind contributions to Operational Activities (IKOP) and In-Kind Additional Activities (IKAA) regularly collected and reported thanks to this task, were crucial for the financial success of the SNS JU, while the collection and reporting of additional programme level KPIs from the projects (e.g., number of publications, contributions to standardizations, events), assisted to the understanding of the big picture and the estimation of the impact of the SNS JU on the global stage.

It can be understood that the five tasks of WP1 work in tandem and depend on each other's results and output, to produce their final findings. Via the close collaboration of WP1 partners, it was feasible to achieve all the goals set forth by WP1, and to support the SNS community and the SNS JU office to gain key insights regarding the ongoing and future work of the projects, while also assisting the EU experts to shape the future of the 6G R&I landscape in Europe.

1.3 Collaboration with other projects and groups

It has to be stressed, that several of the outcomes and insights presented in this deliverable are the outcome of close collaboration with other CSA projects (SNS ICE and 6G4Society), SNS JU WGs and 6G-IA stakeholders and -WGs. More specifically the following collaborations can be highlighted:

- Feedback from 6G4Society project was used to update the Vision sections of the Questionnaire.
- Input from 6G4Society and SNVC WGs was utilized for the KVIs status update (Section 2.5).
- Input from SNS ICE on international EU and vertical stakeholders was utilized for the gap analysis (Section 4.1).
- Input from NetworldEurope and 6G-IA WGs was utilized for the update of the SNS road mapping and the definition of WP2025 (Sections 4.3 and 4.4).
- Input from a wide variety of sources (SNS JU Office, SNS JU projects, SB/TB/WG reports, 6G-IA White papers & WGs, etc.) was used for the update of the SNS Vision (Section 5).

1.4 Structure of this document

The rest of the document is structured as follows. Section 2 presents the detailed analysis of the 2024 SNS OPS questionnaire, providing insights regarding the technical, vision and market aspects of the

Call 2 SNS projects, while it also presents the detailed programme level KPIs collected by Call 1 projects (addressing their work in 2023). Section 3 discusses the updates that were implemented on the 2025 version of the annual SNS OPS questionnaire, based on the feedback received by the SNS community, while Section 4 presents the updated SNS Roadmap and the approach to further build the SNS momentum, based on the collected data. Section 5 continues the work on the SNS Vision updates presented in the previous WP1 deliverable (D1.3) and discusses the impact and potential directions for the future of the SNS JU. Finally, Section 6, concludes this deliverable.

2 SNS Progress Assessment 2024

In this section, the analysis of the received input from all active SNS projects is presented, based on the SNS OPS Questionnaire that was circulated in 2024, as part of the SNS OPS Monitoring and Analysis Framework. Following the successful first edition that was launched in 2023, this 2nd edition of the SNS OPS questionnaire was launched in Q1 2024 and addressed the accomplishments of Call 1 projects during the past year (i.e., 2023) as well as the analysis of the newly started Call 2 projects. The call 1 projects were asked to fill in a new section of the questionnaire focusing on accomplishments and achievements of the projects during their first year of operation (i.e., JU metrics), while the call 2 projects were asked to fill in the typical SNS OPS Questionnaire (as updated and presented in deliverable D1.2) comprised of three sections, namely the Technical section, the Vision section and the Market section.

The highlights of the performed analysis were presented to the SNS community during an open webinar[3] on June 27th, 2024, while the complete analysis of the SNS OPS 2024 Questionnaire is presented in this section in detail. The results presented below, are based on the input provided by the 35 call 1 SNS projects and the 28 Call 2 projects.

2.1 Technical Aspects analysis

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

2.1.1 SNS Project Matching to Work Programme Specific Objectives

Question T1: Please indicate which of the following Specific Objectives (SO), as defined in ANNEX II of the 2023 SNS Work Programme, will be addressed as a Primary or Secondary objective from your project?

This question was designed to capture the responses from the Call 2 projects to measure how they reflect their participation with respect to the specific objectives (SO) they are addressing primarily and secondarily.

The responses to this question from 24 call 2 Stream B projects, 1 call 2 Stream C project, and 2 call 2 Stream D projects has enabled an analysis of the key technological improvements targeted by the SNS projects in comparison with the specific objectives (SOs) of the SNS Work Programme.

A full list of the SOs descriptions is found below each chart. With this information, SNS OPS has quantified the SNS projects in terms of the SOs within the Streams they are addressing to ensure a good balance has been accomplished.

Based on the responses to this question on technology outcomes, the following 3 figures summarize the SNS projects technology contributions towards the SOs in their respective SNS Streams (Figure 1 for Stream B, Figure 2 for Stream C and Figure 3 for Stream D), quantifying the Primary and Secondary SOs taken from their perspectives.

Note: ***Primary*** *means that the text provided seemed to indicate that this was the Primary Strategic Objective that the project was addressing.* ***Secondary*** *means there was some elements in the response that indicated the project was also addressing this SO but not as a Primary SO. If the cell was left blank, we assumed there was neither a primary nor secondary interest for this objective.*

[3] https://smart-networks.europa.eu/event/sns-ops-questionnaire-results-webinar/

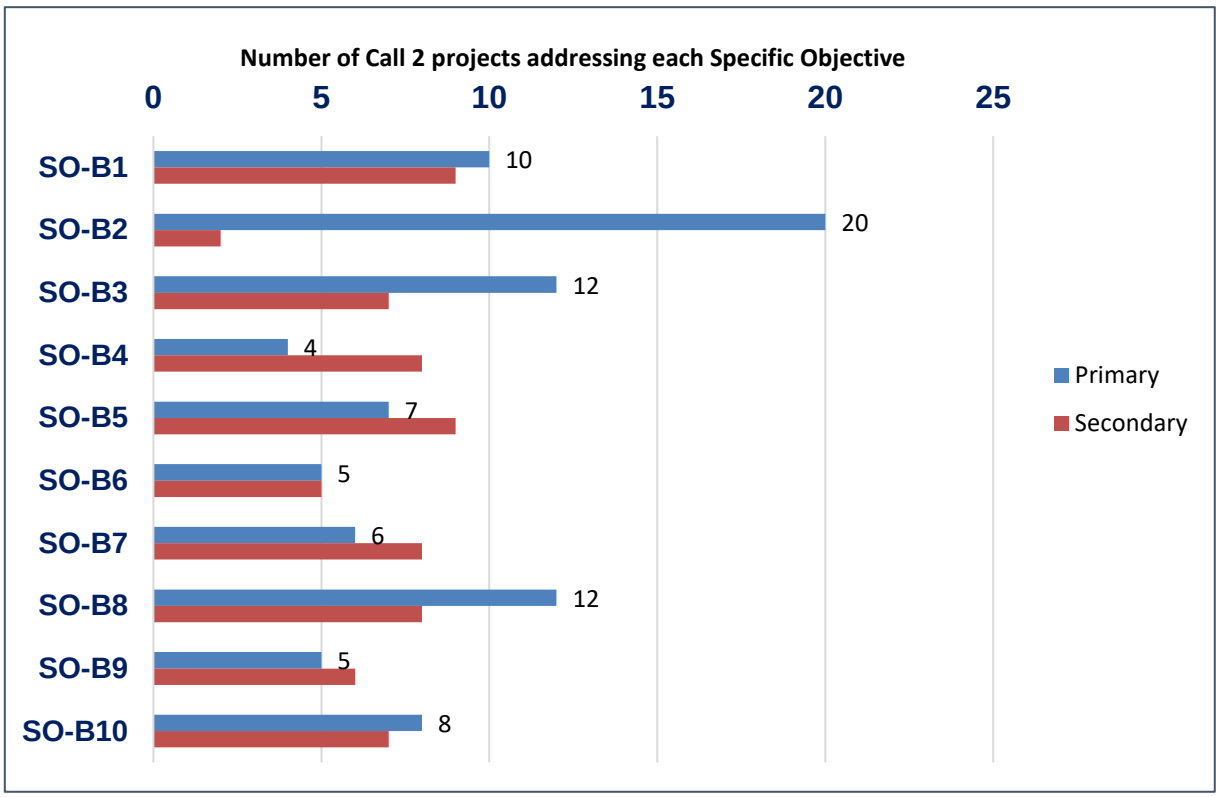

Figure 1: SNS Project matching to WP Specific Objectives – Stream B

SO-B1: Technologies for validation/feasibility of globally accepted KVI's & KPI's
SO-B2: Key technologies/architectures with high potential for 6G standardisation
SO-B3: Optimised architecture, beyond the 5G Service Based Architecture (SBA)
SO-B4: Zero-touch open end-to-end resource management system
SO-B5: E2E Trustworthy & energy-efficient device, network, and service infrastructures, to deliver critical services in a sustainable manner
SO-B6: Dynamic end-to-end distributed security for connectivity, devices and service infrastructures extending the current set of patchy technologies
SO-B7: Managed spectrum and dynamic spectrum sharing across multiple frequency bands, opening new application scenarios
SO-B8: Foster European capabilities in key technologies and notably AI/ML, software and security enablers, advanced signal processing and microelectronics
SO-B9: Longer-term re-examination of fundamental system features/ functions
SO-B10: International cooperation / consensus on critical technologies

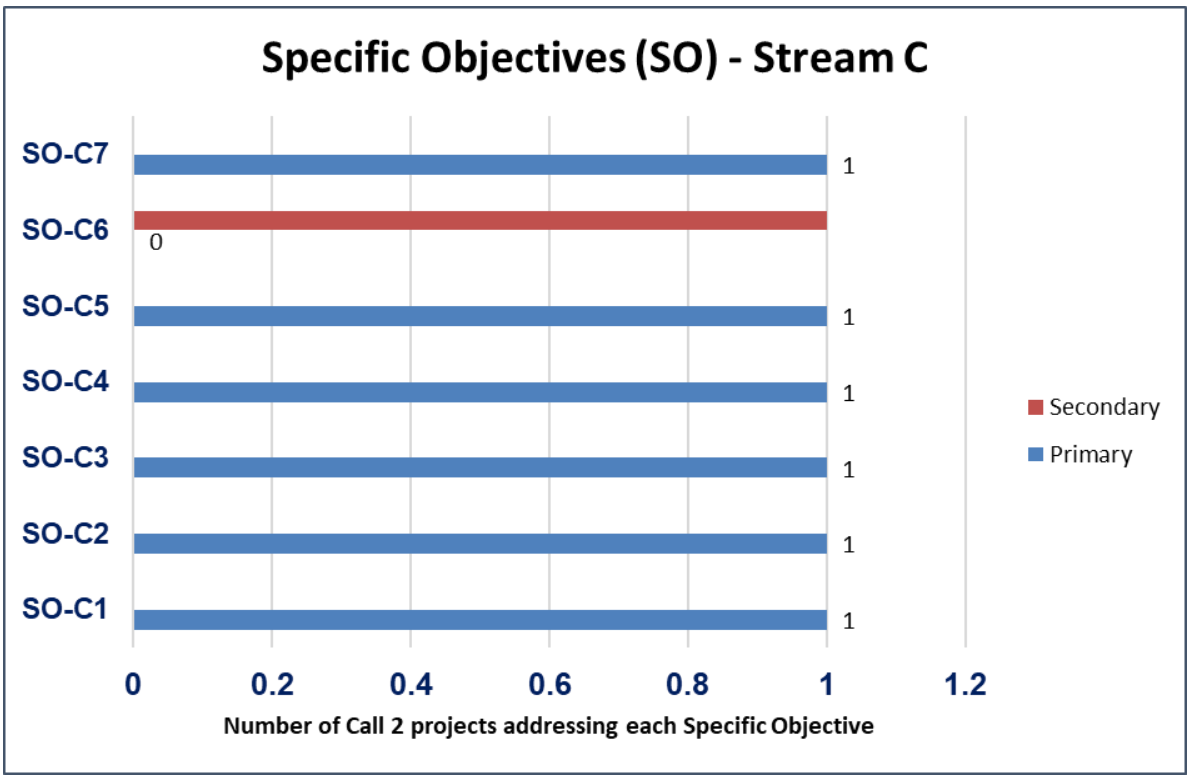

Figure 2: SNS Project matching to WP Specific Objectives – Stream C

SO-C1: Development of EU wide experimentation platforms that can incorporate various candidate 6G technologies for their further validation
SO-C2: Extend experimentation platforms towards a federated approach
SO-C3: Reusability and evolvability of the experimental platforms over the lifetime of the SNS programme
SO-C4: Accessibility / Openness: Use of the platform in subsequent phases of the SNS by a consortia ◊ modular implementation methodology and, open-source solutions
SO-C5: Directionality and optimisation of previous and related investments in Europe: 6G experimental platforms piggybacking on previous investments in Europe
SO-C6: Disruption friendly: Experimental facilities capable of hosting upcoming unplanned 6G disruption and hence guarantee their future-proofness
SO-C7: End-to-end: The target experimental facility should be capable of demonstrating E2E service capabilities and include a full value chain

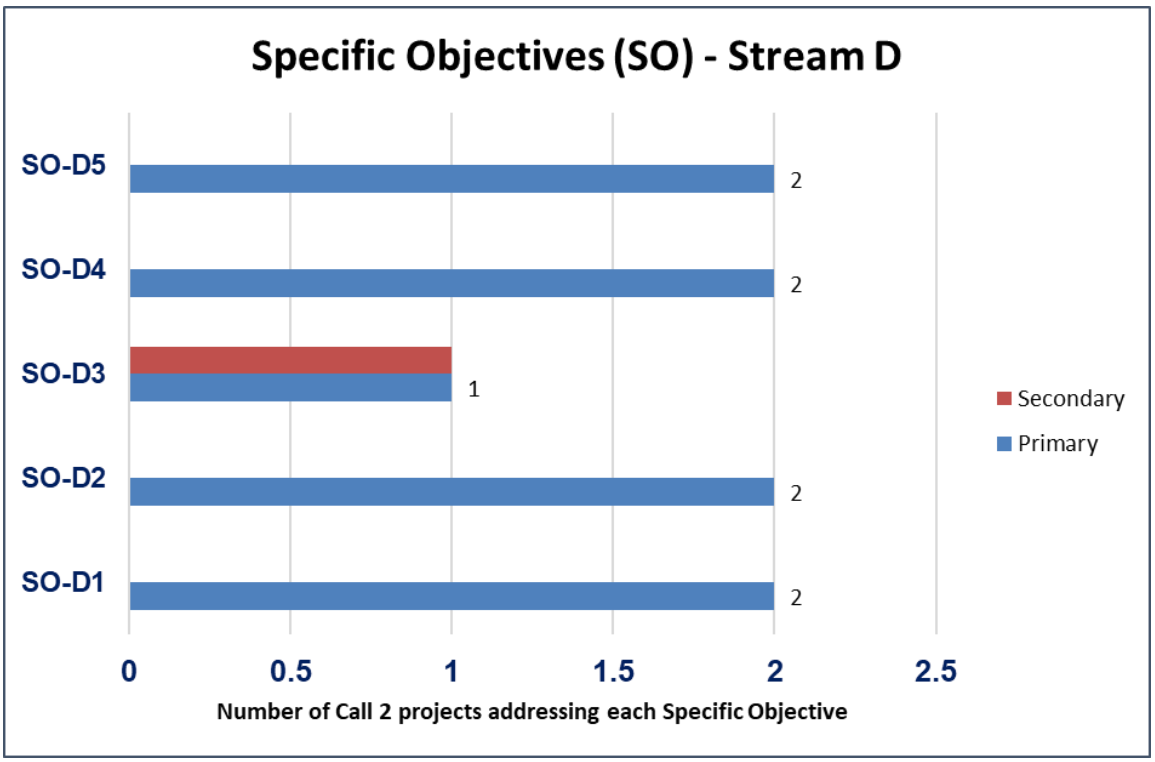

Figure 3: SNS Project matching to WP Specific Objectives – Stream D

SO-D1: Validation of SNS KVIs and KPIs in the context of very advanced digital use cases implemented through Large-Scale Trials and Pilots (LST&P)
SO-D2: Identification of use case specific KVIs and KPIs and how they may be matched by SNS platform KVIs and KPIs
SO-D3: Structured feedback loop from vertical users towards SNS stakeholders, in view of ensuring the best match between 5G Advanced / 6G systems capabilities and users
SO-D4: Integrated validation approach, from 6G platform to use cases, leveraging existing (open) platforms (e.g., developed under Stream C)
SO-D5: Accessibility and openness: The required targeted adaptations of the Stream C infrastructures/platforms as required to support specific Stream D use cases

Key Insights

An analysis of the primary and secondary coverage areas of the projects versus the specific objectives shows that all specific objectives are well matched by the Call 1 projects with the exception of **SO-C6**. Moreover, a healthy balance and complementarity is detected among the projects, ensuring that each SO will be addressed with different levels of scrutiny, i.e., providing higher confidence in the drawn conclusions and allowing for cross-verification of results.

Analysis of the results indicate the following:

- Projects' input was matched to the Specific Objectives (SO) of each stream (as defined in the SNS JU R&I WP 2023).

- The SNS projects' technology contributions towards the SOs was categorized into **Primary** & **Secondary.**

Results indicate:

- ***Good coverage*** of all Specific Objectives of SNS JU WP 2023.
- ***Good distribution*** between Primary & Secondary objectives in Stream B, C and D.

2.1.2 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 T2: Which of the following main KPIs will your project address? Please mention any additional KPIs addressed within your project in the elaboration box?

Figure 4 below, depicts the most popular KPIs addressed by the 27 call 2 R&I projects. The received responses indicate that *Energy Efficiency* is a KPI that the majority of Call 2 projects (77%) will be measuring, as the development of energy efficient solutions is one of the most prominent research directions of the SNS JU.

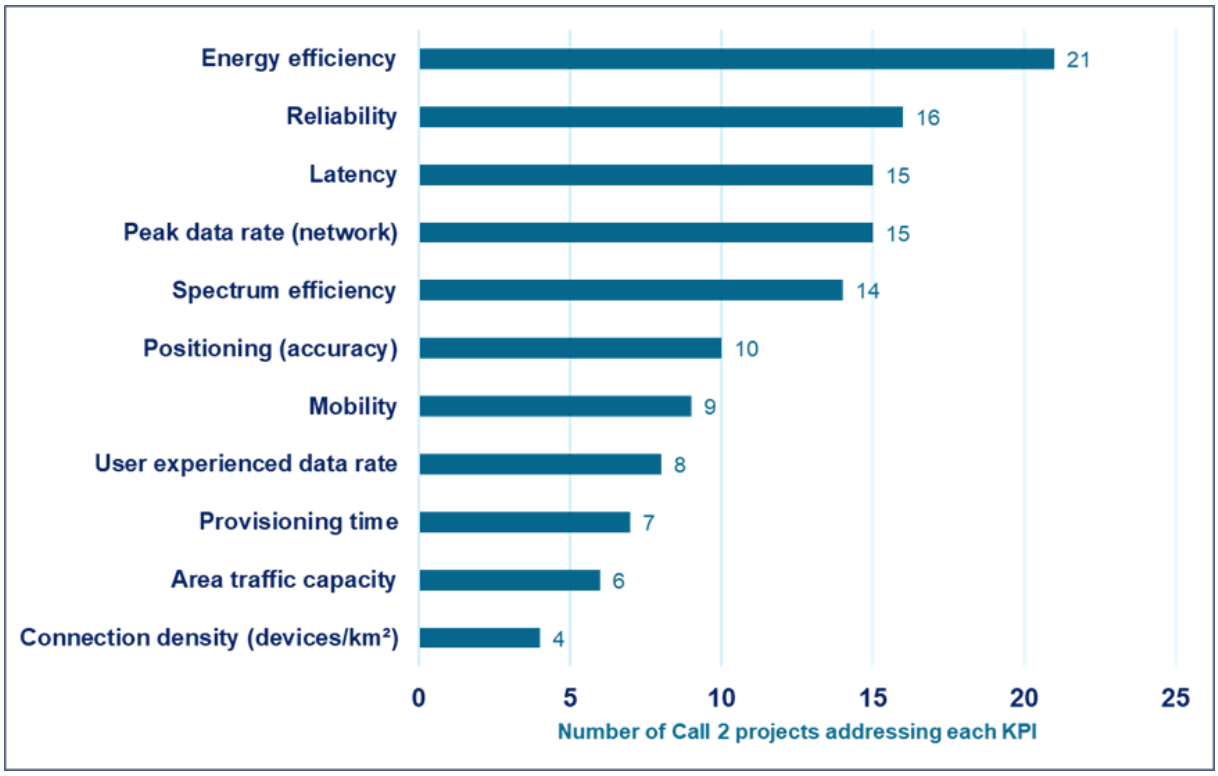

Figure 4: Most popular KPIs addressed by SNS Call 2 projects

Immediately afterwards, a group of KPIs including *Reliability*, *Latency*, *Peak Data Rate* and *Spectrum Efficiency*, seems to aggregate the same interest from the projects as approximately 55% of Call 2 R&I projects will be addressing them. A peak of interest for the URLLC aspects of 6G networks can be observed according to these preferences, as 5G networks focused a lot of eMBB services, thus leaving a lot of room for growth to URLLC services as part of 6G. Besides URLLC aspects, peak data rate always remains relevant, especially with the expected growth of xR and holographic services, expected with 6G. Finally, 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.

Additional KPIs will be addressed by Call 2 projects, depending on the exact scope of each project, the targeted vertical experiments and the developed technologies. The fact that a large number of KPIs is being evaluated by call 2 projects is very important as it showcases that both traditional and alternative aspects of 6G networks are being investigated. Besides the KPIs appearing in Figure 4, some call 2 projects also mentioned additional KPIs, targeting specific functionalities such as, *sensing accuracy*, *trust assessment*, *threat-mitigation efficiency*, *cost efficiency*, *synchronization accuracy*, etc., indicating an even broader spectrum of research.

It is also interesting to analyse how the KPI-focus of Call 2 projects has shifted compared to Call 1 projects (as presented in deliverable D1.2), and what is the overall trend in terms of KPIs within the SNS JU, taking into account all 60 R&I active projects (Call 1 + Call 2). Figure 5 depicts the aggregated statistics in terms of addressed KPIs within the SNS JU, as provided by the 60 Call 1 and Call 2 projects. As expected, the top 5 of KPIs remains unchanged, as Energy Efficiency, URLLC KPIs and spectrum efficiency and peak data rate, aggregate most of the interest of the SNS JU projects. A clear preference can be observed for *Energy Efficiency*, *Latency* and *Reliability* as more than 71% 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 (~45% - 50%).

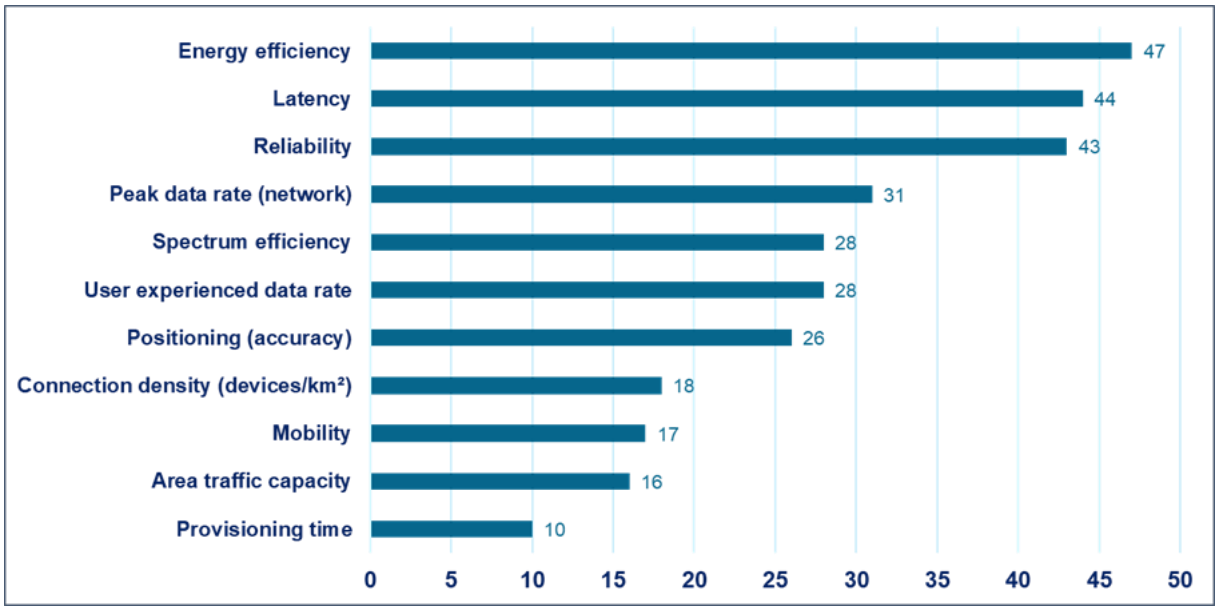

Figure 5: Most popular KPIs addressed – Aggregate Call 1 + Call 2 projects

By cross-comparing Figure 4 and Figure 5, some differences in focus between Call 1 and Call 2 projects can also be observed. For instance, *Positioning accuracy* seems to be more popular within call 1 projects (~50% addressing this KPI), compared to Call 2 projects (~37%), and the same trend is observed with *User experienced data rate* as approximately 60% of Call 1 projects address it, with only 30% of Call 2 projects addressing it. Similarly, approximately 42% of Call 1 projects address connection density while only 15% of Call 2 projects address this KPI. On the other hand, *provisioning time* is a bit more popular with call 2 projects (~26% compared to ~9% for Call 1). It has to be noted that these differences in focus between Call 1 and Call 2 projects are also partially due to the difference in scope between the two different SNS Work Programmes (the call to action that these projects respond to).

Key Insights

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

- Good coverage of all main KPIs by both SNS Call 1 and Call 2 projects.

- URLLC type KPIs & Energy Efficiency are the most popular throughout both waves of projects (no variation observed).
- Peak Data Rate & Spectrum efficiency are also very well addressed in both Call 1 and 2 projects.
- Positioning, Mobility, User data rate & Connection Density a bit more popular in Call 1 projects.
- A macroscopic analysis of the interest of the projects can derive three distinct tiers of KPIs:
    - 1st Tier (Most addressed): Energy Efficiency, Reliability, Latency.
    - 2nd Tier (Popular): Peak data rate, User data rate, Spectrum efficiency, Positioning.
    - 3rd Tier (addressed per case): Connection Density, Mobility, Area traffic capacity, provisioning time.

2.1.3 SNS Project Technological Focus

The goal of this section is to get a better understanding of the technological focus of the SNS Call 2 projects and the technologies, features and mechanisms investigated within each project, along with the precise network or service aspect being investigated. The formulation of the respective question is shown below (T3), while Figure 6 depicts the analysis of the received answers.

Question T3: 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?

The examination of Figure 6, reveals that *System network architecture and control* is the most addressed topic within the SNS Call 2 R&I projects, closely followed by *AI/ML powered technologies, Energy efficiency solutions* and *low energy communication solutions*. These selections match very well the EU (and global) research trends (as analysed in the SNS ICE deliverable D1.2) as AI-enabled mechanisms are potentially the hottest research topic at this stage, while sustainable, energy efficient and low energy 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* is justified by the fact that these are still the early phases of 6G development, and one of the key requirements from the SNS work programme was the investigation of the future architecture.

Another group of heavily researched areas within the SNS Call 2 projects consists *of Edge and Ubiquitous computing, Service resource management, orchestration of resources, Integrated Sensing and Communication (ISAC)* and *novel Radio technologies (mmW, THz, etc.).* These categories reflect very well the most promising areas that have been identified for the development of 6G networks, as the proliferation of softwarization and the edge-cloud continuum along with novel capabilities such as ISAC and novel spectrum, are considered the key technologies that will deliver the promises of 6G, from global stakeholders.

Besides the mainstream technologies and aspects mentioned before, there are several more technologies investigated by the call 2 projects including micro-electronics, Optical wireless, integration with NTN, new antenna technologies and more. The broad range of technologies and solutions investigated by the call 2 projects, ensures that all relevant aspects and solutions will be evaluated within the SNS JU and the most suitable and capable ones, will be promoted for 6G standardization. It also provides confidence in the continuous improvement of EU expertise on multiple fronts and assists towards the technological sovereignty of Europe.

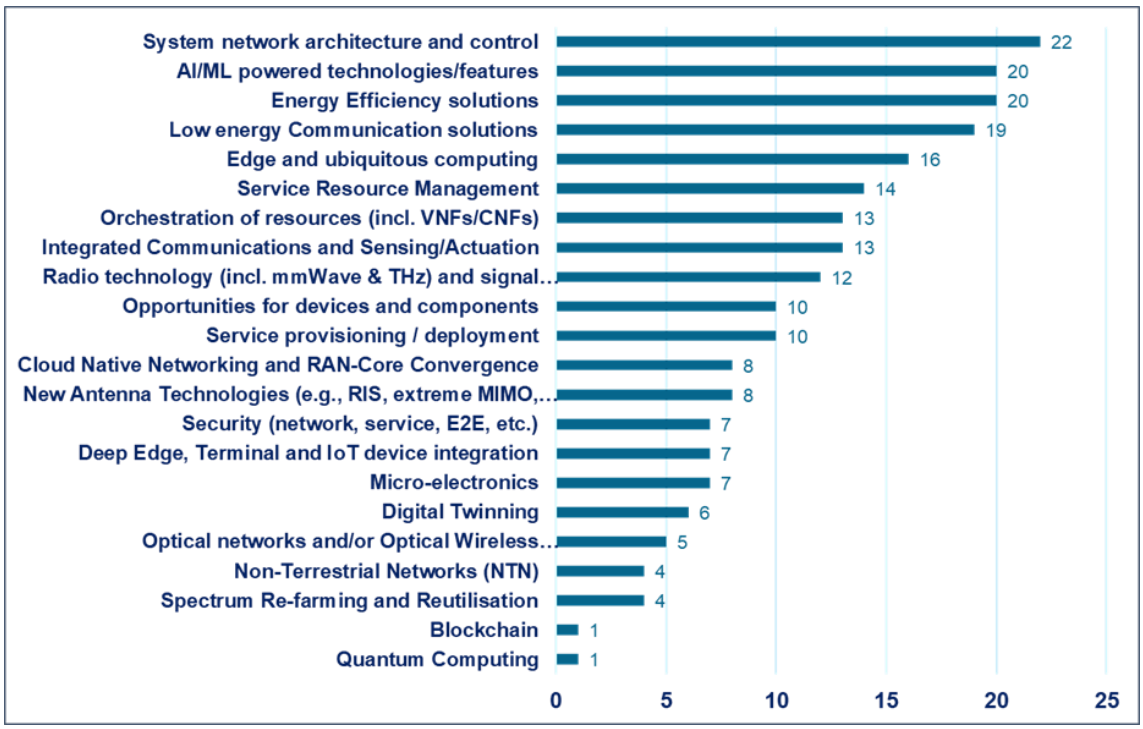

Figure 6: Technological issues/aspects addressed in SNS JU - Call 2 projects

Similarly, with the KPI analysis, it is of particular interest to investigate the differences in scope between Call 1 and Call 2 SNS projects, as well as to provide the overall picture for all 60 active SNS R&I projects. Figure 7 provides the aggregated numbers for Call 1 and Call 2 projects in terms of investigated technologies. There is no major difference observed with Figure 6 as the main trends remain the same, with AI/ML technologies and System architecture and control being by far the most investigated technical aspect within the SNS JU. 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-comparison opportunities and ensures that even less-well researched angles 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 Call 1 and Call 2 projects, provides confidence that a broad range of technologies will be evaluated by EU researchers, arriving at safe and cross-validated conclusions, which will help deliver the best version of 6G.

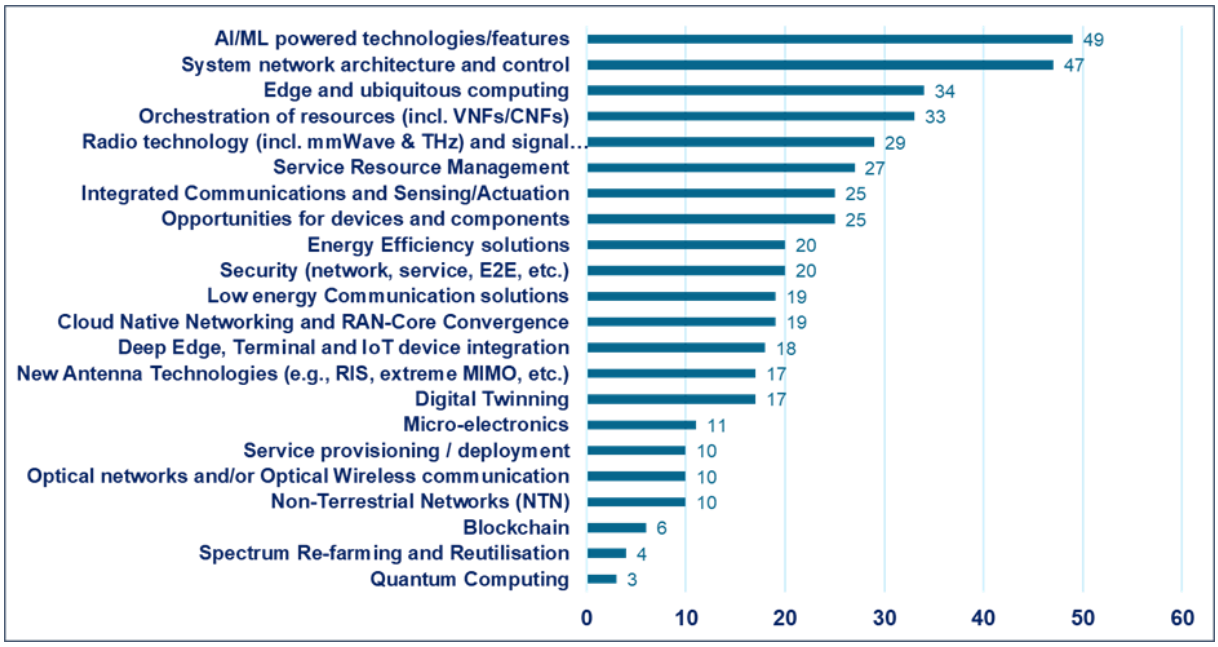

Figure 7: Technological issues/aspects addressed in SNS JU – Aggregate Call 1 + Call 2 projects

Key Insights

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

- System architecture and control is heavily researched due to the fact that these are still the early phases of 6G development, and finding the optimum architecture is crucial.
- AI/ML is used as a global enabler within both Call 1 and Call 2 projects.
- Very good coverage of a broad range of technological enablers observed by both Call 1 and Call 2 projects.
- Additional service-specific enablers will be used, offering possibilities for significant breakthroughs / insights and enabling cross-validation of results.

2.1.4 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 T4: 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 8 depicts the number of Call 2 projects addressing each of the major vertical sectors identified within the SNS JU. This analysis offers a high-level view of the trends within the SNS JU regarding the most affected vertical industries 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 2 projects as more than 10 vertical sectors are addressed within the 2nd SNS JU call alone. The most prominent sectors seem to be Industry 4.0 and Smart City and Tourism, while the automotive sector and the media/xR sector are also among the favourites of call 2 projects. This classification comes as no surprise, as the vertical sector of Industry 4.0 and Manufacturing has always been among the top priorities for European stakeholders, while the Automotive & Smart Cities sectors were specifically targeted by the SNS JU Work Programme 2023 (2nd call of SNS JU); moreover, stream D projects were requested to address these sectors as priorities to ensure that European expertise would continue to be built on these 2 pivotal sectors for Europe.

Besides the high-level vertical sector, it is interesting to know what exact use cases and/or applications are being developed by the projects, as this information would allow for a more nuanced analysis and would indicate the stakeholders' exact interest. Figure 9 depicts the classification of developed applications / use cases by Call 2 projects, indicating once again a SNS JU priority for Transport & Logistics, Industry 4.0 and Smart City applications. Additionally, strong interest is revealed for applications / use cases regarding Intelligent Networks, Cooperative Robots, Imaging and Sensing, Digital Twinning and Metaverse. Once again, the significant variety of developed applications (more than 16) and the broad range covered, is an advantage for the SNS JU, while the overlap of several projects developing similar applications, offers benchmarking and cross-validation opportunities.

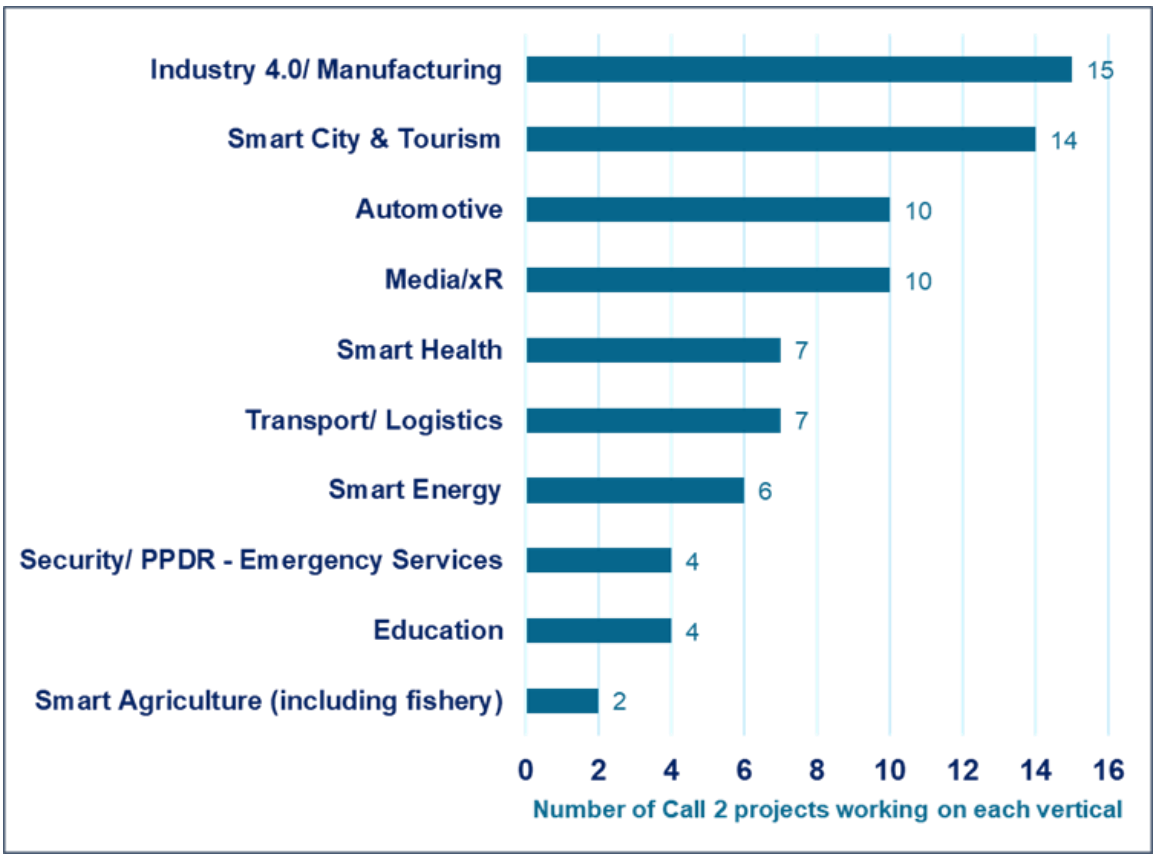

Figure 8: Main vertical sectors addressed in SNS JU - Call 2 projects

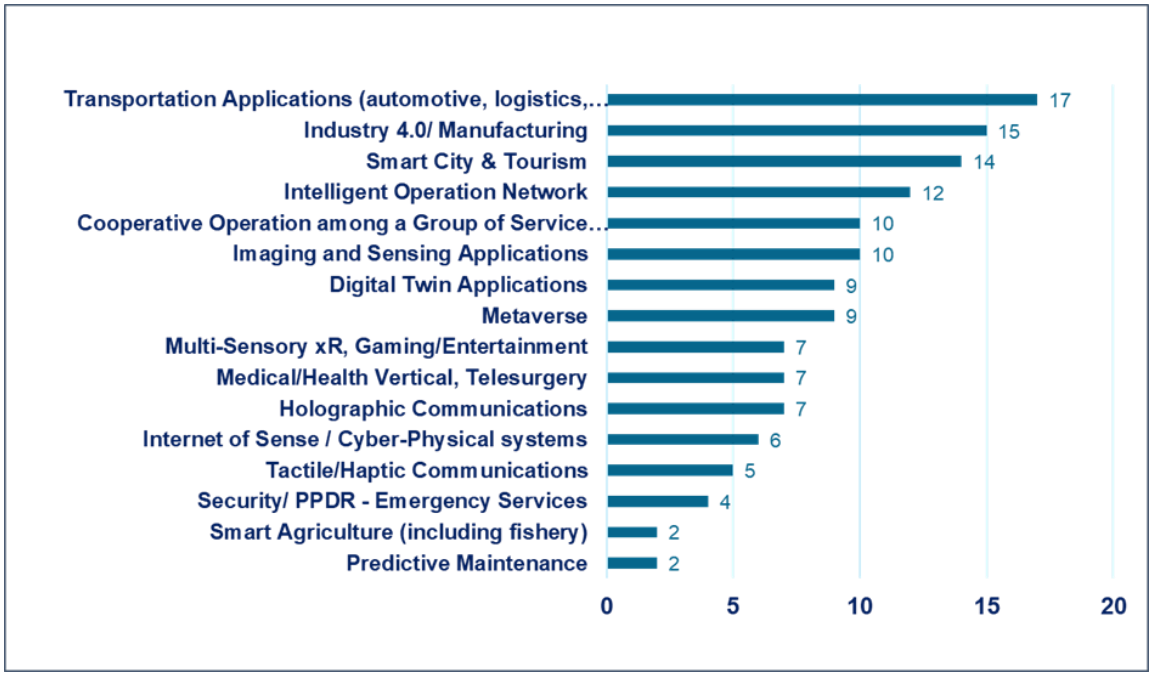

Figure 9: Main Use Cases / Applications developed in SNS JU - Call 2 projects

Some potentially more interesting insights may be derived from the analysis of the applications / use cases developed by all the active SNS JU projects (call 1 + call 2), as depicted in Figure 10. As expected, Industry 4.0 applications remain at the top, confirming the strong influence of this vertical in European 6G R&I activities, while Digital Twinning and Transportation (including automotive) & Logistics applications follow closely behind, showing current trends in EU 6G research. The order of the other vertical use cases does not change much compared to the prioritization of Call 2 discussed in the previous paragraph; however, the influence of specific SNS JU calls can be observed. For instance, multi-sensory

/ xR applications and Security / PPDR applications were more prominently features in call 1 projects. 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.

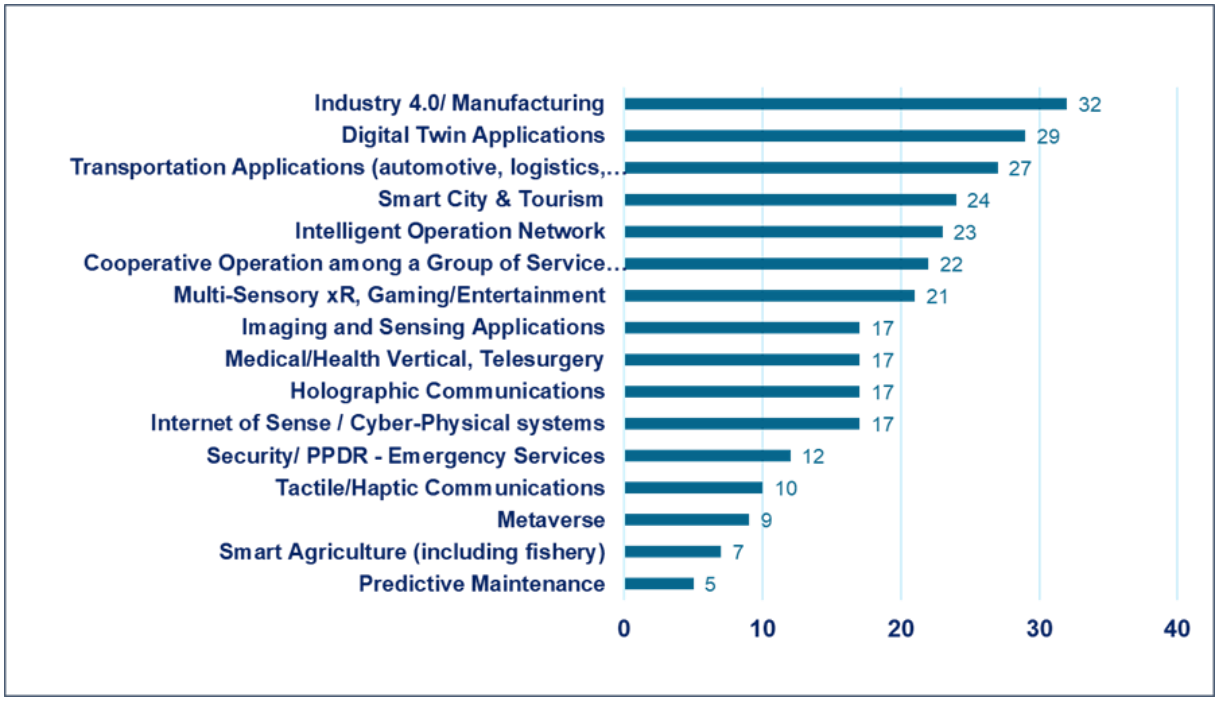

Figure 10: Main Use Cases / Applications developed – Aggregate Call 1 + Call 2 projects.

Question T9: How do you engage verticals in your project?

Besides 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 11 below presents a comparative analysis of how the different projects engage vertical stakeholders in call 1 and call 2, while Figure 12 provides the total (cumulative) numbers for this metric (both calls). Based on this analysis, it can be determined that most projects use vertical stakeholders for the provisioning of requirements from their side and that this trend has not changed from call 1 to call 2 projects. The same applies for the "*use of vertical devices / equipment for testing / trialling purposes*", which is consistently the 2nd most popular options among projects. It is interesting to note that "End user testing" has gone from 3rd place among the call 1 projects to the last place among call 2 projects, as only 3 call 2 projects are using vertical stakeholders to test their solutions. This can be explained by the fact that call 1 had a much stronger focus on testing / trialling with 3 stream C projects and 4 stream D projects being funded (which further include open calls), while in call 2 only 1 stream C and 2 stream D projects were commissioned. Overall, it is very encouraging to verify the strong involvement of vertical stakeholders from multiple positions and in multiple roles within the SNS JU projects, which may lead to the development of useful 6G features and solutions for vertical stakeholders, maximizing the societal and economic impact of the developed SNS JU solutions.

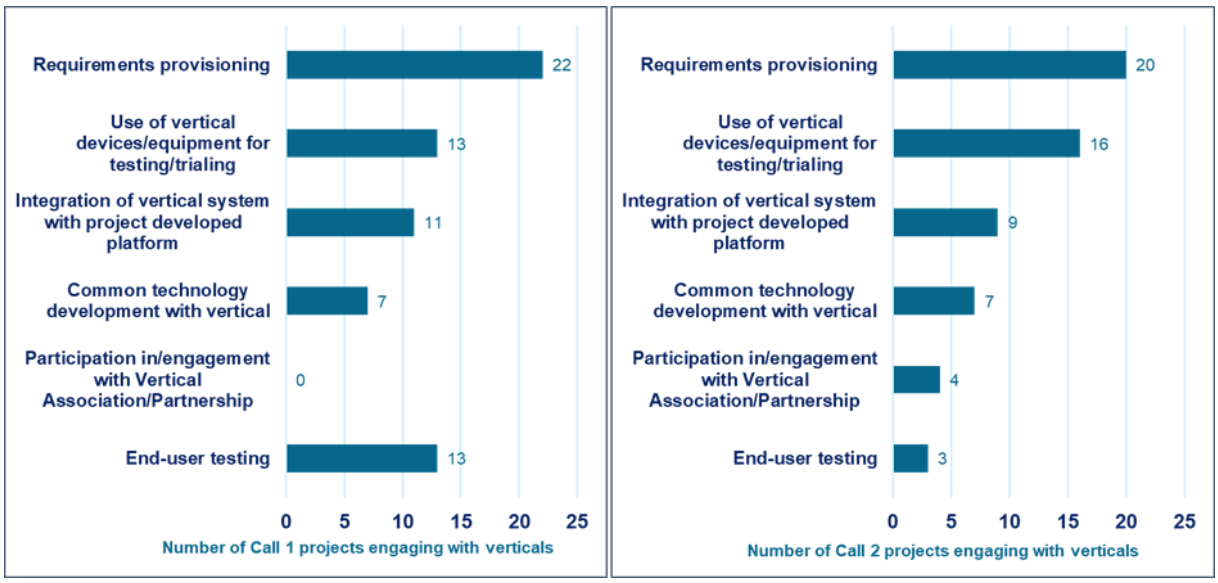

Figure 11: Engagement of Vertical stakeholders in SNS JU projects – Call 1 vs Call 2 projects

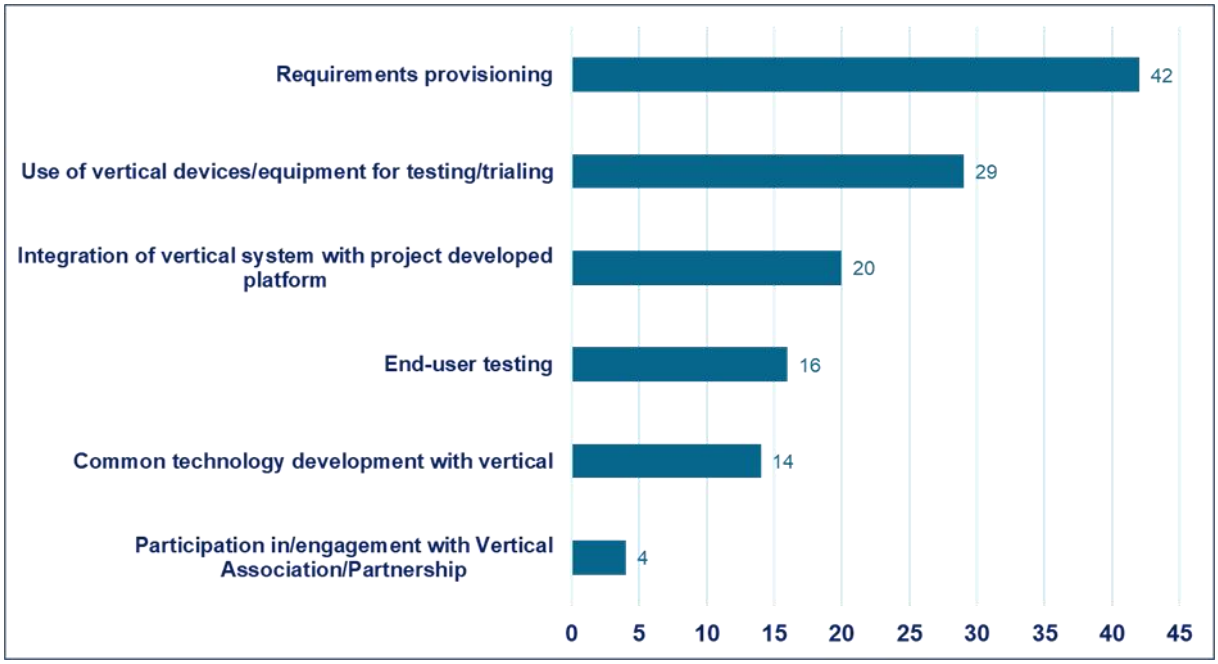

Figure 12: Engagement of Vertical stakeholders in SNS JU projects – Aggregate Call 1 + Call 2 projects.

Key Insights

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

- Verification of the SNS JU's focus on supporting traditional EU industrial sectors with 6G such as Industry 4.0, Automotive / Transport and Smart City & Tourism.
- Strong interest in multiple novel sectors with significant overlap offering cross-validation and verification opportunities.
- Very good coverage of a broad range of vertical sectors and vertical applications by both Call 1 and Call 2 projects, maximizing the potential societal and economic impact of the developed solutions.
- Most vertical stakeholders are involved in the SNS JU either to provide their sector-specific requirements or to enable the use of their sector-specific equipment in 6G tests / trials.

2.1.5 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 within the SNS JU projects and the type of AI/ML mechanisms developed by the projects. To that end, Question T5 was addressed at the projects as follows:

Question T5: 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 13 below depicts the statistics on the number of projects making use of AI/ML mechanisms from call 1 (left) and call 2 (right). It immediately becomes understood that AI/ML plays a prominent role in both calls as 32 out of 33 call 1 projects will develop AI/ML mechanisms while 24 out of 28 call 2 projects will also make use of AI/ML. This is translated to an impressive 92% of SNS JU projects making use of AI/ML mechanisms, which confirms the alignment of the vision of the EU researchers with the global view that AI will be one of the main building blocks of future networks and services.

Call 2 projects were further asked[4] whether they will be able to publish the data sets that they will be using for the training of their AI models, as this could be beneficial for the research community. 25% of the projects already confirmed that they will ensure that access to their AI training data sets will be provided while another 47% mentioned that they are exploring this option but cannot commit to it yet (too many unknowns at the early stage of the projects when this questionnaire was filled). The remaining 28% of projects mentioned that providing access to the data sets was highly unlikely. This can be attributed to a couple of reasons such as the use of confidential data, or the existence of an exclusive use permit from the data source.

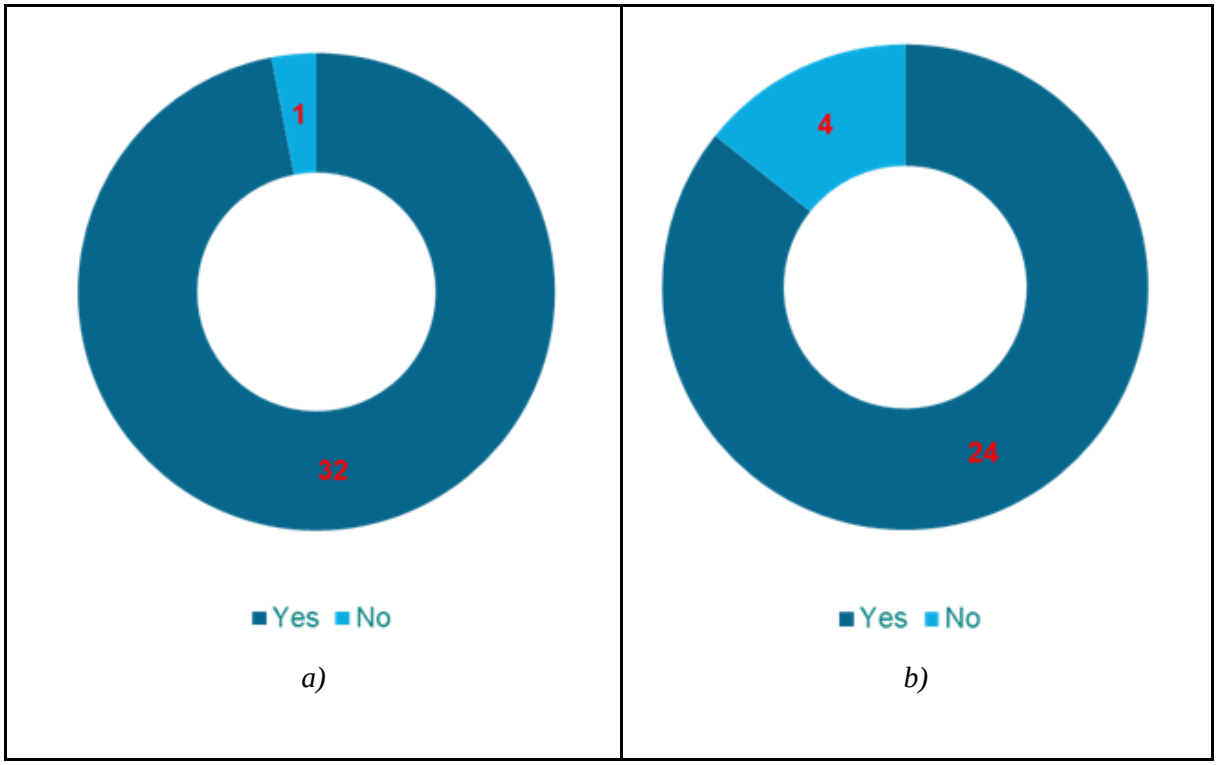

Figure 13: Use of AI/ML mechanisms in a) Call 1 SNS JU projects (left) and b) Call 2 SNS JU projects (right)

The questionnaire further inquired about the type of AI/ML mechanism being developed by the projects and the network layer it would be used on. By combining data from the 2023 and 2024 questionnaires the complete picture of the AI/ML use within SNS can be drawn, as depicted in Figure 14. The received responses suggest that the majority of the developed AI/ML mechanisms are targeting *Network*

[4] This question was not asked during the 2023 Questionnaire to Call 1 projects, hence there is no data for Call 1 projects.

Management & Orchestration functionalities, indicating that this is perhaps the most fruitful field for early deployment of AI mechanisms. 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 layer 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 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.

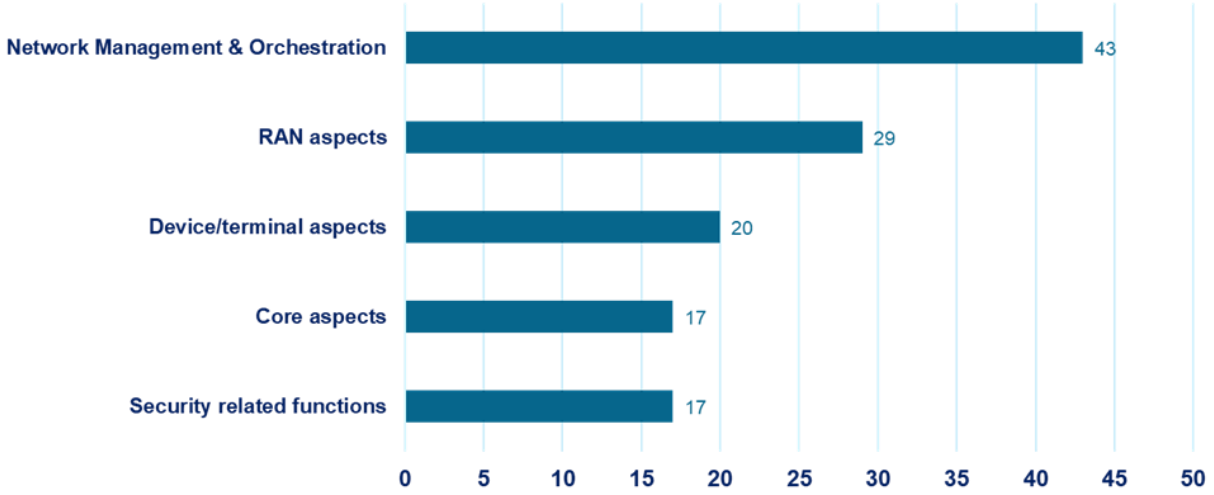

Figure 14: AI/ML targeted Functionality within the SNS JU projects – Aggregate Call 1 + Call 2 projects.

Key Insights

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

- The use of AI/ML is pervasive within the SNS JU as 92% of active projects are making use of AI/ML functionalities.
- The provision of suitable and proper AI training data sets remains problematic and one of the major challenges that need to be solved.
- The majority of AI/ML mechanisms developed within the SNS JU is targeting Network Management & Orchestration & RAN functionalities, which seem to be fruitful layers for the early deployment of AI/ML.
- The use of AI/ML will be pervasive within 6G networks, as relevant mechanisms are being developed for all the envisioned network layers. The SNS JU researchers seem to embrace the idea of an AI-native network.

It has to be stressed, that based on the insights that were delivered from this question to the SNS community, the SNS Technology Board[5] (TB) decided to proceed to the formation of an internal task-force that would aggregate additional details on the methodology, approach and AI-mechanisms being developed by the various SNS projects, with the aim to publish a white paper on this subject. These efforts came to fruition, and on January 2025, the SNS TB published its 1st white paper [1], presenting a detailed analysis and statistical details regarding the AI/ML mechanisms being developed in SNS, including details such as type and method of mechanisms, the goal of the mechanisms, input and output data being used, timing of the mechanisms and more. The white paper is publicly accessible via the SNS JU website, while a dedicated webinar to present its key findings was organized by the SNS ICE project

[5] The collaborative body of the Technical Managers of all active SNS JU projects.

(in collaboration with the TB). The presented material and recording of the webinar are available on the event page[6].

2.1.6 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 T6: Which standardization / specification bodies will your projects target for contributions?

In total, 22 call 2 projects have concrete plans to contribute to various groups within different SDOs, with 126 unique targets identified based on the responses. Figure 15 depicts the categorization of the received responses per stream. As expected, Stream B projects are targeting most SDO groups and sub-groups, as they comprise the vast majority of Call 2 projects (24 out of 28). The target of contributing to 26 SDO groups by the 2 stream D projects is quite impressive and ambitious.

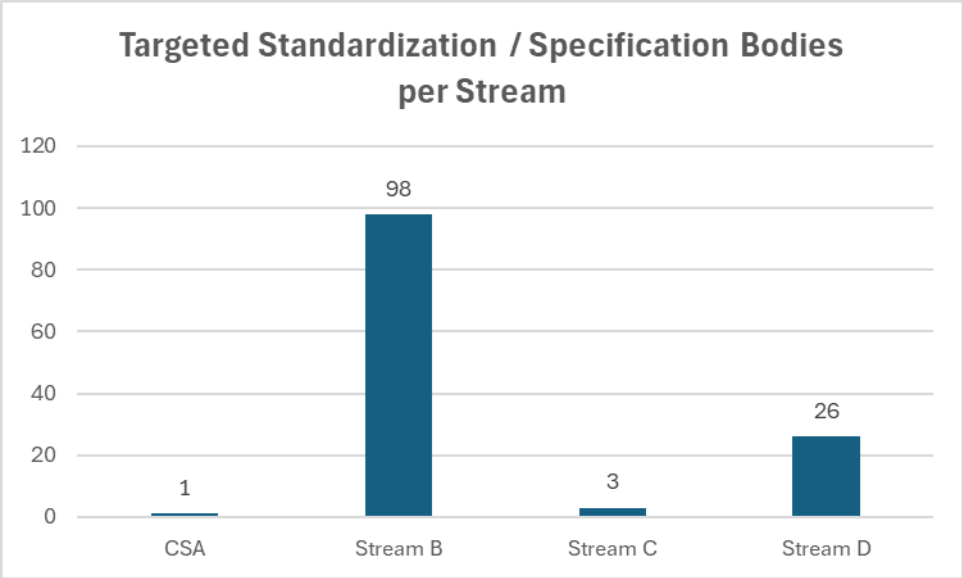

Figure 15: Targeted Standardization bodies by call 2 projects (per stream)

The results depicted in Figure 16 highlight the targeted top 5 SDOs by the Call 2 projects. It can be observed that 17 projects target contributions towards ETSI, 15 projects to 3GPP, 13 projects to O-RAN, 7 projects to ITU and 3 projects to IETF/IRTF.

[6] https://smart-networks.europa.eu/event/sns-ice-webinar-on-the-white-paper-on-ai-ml-as-a-key-enabler-of-6g-networks/

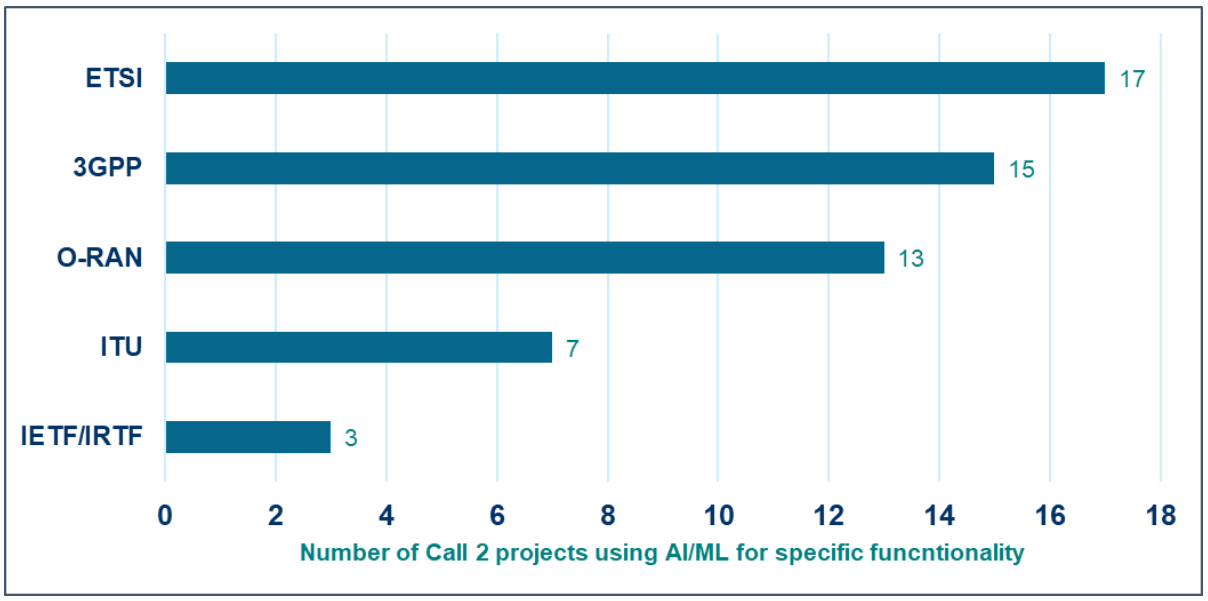

Figure 16: Target for SDO contributions by SNS Call 2 projects

When analysing the targeted specific standardization / specification groups from Call 2 projects (Figure 17), several specific groups and sub-groups can be identified. The most popular groups identified are, 3GPP-SA2, O-RAN - WG3, ETSI - ISG ZSM, 3GPP - SA5, O-RAN - WG2 and 3GPP - SA6.

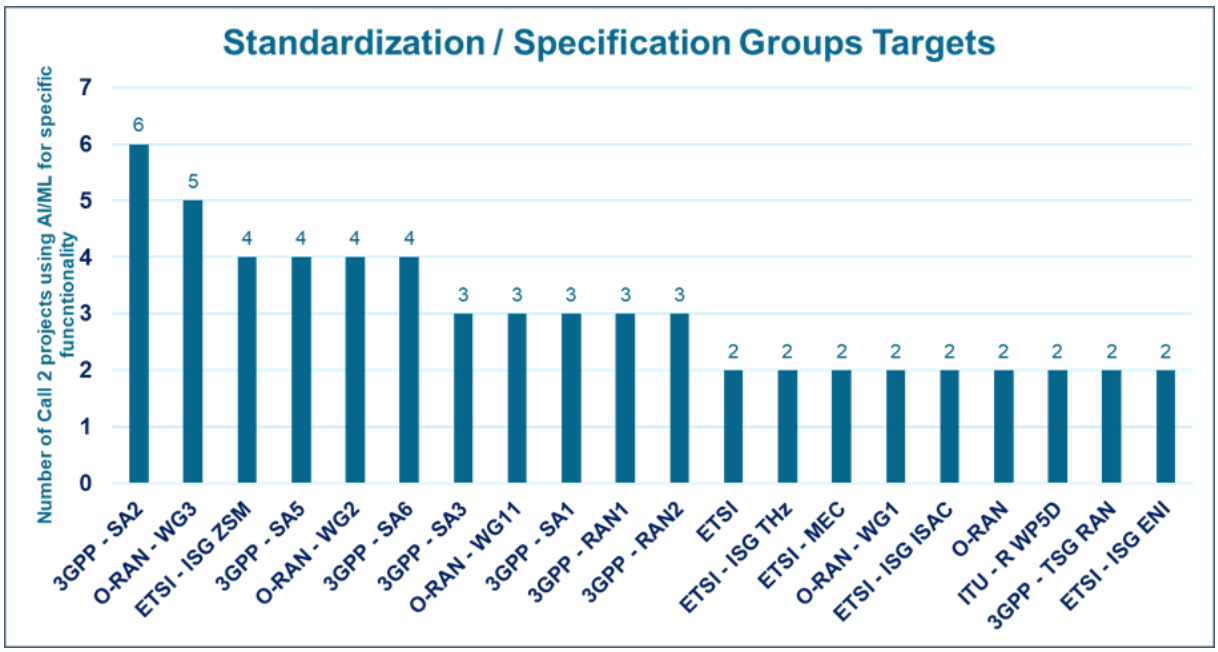

Figure 17: SDO groups targeted by SNS Call 2 projects

An additional question (T11) 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 T11: To which Open Source organisations does your project contribute?

Figure 18 depicts the number of open-source organizations targeted by call 2 projects, categorized per stream. It can be observed that in total there are 67 targeted groups and sub-groups for their contributions to various open-source organizations and Stream B projects are the main contributors (as expected as the stream B projects comprise the majority of call 2 projects).

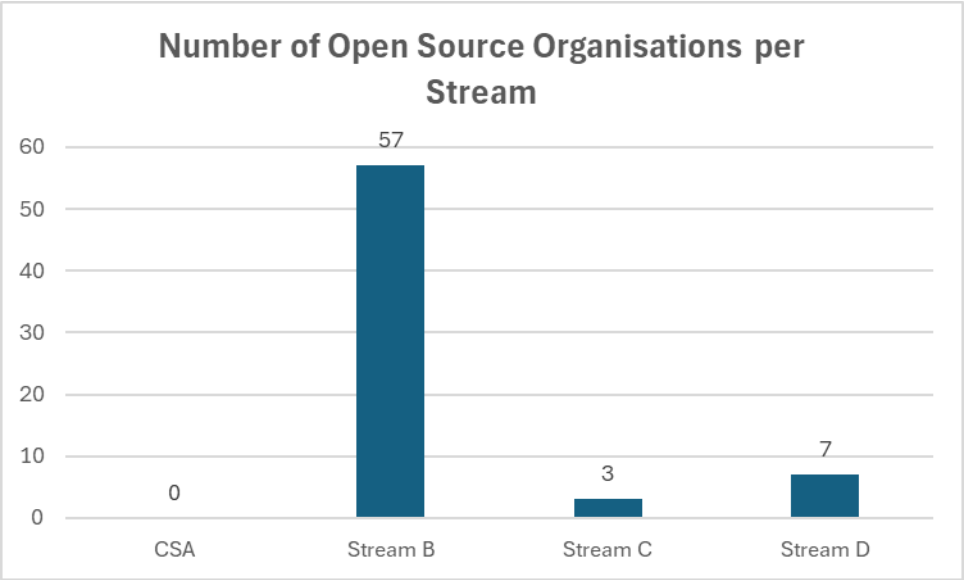

Figure 18: Targeted Open-Source organizations by SNS call 2 projects (per stream)

When checking the open-source organizations that are being targeted (Figure 19), the main targets are O-RAN, followed by OAI, OpenAirInterface (OAI) and CAMARA.

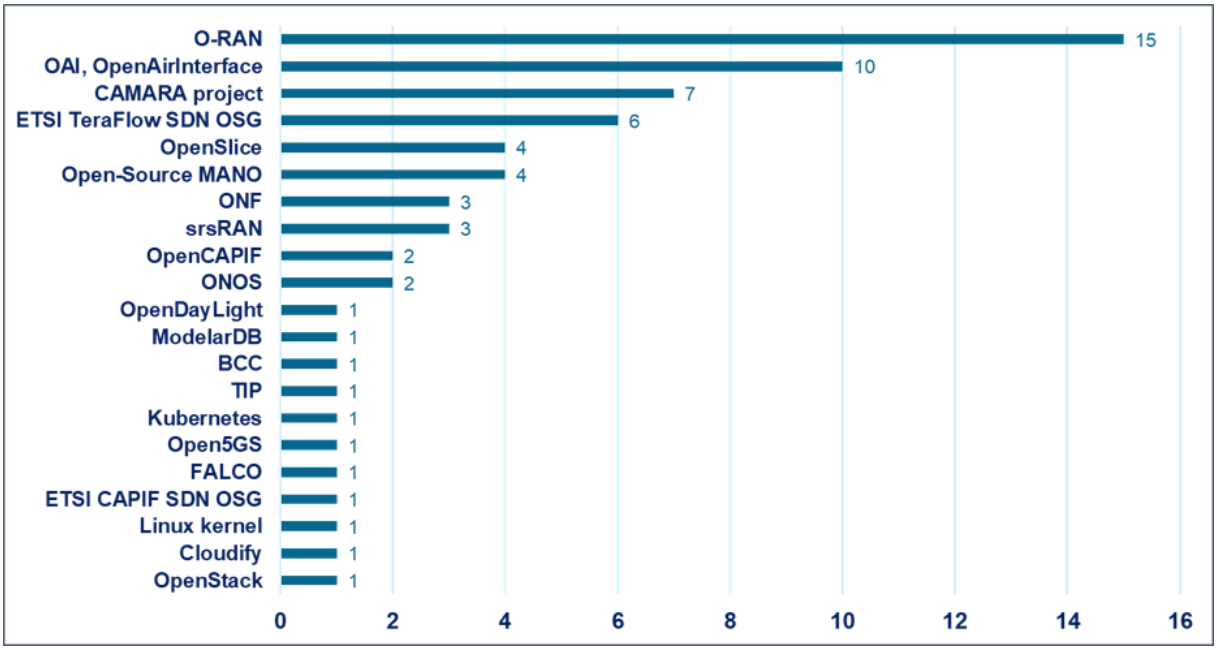

Figure 19: Targeted Open-Source organizations by SNS Call 2 projects

Key Insights

Overall, when evaluating the outcomes of the questions targeted at standardization (T6 & T11) 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 2 projects.
- A vast range of different sub-groups is targeted within each of the SDOs, indicating significant diversity of targeted technologies, being developed within SNS projects.
- The majority of the contributions originate from Stream B projects. This is expected as stream B projects comprise the majority of call 2 projects.
- ORAN is by far the most targeted open-source organization by SNS call 2 projects, however a significant range of other open-source bodies (more than 20) are also targeted.

2.1.7 Validation Methodology / Equipment & Targeted Trials/Tests

Following question on standardisation, the questionnaire also included specific questions on targeted demonstration, trials and pilots. The question T7 addressed the type of end-user equipment.

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

The results for call 2 projects are depicted in Figure 20. The most popular devices are *Mobile phones*, closely followed by *CPEs*, *Modems/Routers then IoT sensors*. Then, in a second group, specific equipment is also targeted *Robots/Cobots*, *On Board Units (V2X)*, *XR Equipment* and *Drones*. It has to be noted that *On-Board Units* target a specific technological area (Transport), covered (mainly) in call 2 Stream D project. The answers show a great coverage of devices for targeted tests and trials while as indicated, there is no plan to use *Satellite Receiver*s from Call 2 projects.

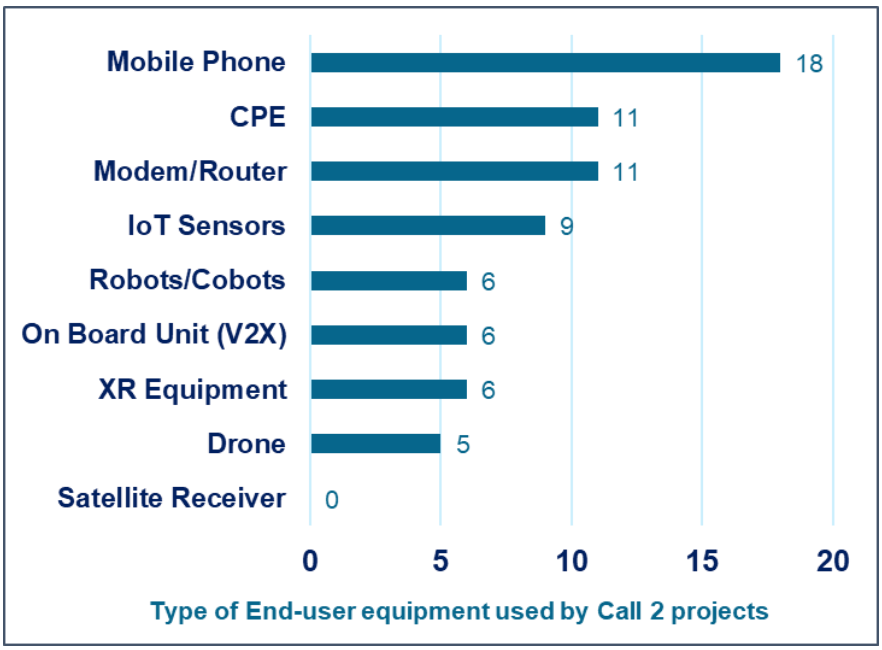

Figure 20: Use of End-User Equipment in testing and trialling by SNS call 2 projects

It is interesting to analyse how the targeted devices of call 2 projects have partly shifted compared to Call 1 projects (as presented in Deliverable D1.2), and what is the overall trend in terms of equipment within the SNS JU, taking into account all 60 R&I active projects (Call 1 + Call 2). Figure 21 depicts the aggregated statistics in terms of targeted equipment, as provided by the 60 Call 1 and Call 2 projects.

Mobile phones are clearly the most popular UE for projects of both calls (63%). The second group of equipment is confirmed with CPEs, Modems/Routers then IoT sensors (around 40%). Then the third group is including Drones and On Board Units (V2X) (around 20%), considering also their use by call 1 projects. Then the last group is including Robots/Cobots, XR Equipment and Satellite Receivers (around 9%). It has to be noted that there is no Robots/Cobots & xR in call 1 projects and no satellite / NTN UEs in call 2 projects. As reported in SNS OPS Deliverable D1.2, 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.

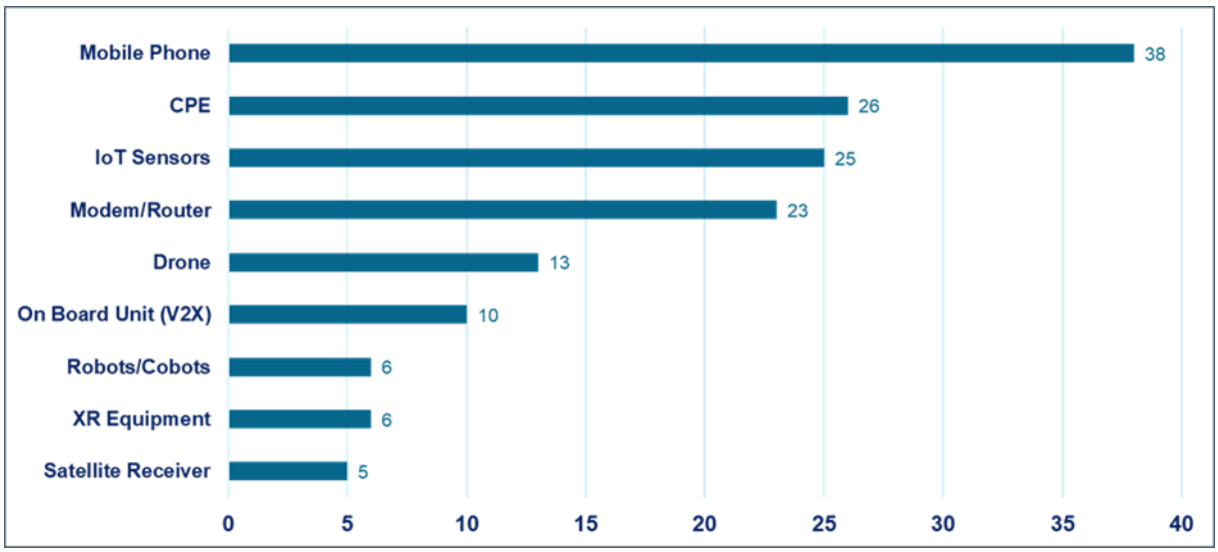

Figure 21: Use of End-User Equipment in testing and trialling – Aggregate Call 1 + Call 2 projects.

Key Insights

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

- Mobile phones are the most popular UE for projects of both calls.
- Relatively steady trends across the 2 calls.
- No satellite / NTN UEs in call 2 projects.
- No Robots/Cobots & xR in Call 1 projects.

Following question on end-user equipment, the questionnaire also included specific questions on targeted demonstration, trials and pilots. The question T8 addressed the validation method.

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 22 depicts the statistics in terms of validation methods and related planning, as provided by call 2 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 *Lab Validation (TRL 4)* as for call 1 projects. Then it is followed by *Experimental PoC (TRL 3)* and *Trials* (TRL 5/6) These methodologies are selected/preferred by the majority of the call 2 projects. There are very few planned *Pilots* (TRL 7) and also very few validation experiments for *High-Risk* research (TRL 2). Concerning the timing for the validation, not surprisingly, call 2 projects that started contractually in January 2024 will implement their validation mainly in 2026, during the second year of the project.

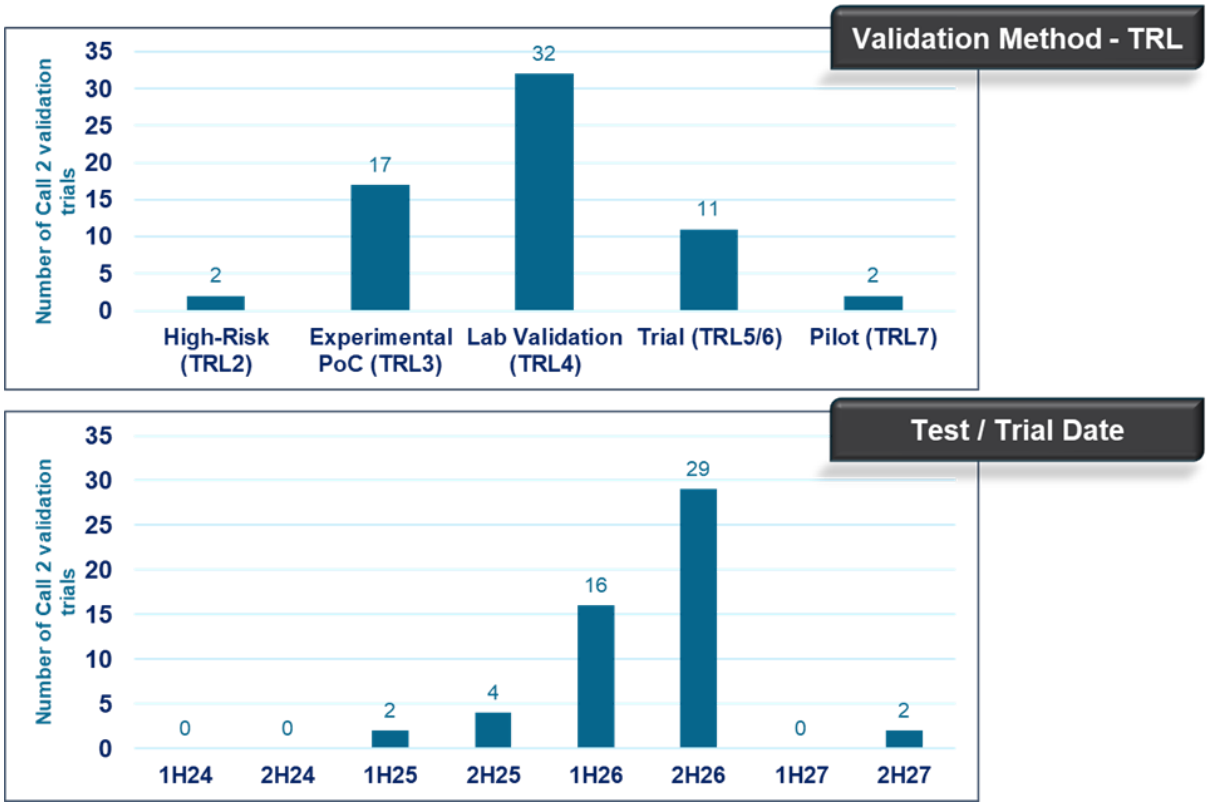

Figure 22: Validation methods for developed technologies and related planning –Call 2 projects

Figure 23 depicts the statistics in terms of validation countries, as provided by call 2 projects. The experiments/trials take place in 19 EU countries and there is clearly a good spread of test/trial sites across Europe for call 2 projects. The first country is Greece, followed by the groups of Spain and United Kingdom, then France and Belgium, then Poland and Italy then additional countries. The statistics are directly correlated to the consortia of the call 2 projects and the location of the related partners testbeds, experimental facilities and platforms.

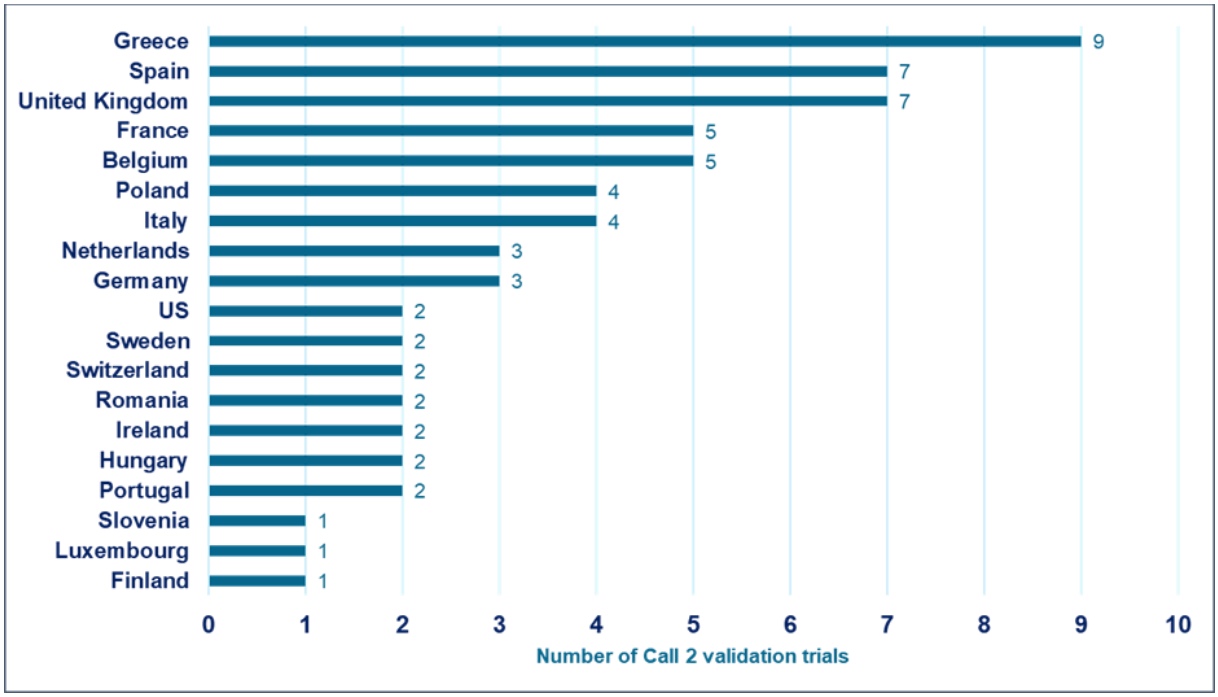

Figure 23: Validation methods for developed technologies and related planning –Call 2 projects

Key Insights

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

- Validation in the lab (TRL4) is the most popular validation method among Call 2 projects.
- TRL3 PoCs and TRL5/6 & 7 (more advanced trials) are also well covered within Call 2 projects.
- Limited 'high-risk' experiments also to take place within Call 2 projects.
- Projects still need more time to prepare their experiments/trials (most are planned for 2H26).
- Early experimentation set to begin by early 2025.
- Experiments/trials to take place in 19 EU countries. Good spread of test/trial sites across Europe detected for call 2 projects.
- Greece, Spain and UK 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 first contributions/presentation in the Trials WG online meetings and (2) to the forthcoming SNS T&Ps Brochures.

2.2 Vision aspects analysis

The vision section of the questionnaire comprised five questions, all multiple choice. All questions were open for free text comments.

In the survey, the following topics were addressed:

- Societal challenges.
- Societal values.
- KVIs.
- 6G Vision.
- Sustainability.

The purpose of this section has been to understand how the projects from Call 2 see themselves contributing to the bigger picture and visions for the SNS programme.

Below, the outcome of the survey for the individual topics are presented one by one. The analysis covers both aggregated and individual Streams (B, C, D and CSA) statistics. The aggregated statistics are given as number of responses per choice, while when splitting into Streams a percentage of the projects per Stream is given. This makes sense, since the number of projects per Stream is quite different.

An important note to make on the per Stream analysis is the fact that most projects in Call 2 are Stream B (24 out of 28 in total). There are only two Stream D projects and only one Stream C and one Stream CSA. This means that the overall analysis results are dominated by the Stream B responses. Per Stream analysis should be interpreted carefully, but we have chosen to include it for completeness.

In addition to the direct answers to the multiple-choice questions V1 to V5, the projects were also given the opportunity to give an open comment related to the vision work.

2.2.1 Societal challenges

Question V1: What are your contributions to the SNS societal challenges?

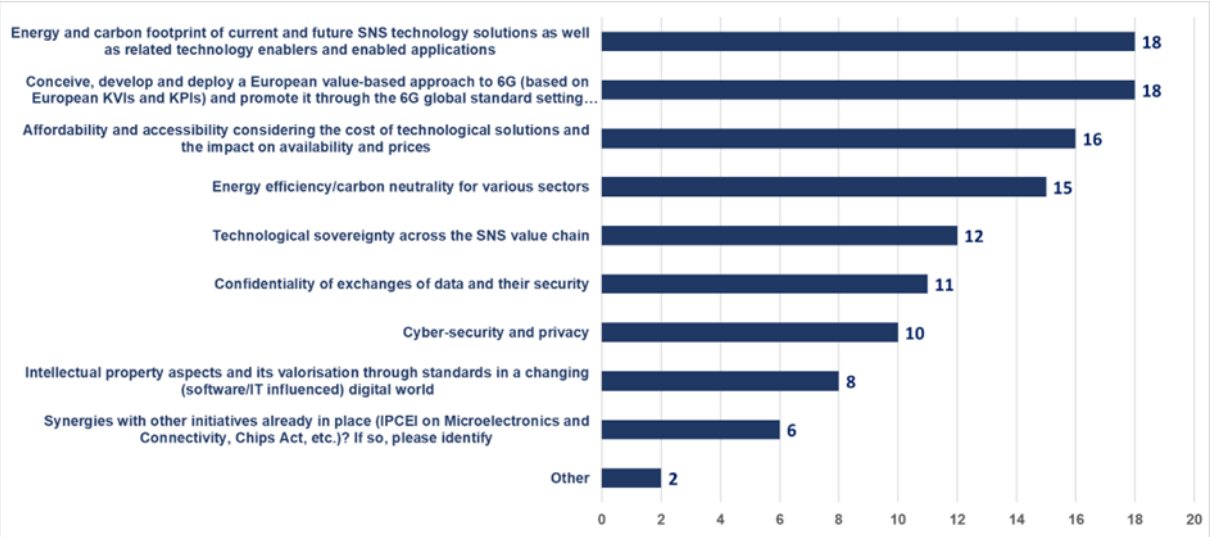

Figure 24: Contributions to societal challenges by SNS JU Call 2 projects, aggregated (all Streams).

Figure 24 shows the responses received in total from all projects. The focus of the projects is strong on technology challenges, more particularly in two main areas. The first is the strong commitments on energy and carbon footprint, efficiency and neutrality. Second, on the affordability and accessibility of the technology. It is also a significant support to a European value-based approach to 6G. Security and confidentiality challenges are scoring below middle. Further in the lower end, we find IPR and synergies with other initiatives.

Comparing to the first analysis from the Call 1 projects documented in SNS OPS deliverable D1.2, we proposed that non-technical challenges should be given more emphasis, and we formulated the answer options accordingly in the latest questionnaire to catch if this has been emphasized by the Call 2 projects. This is apparent in the high scores on the questions related to the European value-based approach and the affordability and accessibility considerations. Further analysis of the responses for the different Streams is shown in Figure 25.

As for all the questions, in the per Stream analysis, Stream B projects follow the overall trend. The Stream C project in Call 2 only emphasizes the Energy efficiency/carbon neutrality for various sectors. Both Stream-D projects emphasize the energy and carbon emission challenges for both the 6G technology and for other sectors. This is likely to be central to the trials they will perform. One of the Stream D projects is also focusing on cybersecurity, privacy and confidentiality. The CSA project in Call 2 is very much concerned with addressing societal challenges, except IPR and confidentiality. Additionally, it is concerned with the integration of ethics, legal, social science, and humanities perspectives into the development of 6G technology to ensure that technology is developed responsibly and in alignment with societal values and sustainability goals, which strengthens the multiple-choice response.

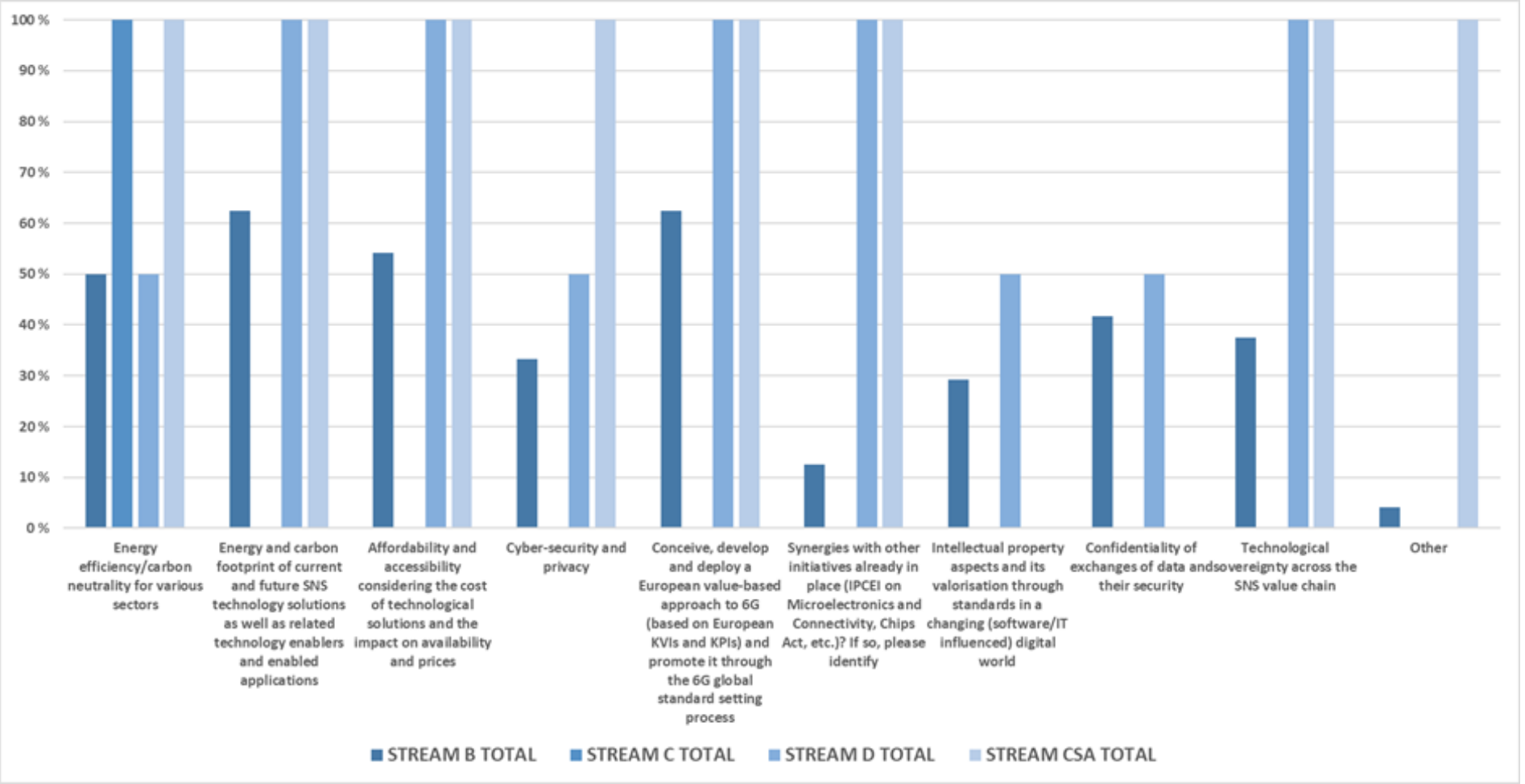

Figure 25: Contribution to societal challenges – per Stream analysis. The value given is the percentage of projects per Stream.

Key Insights

- Project are focussed on technology challenges, especially related to energy and carbon emission.
- A European value-based approach towards KVIs and standardization is equally important.
- Cybersecurity, privacy and confidentiality have a middle score, except for one of the Stream D projects.
- The Stream CSA project 6G4Society is following up most of the societal challenges.

The observations of the middle and lower end scores calls for increased emphasis on especially the security, privacy, confidentiality and IPR aspects. These challenges have been given more emphasis in the overall objectives of the SNS R&I Workprogramme 2024[7], which is a basis for the Call 3 projects starting in January 2025.

2.2.2 Societal values

Question V2: Which societal values are addressed in your project?

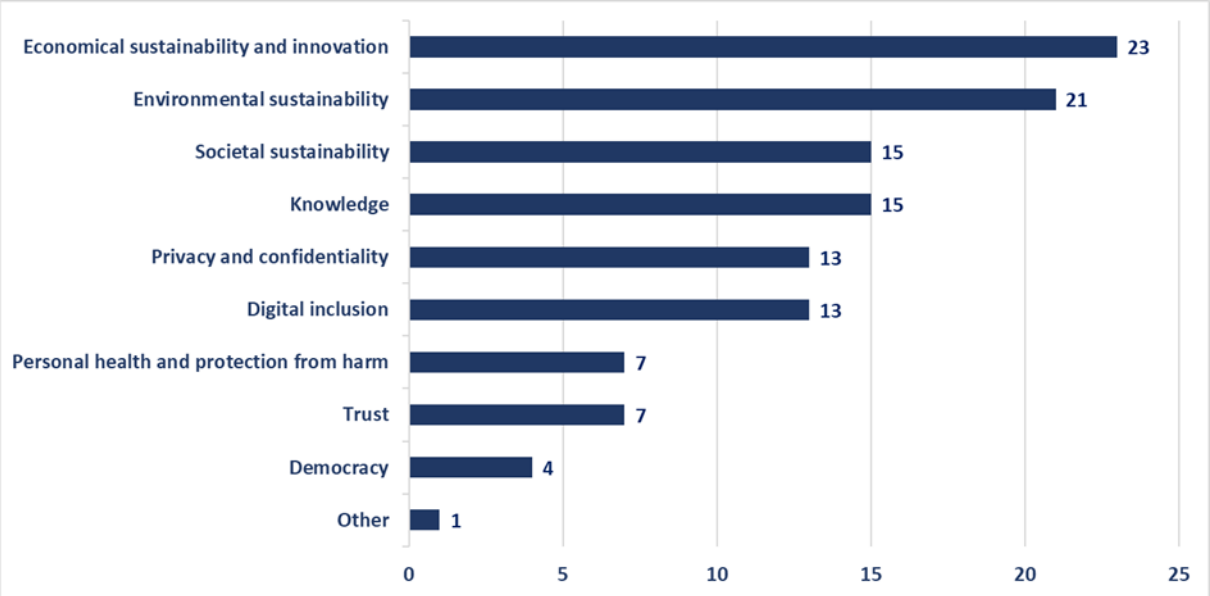

Figure 26: Societal values addressed by SNS JU Call 2 projects.

From Figure 26, it can be observed that supporting Sustainability is the most important value for the Call 2 projects. In the middle range comes Knowledge, Privacy and confidentiality and Digital inclusion. The lower end contains Personal protection, Trust and Democracy. These values are not considered essential for the projects. The fact that Trust scores low is consistent also with the lower emphasis on Security and Privacy for question V1.

Comparing to the first analysis from the Call 1 projects documented in SNS OPS deliverable D1.2, Digital inclusion (13/28 = 46,4%) has a higher score than last year's Inclusiveness (11/33 = 33,3%). Though the term might have been understood differently.

Figure 27 shows the response to societal values per Stream.

[7] https://smart-networks.europa.eu/wp-content/uploads/2023/11/sns-ri-work-programme-2024.pdf

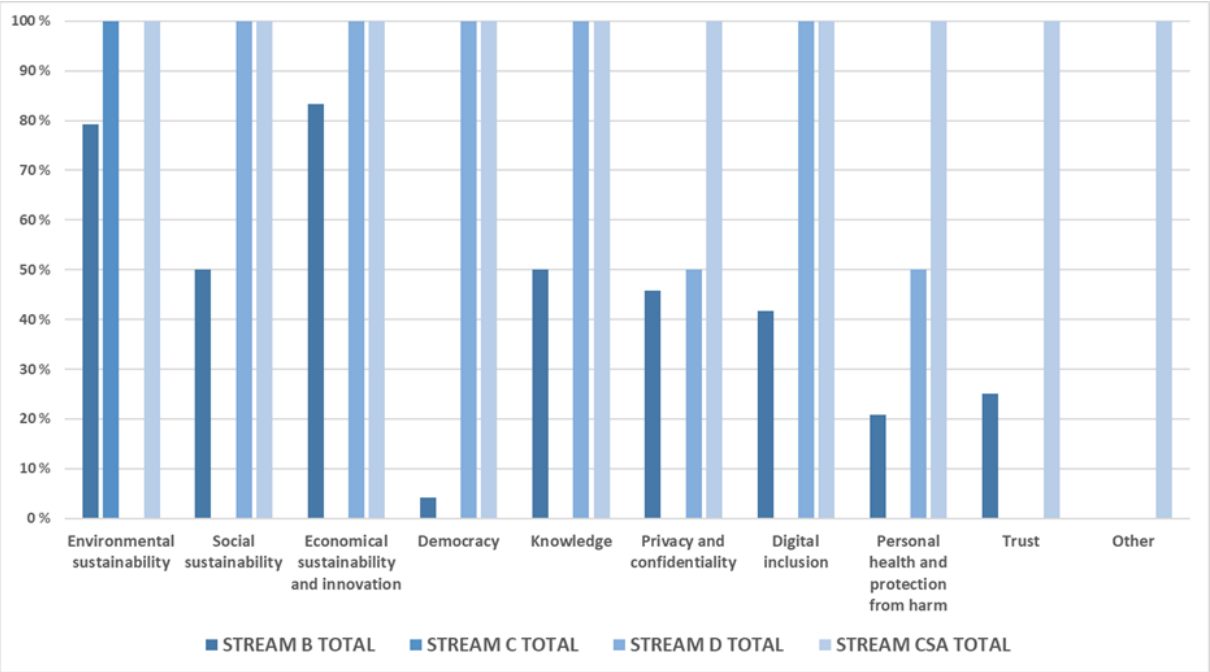

Figure 27: Societal values addressed by SNS JU Call 2 project – per Stream.

As for all the questions, in the per Stream analysis, Stream B projects follow the overall trend. Regarding the Stream C project, the only emphasis is on Environmental sustainability, consistent with the response in question V1. Stream D projects have clear emphasis on most values, except Environmental sustainability and Trust. The CSA project puts emphasis on all Societal values, which makes sense due to the project focus and objectives, which is also expressed in their free text comment.

Key Insights

- Sustainability is central for many projects.
- Privacy and confidentiality together with Digital inclusion is important for approximately half of the projects.
- Few projects find Personal health and protection from harm, Trust and Democracy important for the focus.

As observed from the analysis of V1 Societal Challenges, the focus is high on sustainability, while values like trust and democracy does not seem as important.

2.2.3 Key value indicators (KVIs)

Question V3: Does your project address Key Value Indicators (KVIs)? If yes, which method do you plan to use?

In the questionnaire for Call 1 projects, analysed in SNS OPS Deliverable D1.2, we asked the projects about Key Values (KVs) directly in a free text form. The insights from this were that the notion of KVIs were difficult to grasp at that time, and that the value of the outcome was limited.

For Call 2, we instead chose to focus on the projects' methods to address KVIs. Therefore, any comparison with the Call 1 questionnaire analysis is not possible.

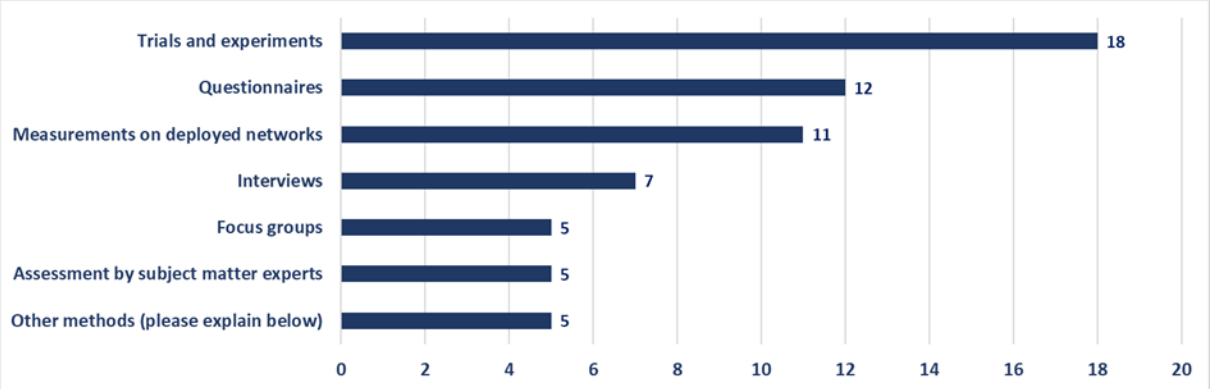

Figure 28: Approach for addressing Key Value Indicators (KVIs) by SNS JU Call 2 projects.

From Figure 28, Trials and experiments are the preferred method by most projects, followed by the use of Questionnaires and Measurements on deployed networks. Interviews, focus groups, using subject matter experts is in the lower end. There are also some other methods planned, expressed in the free text answers.

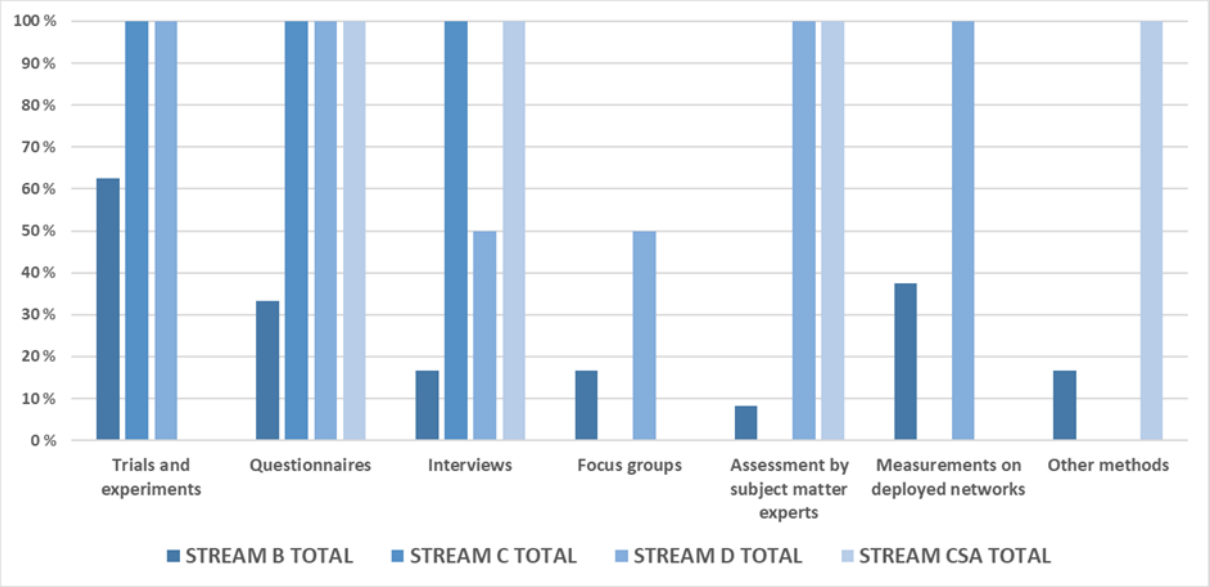

Figure 29: Approach for addressing KVIs by SNS JU Call 2 projects – per Stream.

In Figure 29, the responses per Stream is shown. Stream B and D projects are focusing on Trials and experiments, and Measurements on deployed networks. Stream C and D projects will in addition use Interviews.

Stream B, C and D projects are aiming for different TRLs, which explains their approaches. Stream B is typically low TRL, which explains their use of trials and experiments, but also interesting to see that they plan to use existing networks, which probably cam include both commercial and experimental networks. It is more obvious for Stream D projects, working on high TRL innovations, to use both the experimental platforms they control, as well as doing pre-pilots on deployed networks. Stream C projects, on the other hand, are focusing on developing and building experimental platforms, thus use of deployed networks is not relevant.

The CSA project is using Questionnaires, Interviews, Assessment by subject matter experts and other methods, which have not been specified. Also interesting to see that one of the Stream D projects also intends to use Focus groups in their work.

A few free text inputs from the Stream B project mentions the use of the 6G-IA Vision WG as a reference, or that suitable KVI assessment methods will be addressed and decided during the project.

Key Insights

- Stream B, C and D projects focus on Trials and experiments.
- Stream B and D also plans to exploit Measurements on deployed networks.
- Questionnaires and Interviews are used by many projects, especially by the CSA project.
- Focus groups are only used by four Stream B projects and one Stream D project.

2.2.4 6G Vision

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

Figure 30 shows the multiple-choice responses. All projects are conscious about affordability, scalability and flexibility, while great coverage and the unification of the physical, digital and human worlds are of medium importance.

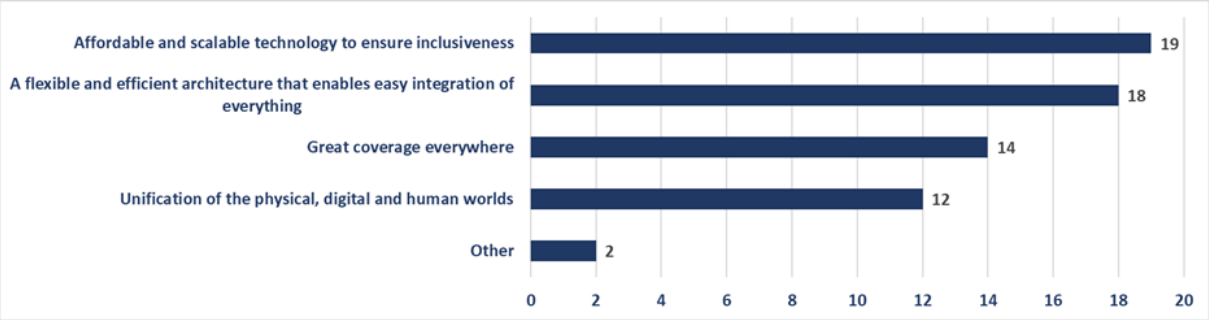

Figure 30: 6G Vision contributions as reported from the Call 2 SNS JU projects.

Figure 31 shows the responses per Stream. It should be noted that the Stream C project in Call 2 has not reported any contributions to the 6G vision. The CSA project is commenting that the 6G progress must align with societal values and sustainability goals, not just technical objectives.

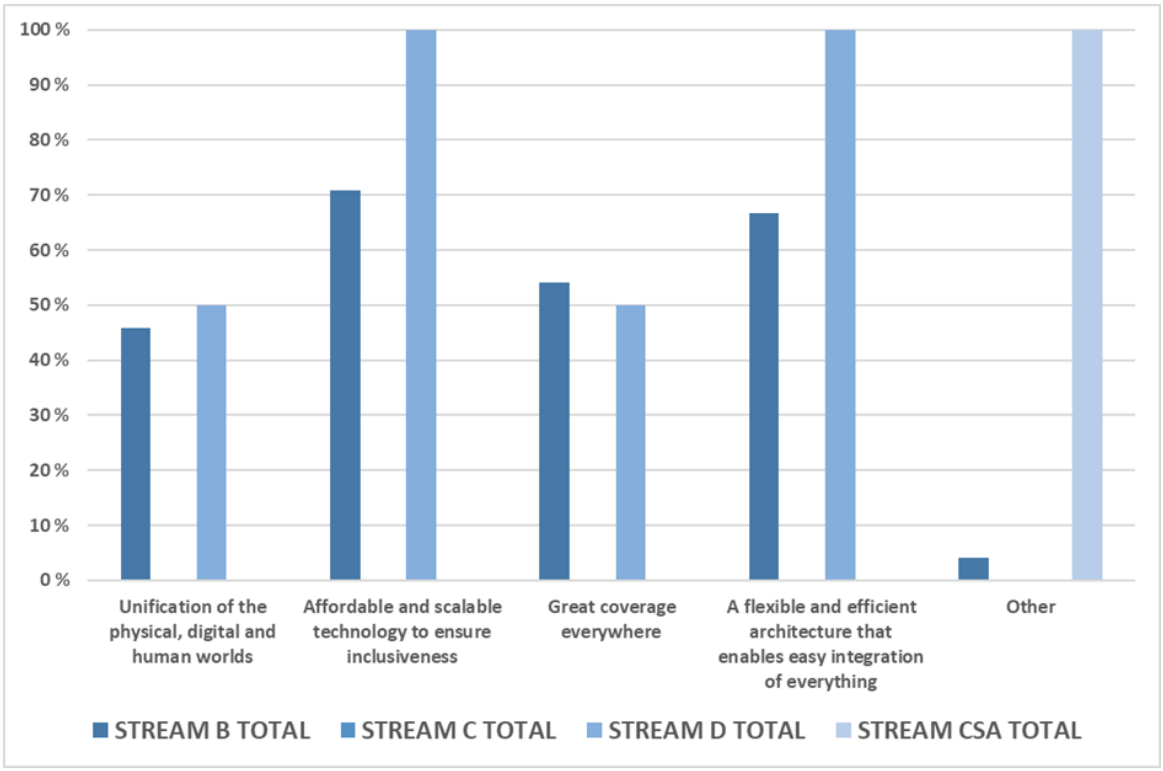

Figure 31: 6G Vision contributions as reported from the Call 2 SNS JU projects – per Stream

Key Insights

- Project are conscious about affordability, scalability and flexibility.

- Coverage and unification of physical, digital and human worlds are of medium importance.
- The Stream C project does not report any contribution among the suggested topics.
- 6G4Society reports on other contributions that alignment between technical objectives with societal values and sustainability goals.

The overall insights gained will be used to create a more targeted approach for the Call 3 questionnaire, where the latest edition of the 6G-IA Vision WG White paper will be consulted.

2.2.5 Sustainability

Question V5: As sustainability is essential for B5G/6G networks, which UN Sustainable Development Goals (SDGs) will your project contribute to?

This is the only question that is unchanged from the Call 1 survey to the Call 2 survey. Therefore, we present both to compare. Since there are different number of projects in the two calls (35 in Call 1 and 28 in Call 2), the results are shown as percentages. The overall analysis is shown in Figure 32.

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).

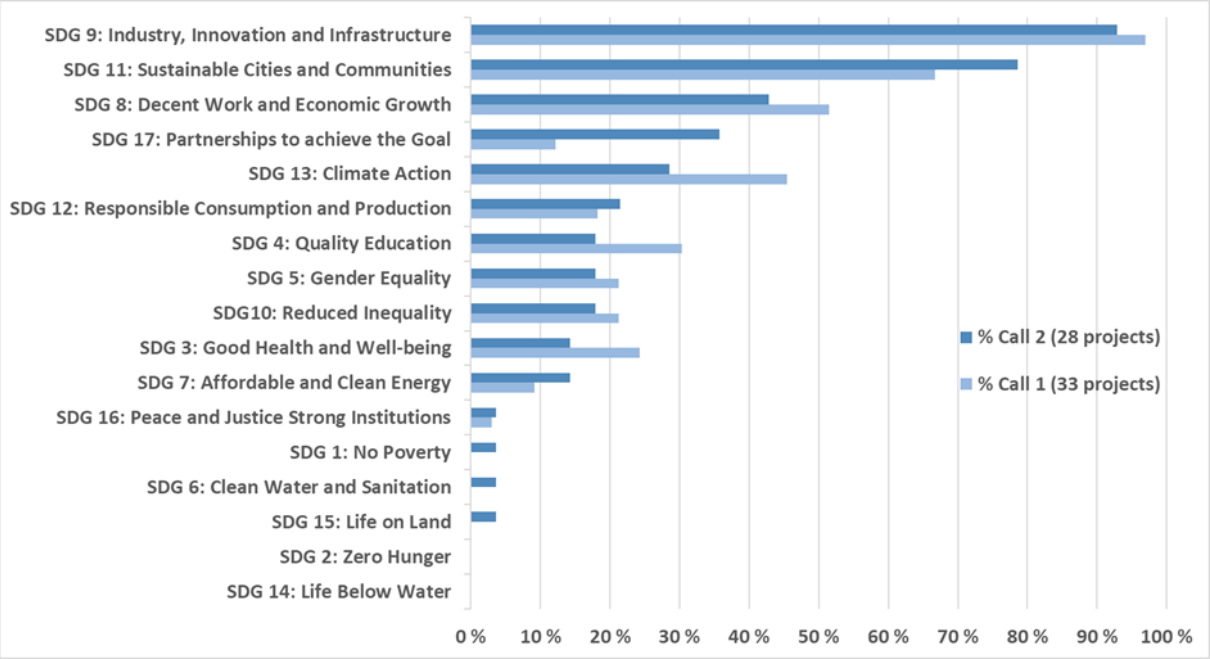

Figure 32: Contributions to UN SDGs by SNS JU Call 1 and Call 2 projects – compared

Investigating Figure 32, it becomes evident that both Call 1 and Call 2 projects have these four SDGs on top of their priorities, but we also see that Call 2 projects have more attention to SDG 17 Partnerships to Achieve the Goal (36% for Call 2, and 12% for Call 1), and SDG 13 Climate Action has less focus (29% for Call 2 and 45% for Call 1). Other SDGs gains less attention, generally below 20%).

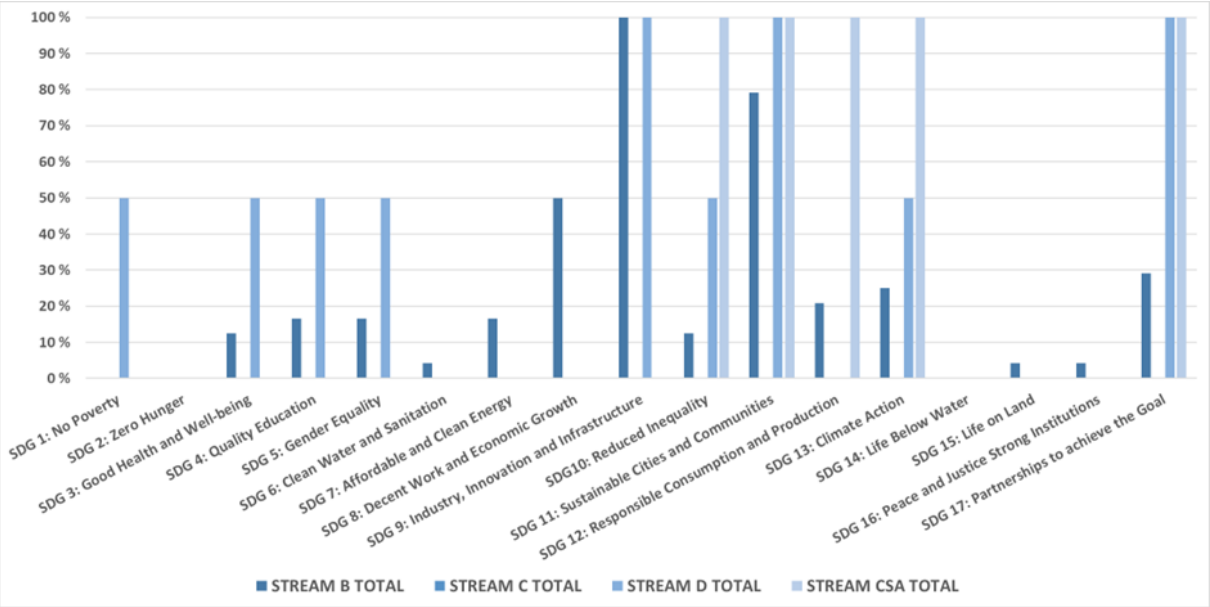

Figure 33: Contributions to UN SDGs by SNS JU Call 2 projects – per Stream

Figure 33 depicts the focus on SDGs in Call 2 projects depending on the stream. From this, we can see that all Stream B and D projects have a focus on SDG 9 Industry, Innovation and Infrastructure. We also see that the Stream C project in Call 2, does not report any focus on SDGs.

One of the Stream D projects also explains that enabling easy access to advanced experimentation frameworks and providing open-source frameworks and facilities for the development of novel features implicitly supports SDG 10 Reduced Inequality.

Key insights

- Call 2 projects have set three of the targeted SDGs (8, 9, 11) from the SNS Workprogramme as their top priority, similar to what we saw for Call 1.
- Call 2 projects have higher priority on SDG 17 Partnerships to Achieve the Goal.
- Call 2 projects have less priority on SDG 13 Climate Action.

Without drawing any conclusions, the "shift" from SDG 13 to SDG 17 may reflect a recent global trend where the attention to the climate work has weakened. The increased attention to SDG 17 may be in contrast to the trends towards more polarization.

2.2.6 Other comments to the vision aspects

The projects were given the opportunity to give an open comment to the vision aspect of their work. Two projects took the opportunity, one Stream B project and one Stream D project.

One aspect is that responses should be seen as preliminary, because the projects are in an early stage, running only for a few months.

Further, the evaluation of the benefits of the use cases from a societal and human perspective is an important target in which aspects such as assessing health benefits, improved students' experiences, advanced agricultural development and more aware cities and operations. Security is also of paramount importance to enable user trust in the provided services. Security must be ensured end-to-end.

2.3 Market aspects analysis

Market forecasts are paramount to uphold an effective strategy for the SNS ecosystem. Understanding the end-user needs, making evidence-based decisions and predicting customer behaviour help to gain Europe a competitive edge in the global market.

Market section overview

The central objective of this section was to gain an in-depth understanding of the Call 2 projects projections and expectations regarding the evolution of the 6G market over the next years. The outcomes will help the SNS JU to understand whether the subject and work of the projects are aligned with the expected developments of the market; where the potential challenges may lie; and overall, will feed the SNS vision and strategy.

The market section of the questionnaire comprised nine (9) questions. Six (6)Six questions were multiple choice and the other three (3)three were free text. All questions offered the possibility to elaborate on the response, including the addition of options that were not listed in the pre-defined answers for the multiple choice.

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 28 projects per option. Unlike in 2023, no differentiation has been made regarding the project streams since there were no significant variations due to the low number of projects in Stream C and Stream D. In order to facilitate comparisons, the responses are expressed in percentages.

The free text questions were analysed in-depth and grouped according to the commonalities identified. Subsequently, the categories emerged were enriched with specific insights noted by the projects.

This mixed approach of qualitative and quantitative questions provides robust evidence 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 and Call 2 projects is provided to showcase the evolution in the responses.

2.3.1 Market changes expected with the advent of 6G

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

Energy-efficiency is expected to experience the biggest market change, according to 75% of the projects (Figure 34). The advent of 6G will help to progress towards sustainability goals. Some of the technological innovations mentioned by the projects include *AI-driven predictive analytics*, which can forecast demand and subsequently adjust networks operations to minimise energy usage, *energy harvesting and low-power operations*, with the development of new materials and technologies that reduce the carbon footprint, and *semantic and goal-oriented methods*, which can contribute to greener networks reducing redundant data transmissions and overall ensuring a more intelligent allocation and use of network resources.

Projects also suggested the implementation of economic incentives to lower energy consumption as well as embedding environmental sustainability as a core value into 6G to enhance social acceptance and ease regulatory challenges, facilitating a smoother deployment.

The optimisation of the energy and carbon footprint in the provision of a service demands new mechanisms. Measures such as energy-driven orchestration and service level agreements (SLAs) limiting the energy use can achieve this. Moreover, the integration with emerging technologies such as AI and blockchain can contribute to enhanced energy efficiency across domains, according to projects.

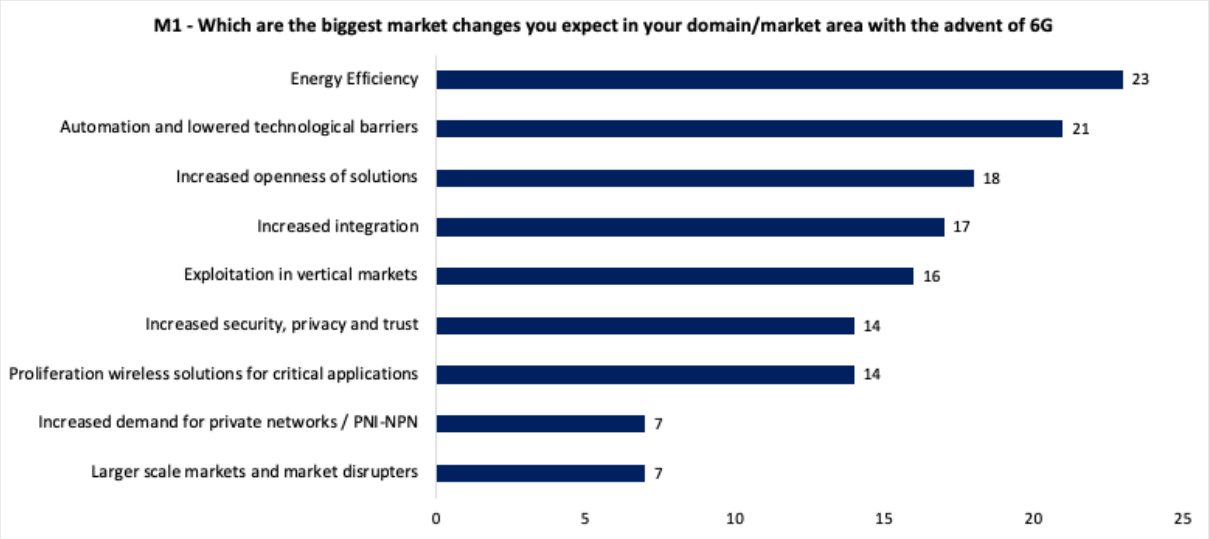

Figure 34. Biggest market changes expected with the advent of 6G

Similarly, automation and lowered technological barriers are predicted to have a substantial impact across different domains as indicated by 72% of the projects. The integration of AI and ML enable network and service management automation as well as data-driven security solutions that can respond to emerging threats, enhancing network reliability and trust.

Automation is essential to reduce operational costs as well as technological barriers. These are expected to facilitate smaller players to enter the market and enable a broader adoption. However, projects also underline the need to build trust in these technologies through transparent practices and robust regulatory frameworks.

Increased integration and openness of solutions are also anticipated to have a remarkable impact. Interoperability will foster collaboration and innovation across industries while open solutions and the integration with vertical markets will enable the creation of new services and business opportunities, driving growth and unlocking new possibilities. For instance, the integration of communication, sensing and computing capabilities to support real-time and low-latency applications in vertical markets is highlighted. Moreover, projects stress that 6G will lead to new specialised applications in industry, healthcare and automotive, among other verticals.

Regarding security, privacy and trust, AI/ML-based solutions are deemed critical to mitigate cybersecurity risks by safeguarding network services, infrastructure, and data. The need to preserve the privacy of individuals, upholding users' fundamental rights, is deemed critical for user adoption.

Larger scale markets and market disrupters, as well as private networks/PNI-NPN are considered to have the least overall impact. Other market changes mentioned, not included in the pre-defined answers, are end-user and societal acceptance of 6G and ubiquitous connectivity.

Market changes related to integration and openness of solutions, energy efficiency, proliferation of wireless solutions, and increased security, privacy and trust are relevant across both Call 1 and Call 2 projects.

Key insights

- **Energy efficiency** is predicted to be a major market driver: a sustainable 6G and a 6G for sustainability.
- AI and ML-driven **automation** will improve network and service management whilst enhancing security thus safeguarding network services, infrastructure, and data.

- **Integration and openness of solution**s are expected to have a remarkable impact, fostering collaboration, innovation and new business opportunities.
- **Security, privacy and trust** will be crucial in ensuring user trust shaping the consumer adoption of 6G services.

2.3.2 Technologies and innovations expected to drive the telecommunications market

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

As depicted in Figure 35**,** Open & disaggregated solutions and AI-based solutions (82%) are anticipated to be main drivers in the telecommunications market. Localisation & Sensing alongside Sustainability and Energy Efficiency are also remarkable (75%). On the contrary, RAN devices and TN-NTN-PN integration and interoperability are estimated to have a lower impact**,** although still relevant according to various projects.

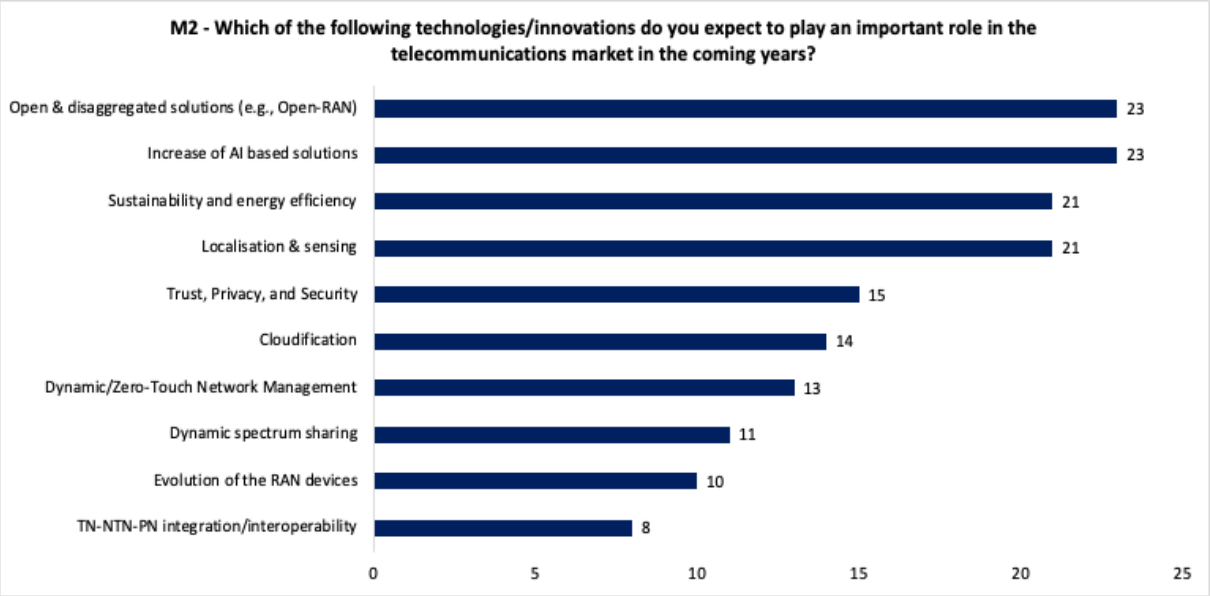

Figure 35: Technologies and innovations expected to play a major role in the telecoms market

Observing Figure 36, open and disaggregated solutions are anticipated to play the largest role in shaping the telco market in the coming years according to 82% of the projects in the Call 2 vs. 58% of the Call 1 projects. AI-based solutions and sustainability and energy efficiency continue to be amongst the top technologies.

Location and sensing have gained relevance with 75% of Call 2 projects indicating innovations in this domain will have a great impact vs. 55% of the Call 1 projects. Similarly, cloudification has also been identified as a relevant trend by half of the Call 2 projects vs 36% of the Call 1 projects.

Dynamic / Zero-touch network management appear to have lost relevance, with 46% of the Call 2 projects choosing this technology vs. 64% of the Call 1 projects.

It is important to note that slightly more than 50% of the Call 2 projects have placed considerable importance in Trust, Privacy and Security (this was not an option in the questionnaire addressed to Call 1 projects). Generative AI is also cited as one of the most promising upcoming technologies.

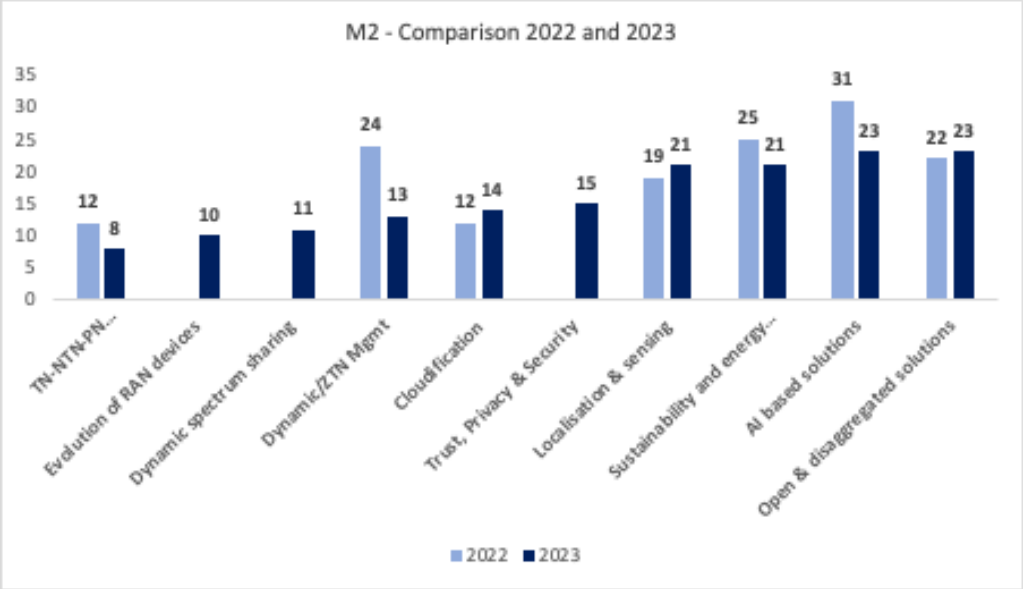

Figure 36: Technologies and innovations expected to play an important role in the telecommunications market. Comparison Call 1 vs Call 2 projects

Key insights

- **Open and disaggregated solutions and AI based technologies** are predicted to become major market drivers in the telecommunications sector.
- **Sustainability and energy efficiency r**emain key while **localisation & sensing** are gaining traction in the market.
- **Cloudification** is a rising trend and **trust, security and privacy** are gaining importance.
- Interest in **dynamic/zero-touch network management** has declined amongst the Call 2 projects.

2.3.3 Vertical sectors most impacted by the advent of 6G

Question M3. Which vertical sectors do you expect to be affected the most with the advent of 6G?

According to the results presented in Figure 37, Industry 4.0/Manufacturing is expected to be the vertical sector most impacted by the advent of 6G by a large margin, as indicated by 68% of the Call 2 projects. Opinions are rather varied with respect to the other sectors, none of which reaches a consensus higher or equal to 50%.

Smart Cities are ranked second in terms of the estimated impact of 6G in the sector, according to 46% of the projects. With 36% of the projects, Automotive closes the top three sectors. It is also important to note that Education was indicated by 21% of the projects.

Inversely, Space, Tourism & Culture and Agriculture & Farming are the sectors expected to experience a lesser impact [8].

[8] Note: *Space* was added as a new option to the Call 2 questionnaire. Ecology, including ocean, soil and climate, replaces smart environment, Public Safety was added to Security and PPDR, and, Automotive was split from Transport and Logistics.

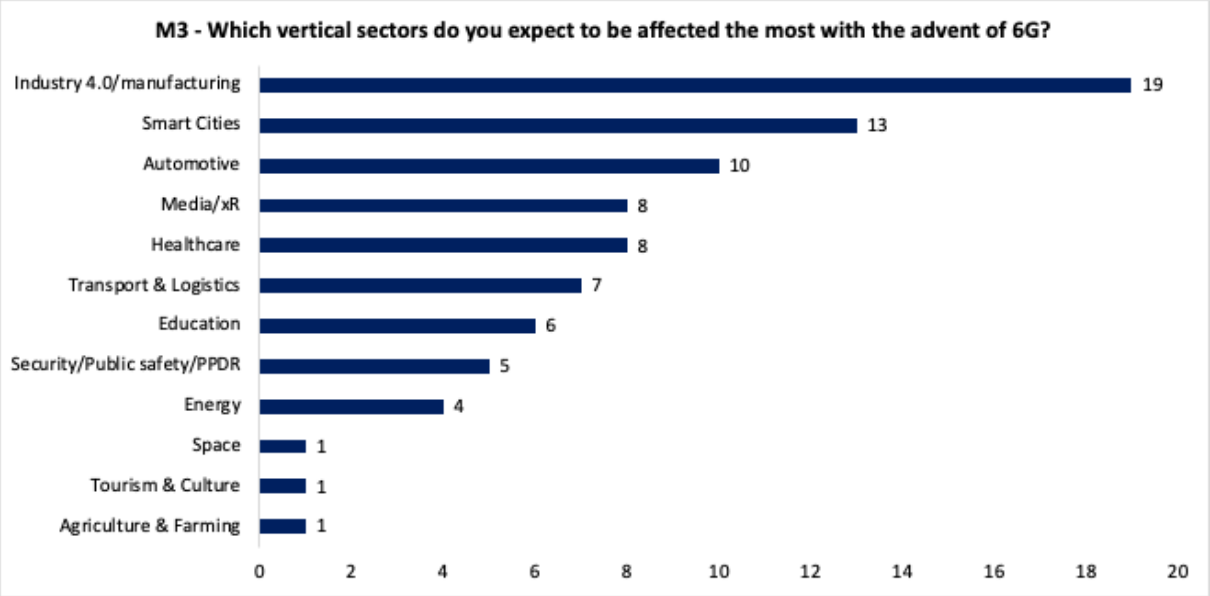

Figure 37: Vertical sectors expected to be affected the most with the advent of 6G

According to the results presented in Figure 38, Industry 4.0/Manufacturing is the sector anticipated to be most affected by 6G. Similarly, the sectors expected to be the least impacted continue to be largely the same, namely: space and tourism & culture. Agriculture & Farming and Energy, which were already on the bottom of the ranking, decreased.

Media/xR, which ranked second by Call 1 (64%), is seen as disruptive by less than 30% of the Call 2 projects, marking an important difference. Smart Cities are anticipated to be highly impacted by 6G by 46% of the Call 2 projects, vs 39% of Call 1. Automotive continues to be on the top, whilst Transport and Logistics are in the middle of the ranking. For Call 1 projects, the three sectors were gathered in the same pre-defined response, which restricts any potential comparison. No Call 2 or Call 1 project selected Ecology or Construction.

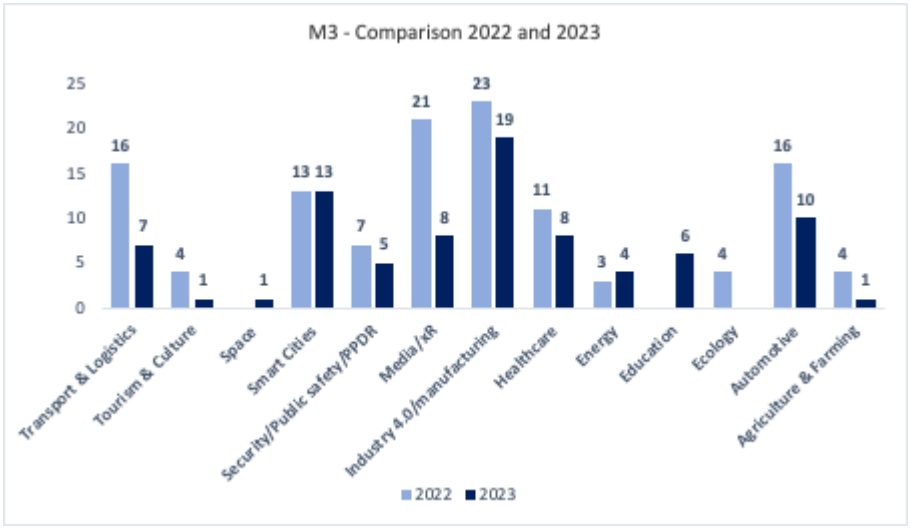

Figure 38: Vertical sectors expected to be affected the most with the advent of 6G (Call 1 vs. Call 2)

Key insights

- **Industry 4.0** is expected to experience the most substantial impact from 6G.
- **Smart cities** rank second and **automotive** closes the top three.
- There was a sharp decline in **media/xR,** which suggests a shift in the priorities of the Call 2 projects or a slower adoption of immersive technologies.
- **Education** has gained visibility, indicating growing interest in 6G-enabled learning solutions.

- Lower impact sectors have remained rather **consistent** over the two last years.

2.3.4 Validating business opportunities in vertical sectors

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

Figure 39 showcases a ranking of the methods used by Call 2 projects to validate the potential business opportunities, generated from the innovations produced during the course of their work, in vertical sectors.

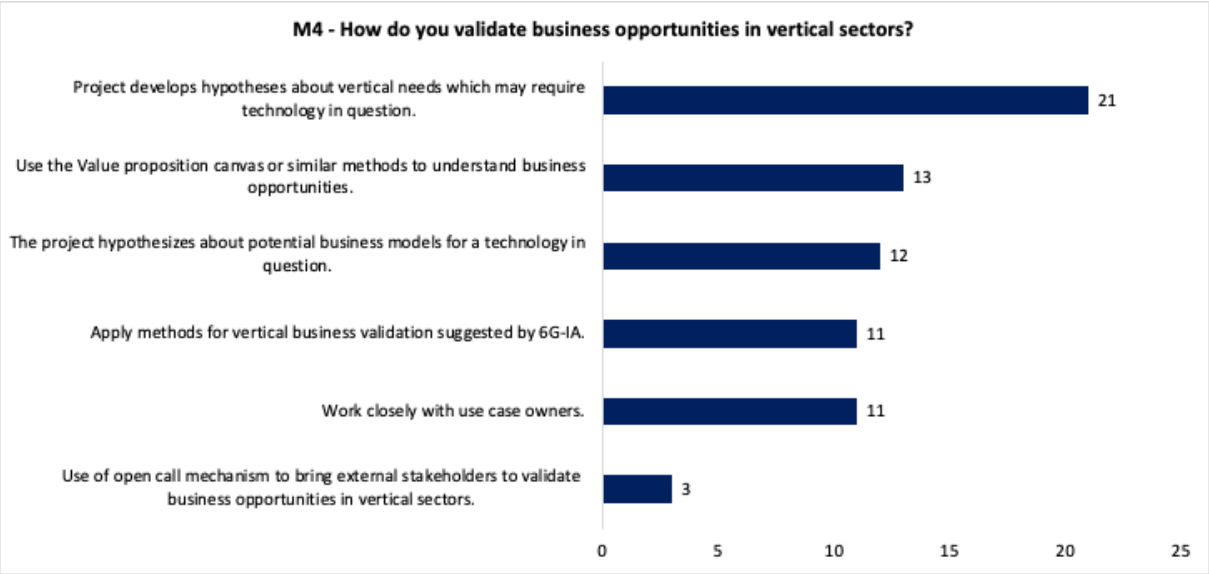

Figure 39: Methods used to validate business opportunities in vertical sectors

The methods used to validate business opportunities vary significantly between Call 1 and Call 2 projects. Working closely with the use case owners was the preferred method by Call 1 projects, with 70% selecting it, whereas only 39% of Call 2 projects opted for this approach. Developing hypothesis about the need of verticals for a specific technology (75%) is the most used method to validate business opportunities among Call 2 projects. Yet only 45% of the Call 1 projects chose it.

The use of the value proposition canvas has grown from 36% among Call 1 projects to 46% among Call 2 projects. The application of methods suggested by 6G-IA has also increased, with 39% of Call 2 projects using it versus 24% of Call 1 projects.

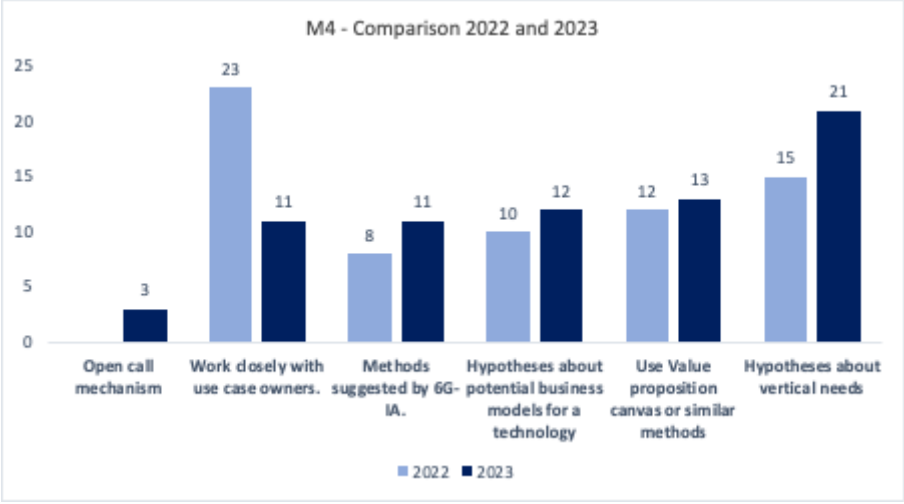

Figure 40: Methods used to validate business opportunities in vertical sectors (Call 1 vs Call 2)

Most of the other methods listed for Call 2 projects, except for the use of open calls, are mentioned on an equal measure, as can be observed in Figure 40.

It is important to note that open calls are linked to specific projects and responses reflect this. This mechanism was not listed in the previous version of the questionnaire.

Most projects combine more than one approach to ensure a comprehensive assessment of the business opportunities in verticals. The engagement with experts and relevant stakeholders in the specific verticals is also mentioned.

Key insights

- There has been a shift in the preferred validation methods. **Developing hypotheses about verticals' needs** is the most used method now.
- The use of structured frameworks such as the **value proposition canvas** and the **methods recommended by 6G-IA** has grown.
- Most projects combine **multiple validation** methods to ensure a thorough assessment of business potential.

2.3.5 Assessing the commercial viability of 6G

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

The results for this question are depicted in Figure 41. Some 80% of the Call 2 projects assess the commercial viability of their innovations through a techno-economic analysis. Only six projects did not select this method. Assessing addressable and serviceable target markets ranks second, with 43% of the projects indicating its use.

The adoption and widespread of innovations, the quantitative modelling of cost side, the identification of cost items and the total cost of ownership are also considered by 25%-30% of Call 2 projects when assessing the RoI. McKinsey's Three Horizon of Growth is the least used approach.

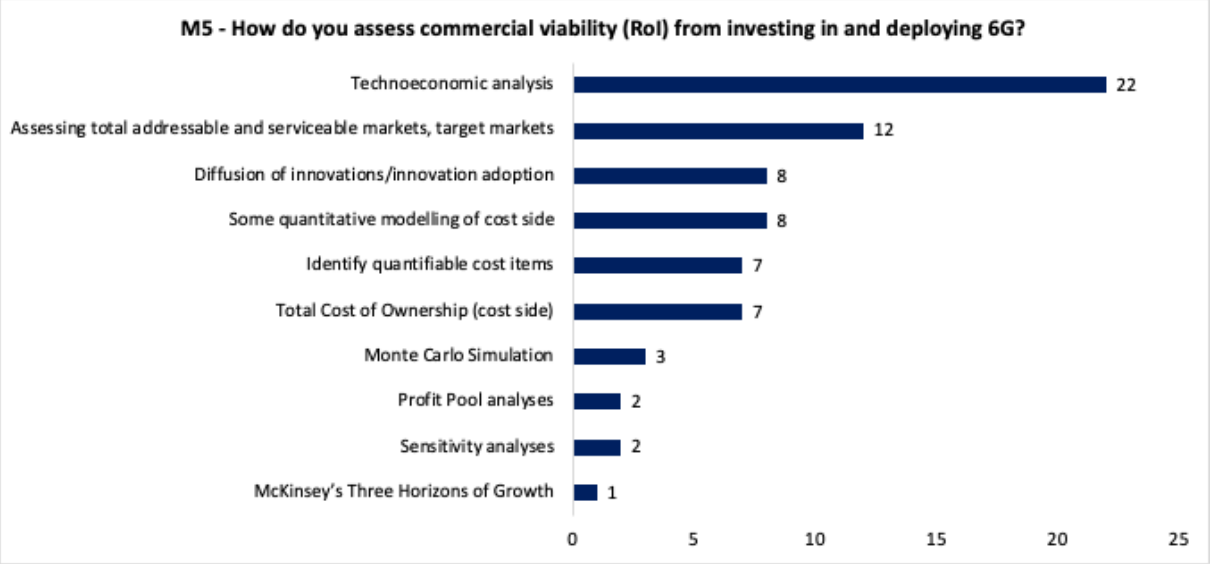

Figure 41: Assess commercial viability (RoI) from investing in and deploying 6G, for 6G providers

One project indicates their goal "to develop a Technology Acceptance Model". Consequently, the viability would be measured by the uptake of 6G by end-users and the societal acceptance.

This question was newly included in the 2024 questionnaire; thus, no comparison can be made with the results of the previous edition of the questionnaire.

Key insights

- **Technoeconomic analysis** is the most used assessment, followed by **market evaluation.**
- Cost-focused assessments, innovation adoption and widespread use are rather relevant.
- McKinsey's Three Horizons of Growth is the least used assessment.

2.3.6 Major bottlenecks for 6G deployment

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

Figure 42 shows there is a wide range of perspectives amongst Call 2 projects regarding the main obstacles for the deployment of 6G networks. The lack of demand and deployment costs are considered the main hurdles to the implementation of 6G, according to 57% and 54% of the projects respectively.

Security and privacy concerns rank third in terms of obstacles for the deployment of 6G as indicated by 43% of the projects. Challenges related to spectrum availability and sustainability seem to be pressuring for 32% of the projects.

The options of sustainability and public trust and acceptance were added in the 2023 questionnaire based on the responses of the previous edition of the questionnaire. Nevertheless, no Call 2 project selected the later as a concern.

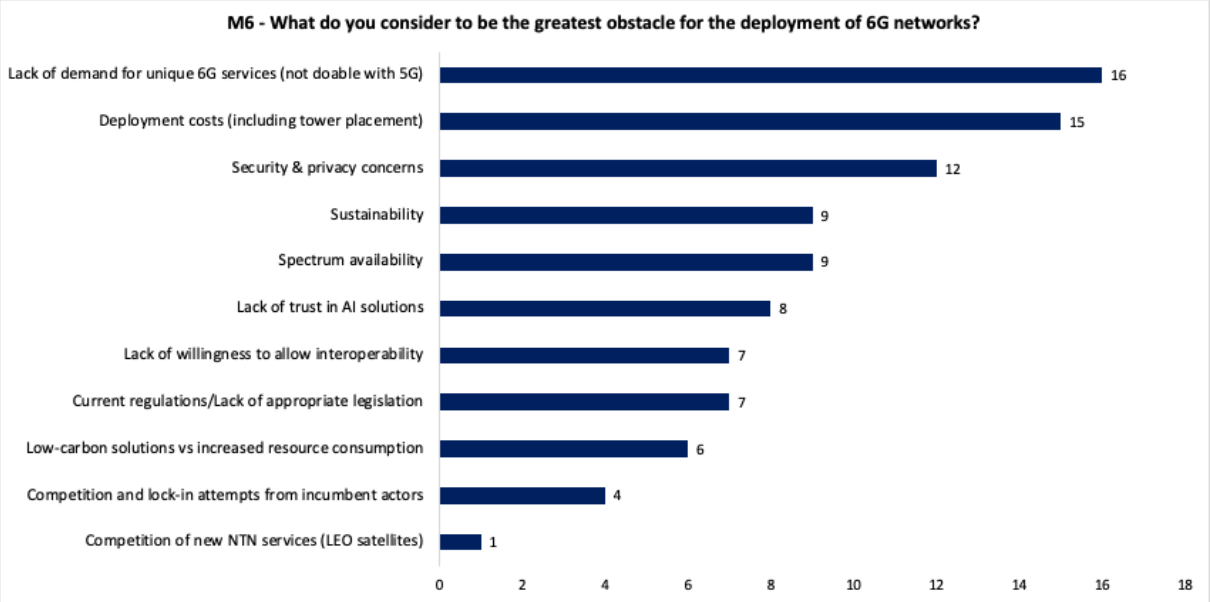

Figure 42: Ranking of the greatest obstacle for the deployment of 6G networks

Call 2 projects seem to have a greater disparity of opinions regarding the main obstacles for the deployment of 6G networks when compared to those from Call 1, as depicted in Figure 43. Generally speaking, the Call 2 projects seem to show overall less concerns about the challenges listed e.g., lack of willingness to allow interoperability, low-carbon solutions, competition and lock-in attempts from incumbent actors, lack of trust in AI solutions, etc.

The lack of demand and deployment costs gather the bigger consensus, yet none of these reaches 60% agreement. For instance, the degree of concern linked to these two obstacles has decreased notably. In particular, costs concerns have diminished from 67% Among Call 1 projects to 54% in Call 2 projects. Obstacles regarding the lack of trust in AI solutions and the lack of willingness to allow interoperability have also reduced.

Security and privacy concerns have increased from 30% among the Call 1 projects to 43% among the Call 2 ones. Likewise, the challenges related to the spectrum availability almost doubled, from 18% for Call 1 projects to 32% among Call 2 projects.

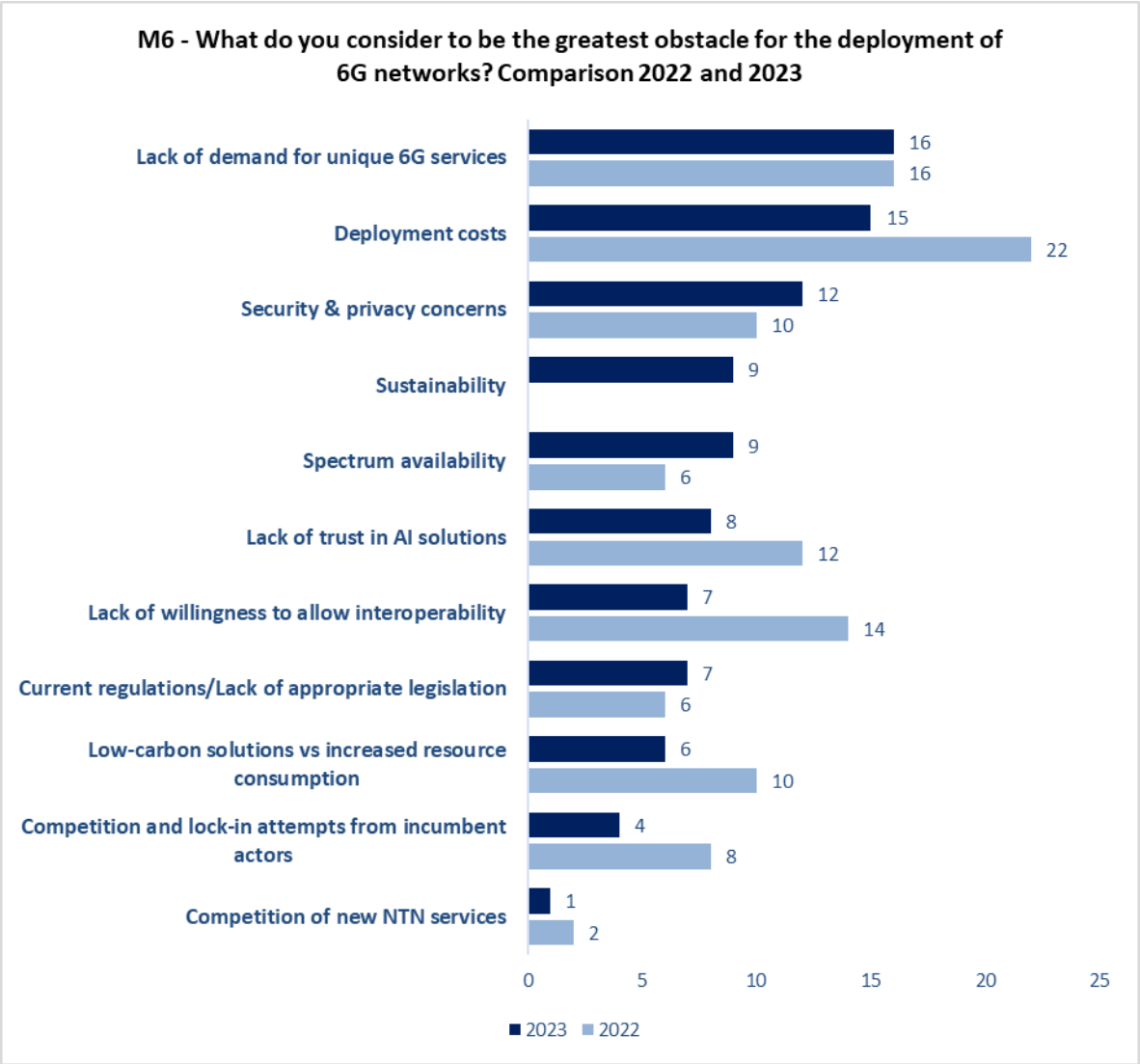

Figure 43: Ranking of the greatest obstacle for the deployment of 6G networks (Call 1 vs Call 2)

Other concerns mentioned by the projects include the lack of business to business (B2B) and business to costumers (B2C) use cases and the research in energy-efficient high-data hardware.

Key insights

- **Lack of demand** and **deployment costs** are the primary concerns, although concerns around the later have decreased notably.
- **Security and privacy** concerns have risen in among Call 2 projects, highlighting an increasing focus on data protection and trust.
- Concerns about **spectrum availability** nearly doubled.
- **Interoperability, AI trust, and incumbent lock-in** are deemed to be less pressuring than in the previous year.

2.3.7 Unlocking new market sectors

Question M7. 4G enabled the "App ecosystem". 5G enables the ecosystem to include more reliable, numerous and bandwidth-rich applications and services addressing mainstream vertical markets. Do you believe enhancing 5G towards 6G can accomplish a similar mobilising of the ecosystem forward? If yes, what would be your estimation as to the novel market sector(s) that 6G may enable?

There is a consensus around the potential of 6G for transforming the current ecosystem. Some Call 2 projects underlined that 6G will help to fulfil the expectations that were not met by 5G whilst further pushing them to new heights, enabling completely new applications and services.

The Call 2 projects have echoed most of the novel markets indicated by the Call 1 projects, i.e., IoT, immersive ecosystem (AR, VR, XR, holographic technologies), or edge computing. Nonetheless, the new projects have provided more detailed insights about the novel markets. Many of the applications are linked to the industry 4.0.

Artificial Intelligence (AI) continues to be considered one of the main drivers of new upcoming markets. For instance, the combination of generative AI and 6G is predicted to create new business models and operational processes, leading to the emergence of new market sectors. Likewise, integrated services that combine domains and technologies and are orchestrated by AI could be key in developing novel markets. The combination of AI with various other technologies is opening a new paradigm in the technological landscape, adding a new dimension to the 6G ecosystem capable of integrating and leveraging the data from different domains for (new) services. Uses include (among others) network optimisation, autonomous decision-making, and enhancement of various applications such as autonomous systems and immersive technologies.

6G will enable enhanced communication services, relaying on technologies such as holographic and quantum communications, as well as in the seamless integration of communication and sensing capabilities. Holographic communications will provide high-fidelity, real-time 3D communications for various applications whilst advanced security and communication capabilities will be guaranteed by leveraging quantum technologies. Furthermore, in the advent of 6G, "networks will facilitate communication and serve as a pervasive sensing infrastructure". The perceptive network concept, which refers to a network capable of sensing and interpreting its environment, allowing it to adapt to changing conditions and user needs, is mentioned. In this regard, the role of massive MIMO (Multiple Input Multiple Output) is underlined.

Similarly, the widespread adoption of immersive technologies such as augmented reality (AR) and virtual reality (VR) will lead to applications spanning various sectors such as gaming, entertainment, education, healthcare, or remote collaboration. In respect to healthcare, 6G will power real-time monitoring, diagnostics, and telemedicine for a more personalised healthcare and an improved remote medicine.

New market segments focusing on societal wellbeing and sustainability will emerge. In fact, the social impact of 6G is anticipated to bring new and advanced solutions to tackle societal challenges promoting digital inclusivity, environmental sustainability, societal wellbeing and more.

The Internet of Things (IoT) anticipated to exploit since 6G capabilities will support a large number of interconnected devices, sensors and actuators, which in turn will enable the creation of comprehensive and detailed digital twin models that allow monitoring and management of assets on a larger scale with higher granularity, applicable in manufacturing, urban planning, and infrastructure management, among other areas.

The integration of IoT devices for efficient resource management, enhanced public services, enhanced sustainability, and better quality of life will also be critical in further developing smart cities. Moreover, Industrial IoT (IIoT) will enhance real-time monitoring and management of industrial processes.

Edge computing is anticipated to be required for extremely demanding yet highly promising new services e.g., automotive (V2X), industrial (IIoT) and end user (XR/VR). Most of the required edge infrastructure would not belong to the MNO providing the access network". Likewise, it is noted the growing 5G/6G virtualisation, in which the core network of the operator is being provided "as a service". The newest trend is to outsource it to some cloud provider (i.e., an external data centre).

6G is also expected to enable advanced radio access technologies, enabling the development of intelligent radio systems and antenna solutions for 6G spectrum. The potential for innovation in network design and optimisation in relation to the Open Radio Access Network (Open RAN) is mentioned.

Finally, 6G could facilitate the widespread deployment of autonomous systems and drones, powered by ultra-reliable communication and precise positioning capabilities, impacting autonomous transportation, delivery services, infrastructure inspection, disaster response, and environmental monitoring.

Key insights

- **6G is expected to act as a catalyst for transforming the ecosystem**, fulfilling unmet expectations from 5G while introducing new applications and services. Many novel markets identified by the Call 2 projects align with those from Call 1 projects.
- The combination of **6G and AI** is considered the key enabler of new markets and new business models.
- **Advanced communication and sensing capabilities** alongside **immersive technologies** are seen as the most promising markets.
- **6G will enable the proliferation of IoT devices and sensors**, which in turn will transform many vertical sectors.

2.3.8 Key Exploitable Results and Technology Readiness Levels

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 the Call 2 are highly diverse. Nonetheless, a general categorisation can be established according to the main topics tackled, as presented in Table 1.

Table 1: Categorization of KERs of SNS Call 2 projects.

Category	KERs
AI and ML integration	• AI/ML reference frameworks for 6G networks such as AI-native toolkits for decision-making, AI- native architectures for resource management, and AI-based orchestration and management services. • Real-time AI/ML solutions for network security and enhanced transparency. • Intelligent orchestration solutions for distributed network management.
Advanced Network Management	• Orchestration and automation: intelligent and distributed orchestration solutions for network computing integration and automation architecture aiming to enhance control and efficiency in network management and data transit systems. • Learning and management, federated approaches to AI-based network functions and federated simulation engines for network digital twins. • Digital twins for network control and planning as well as data harmonisation • Service-oriented architectures for 6G networks and cloud systems.
Security and privacy	• E2E security orchestration systems, including zero-touch security orchestration. • AI-enabled security frameworks such as anti-jamming and intrusion detection systems. • Development of trustworthy and secure frameworks in cross-domain, multi-tenant 6G networks.
Communication and sensing	• Waveform for sensing-as-a-service and semantic communications. • Integration of sensing technologies into communication networks.
Energy efficiency	• New architectures and solutions (automation, AI, energy-aware solutions) to reduce energy consumption and enhance energy efficiency. • Energy-efficient, scalable AI utilising low-footprint neural computing architectures and the semantic properties of information.
6G-specific technologies	• Physical and network architecture - development of secure, scalable frameworks for data exposure and collection and, programmable monitoring platforms. • Advanced spectrum management techniques.

	• Development of high-frequency transmission systems and wideband communication technologies.
6G ecosystem and standards	• Contributions to standardisation bodies. • Key Value Indicators (KVIs) and Key Sustainable Indicators (KSIs) frameworks.

Other KERs consisted of incentive-compatible energy reduction mechanisms, open-source implementation of system components and frameworks, a Technology Acceptance Model (TAM), or advanced antenna systems and reconfigurable surfaces. Some KERs were linked to experimentation.

In comparison to the KERs reported by the Call 1 projects, there is less emphasis in integration-specific results. The categorisation remains relevant with a few additions such as communication and sensing or 6G-specific technologies.

Regarding the analysis of TRLs, the number of assigned TRLs per each KER was counted. For example, if a project mentions seven KERs each expected to reach TRL5 and some other project mentions two KERs expected to reach TRL5, the result is nine KERs in TLR5. As it can be observed in Figure 44, most projects indicated TRLs between 3 and 4, with a few exceptions indicating TRLs ranging from 5 to 7. For instance, out of the 123 KERs specifically listed with their associated TRLs, 24% are expected to reach TRL3, 65% TRL4, 4% TRL5 and other 4% TRL6 and finally, 3% TRL7.

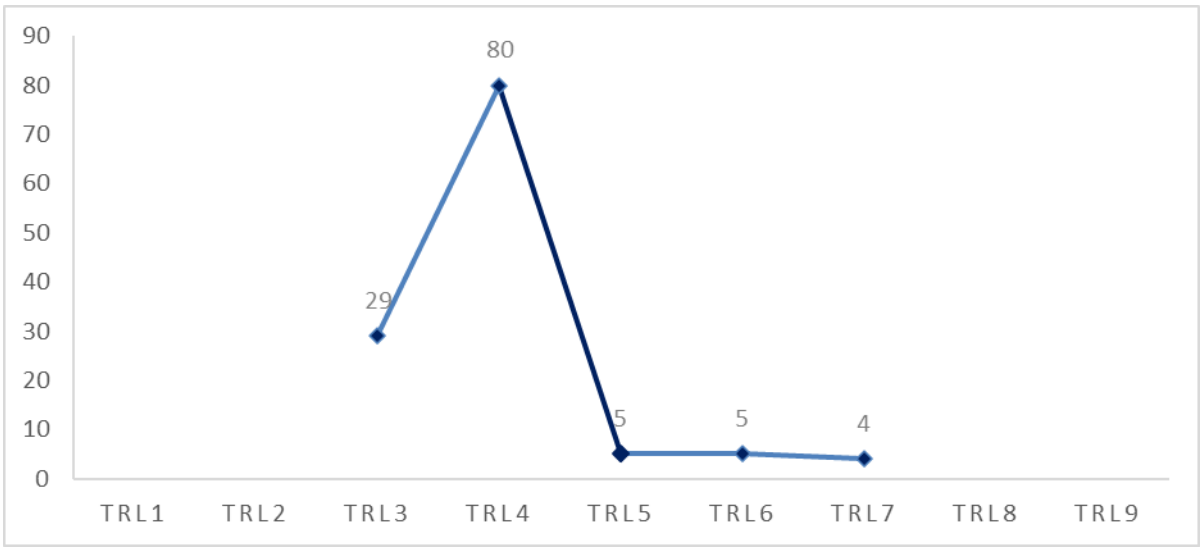

Figure 44: KERs and corresponding TRLs as reported by Call 2 projects.

It is important to note that the highest TRLs were concentrated in a few projects. For instances, KERs expected to reach TRL5 and TRL6 were indicated by three projects and TRL7 by only one project. Three projects did not list specific TRLs for each of their KERs, but a range that went between 3-4 (two projects adding 19 KERs), TRLs 4-5 (one project with seven KERs) and TRLs 5-7 (one project with no specific number of KERs). Four projects did not indicate their TRLs.

The main trend of the Call 2 projects TRLs has remained unchanged with respect to that of Call 1 projects, as it can be observed from Figure 45. Most TRLs continue to be on the mid to lower range. In fact, the Call 2 projects reported lower TRLs on average in comparison to Call 1 projects i.e., TRLs 4 to 5 for Call 1 versus TRLs 3 to 4 for Call 2.

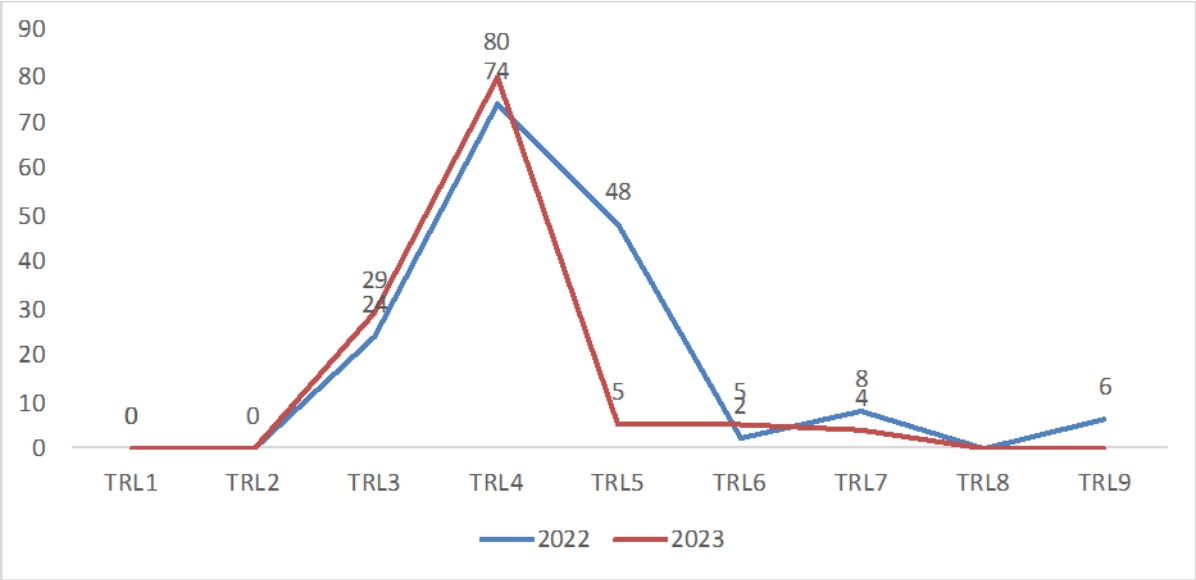

Figure 45: KERs and corresponding TRLs – Call 1 vs Call 2 projects

Unlike the previous questionnaire, Call 2 projects reported lower TRL5, TRL7 and no TRL9.

Key insights

- Projects envision a **wide range of KERs**, which can be broadly categorised into AI & ML integration, advanced network management, security & privacy, communication & sensing, energy efficiency, 6G-specific technologies, and ecosystem & standards.
- **AI, security and energy efficiency** are prioritised.
- Most projects reported **TRLs between 3 and 4**, indicating an early-stage development for innovations. In comparison to Call 1 projects, Call 2 projects reported slightly lower TRLs and shifted to a greater focus on sensing and 6G-specific technologies.
- Growing contributions to standardisation and open-source frameworks as well as the development of Key Value Indicators (KVIs) and Key Sustainable Indicators (KSIs) suggest a broader vision for 6G and the efforts to shape the 6G ecosystem accordingly.

2.3.9 SME participation

Question M9. Does your project promote the participation of SMEs?

The analysis of the questionnaire results allowed to categorise the responses according to the type of support projects provide to facilitate SME participation. Subsequently, the main actions devised to promote SMEs participation in the SNS JU and its projects were categorised into active participation, product and technology development, market expansion, collaboration and networking and open calls.

Most projects actively involve one or more SMEs as consortium members, leveraging their expertise and experience in areas such as AI/ML, quantum technologies, network security, open RAN solutions, ISAC, IoT, or more niche domains such as advanced metering systems for ICT or Other World Computing (OWC). SMEs are also central in supporting technological integration to develop cohesive solutions. Hence, SMEs play a key role in developing new technologies and solutions, as well as in enhancing existing ones in domains like automation, cybersecurity, navigation, cloud-continuum or the metaverse.

In particular, SMEs contribute to the following technologies and solutions: advanced energy metering methods; native AI integration in management and orchestration; adaptive optics; integrated photonics and integrated transmitters; optical antennas, low-power and wireless sensors; Integrated Sensing and Communication (ISAC) applications in autonomous navigation systems (e.g. radar-based ISAC); pulsed MEMS-based LIDAR with sensing; radiofrequency (RF) technology; Reconfigurable Intelligent Surface (RIS) structures; and, digital forensics, Security Information and Event Management (SIEM), and Intrusion Detection and Prevention System (IDPS).

Participating in the SNS JU projects helps SMEs to broaden their product and service portfolios thereby, increasing their competitiveness. SMEs can access new markets, including verticals such as automotive or aerospace and niche markets such as cybersecurity, privacy and security, or cloud services.

Many of the innovations developed within the projects are expected to be of interest for the main mobile network operators (MNOs) and vendors. Yet, projects also highlight that these new business opportunities linked to their work could be exploited by existing and emerging SMEs and start-ups. Novel applications could encourage entrepreneurial activities in a wide range of fields.

Many projects offer SMEs to engage in experimental activities, for example testbeds and proof-of-concept, validating new technological trends and participating in cutting-edge research. These opportunities foster innovation and push SMEs to stay at the forefront of technological advancements. Likewise, some projects include training activities.

Furthermore, several projects devise open calls targeting SMEs, contributing to the convergence of different perspectives and expertise that leads to greater innovation and thus, fostering a more competitive and dynamic ecosystem. As an example, one Stream D project allocates at least 50% of its Financial Support to Third Parties (FSTP) budget to SMEs.

The facilitation of networking among SMEs and of these with industrial stakeholders, academic institutions, and research communities cannot be understated as one of the main benefits of participating in SNS projects. and programme This collaborative approach helps SMEs to build a strong network that supports mutual growth and knowledge sharing. Moreover, projects efforts to promote their technologies, gain visibility, and foster market adoption also support the positioning of SMEs in the SNS ecosystem.

In short, the SNS JU fosters SME growth, innovation, and market competitiveness within the evolving landscape of 6G technologies.

Key insights

- **SMEs are actively involved in the SNS JU**, contributing expertise and driving technology and product development across a wide range of domains.
- The potential to **expand the market and grow the business** thus, enhancing competitiveness, is underlined as one of the main benefits of the SMEs participation in SNS projects.
- Engaging in **collaboration and experimentation** activities enables SMEs to foster cutting-edge innovation.
- **Open calls** encourage the participation of (new) SMEs and facilitate their collaboration with industry and academia, strengthening and solidifying their role in the 6G ecosystem.

2.4 Programme level KPIs (JU Metrics)

To capture the programme level KPIs (JU Metrics) a questionnaire has been generated by the SNS OPS CSA project, to capture the data from the ongoing SNS JU R&I projects (operational for at least 1 year, which for this instance of the questionnaire means Call 1 Projects). These indicators are based on capturing the achievements in each of the SNS projects and consolidating the results to facilitate the progress tracking of the SNS JU programme as a whole and, specifically, to allow the preparation of relevant JU monitoring reports. The key JU Metrics resulting from the answers of Call 1 projects, regarding their achievements in 2023, are depicted in the Infographic of Figure 46.

Figure 46: SNS JU Highlights based on Call 1 project achievements within 2023

The remainder of this section provides a thorough analysis of each question and analyses the responses received by the Call 1 projects.

Question 1: How many events (webinars, workshops, sessions, panels, keynotes) has your project organised in 2023?

This question aimed to understand the details of the events organised by Call 1 projects in 2023. As depicted in Figure 47, in total 100 events were organised, almost half of which by Stream B projects (43 events). This was followed by the CSA projects (19), Stream A (14), Stream D (13), and Stream C (11) projects.

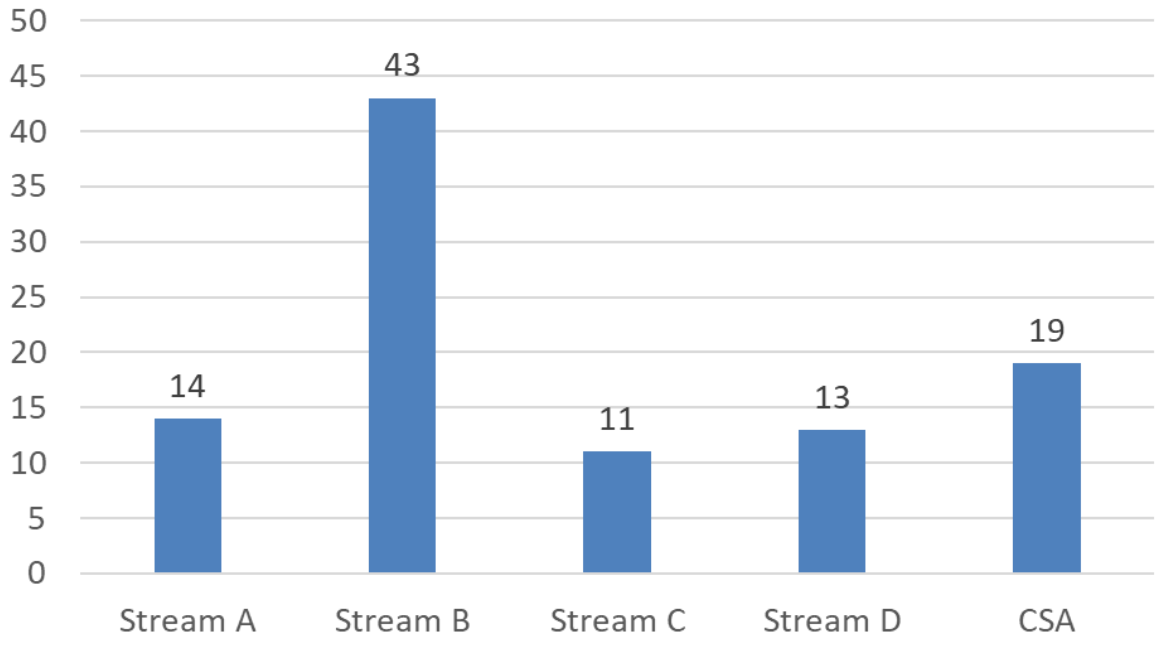

Figure 47: Number of events organized by Call 1 projects within 2023

As observed when looking at Figure 48, the majority of the organised events are workshops (34), followed by webinars (26) and special sessions (9).

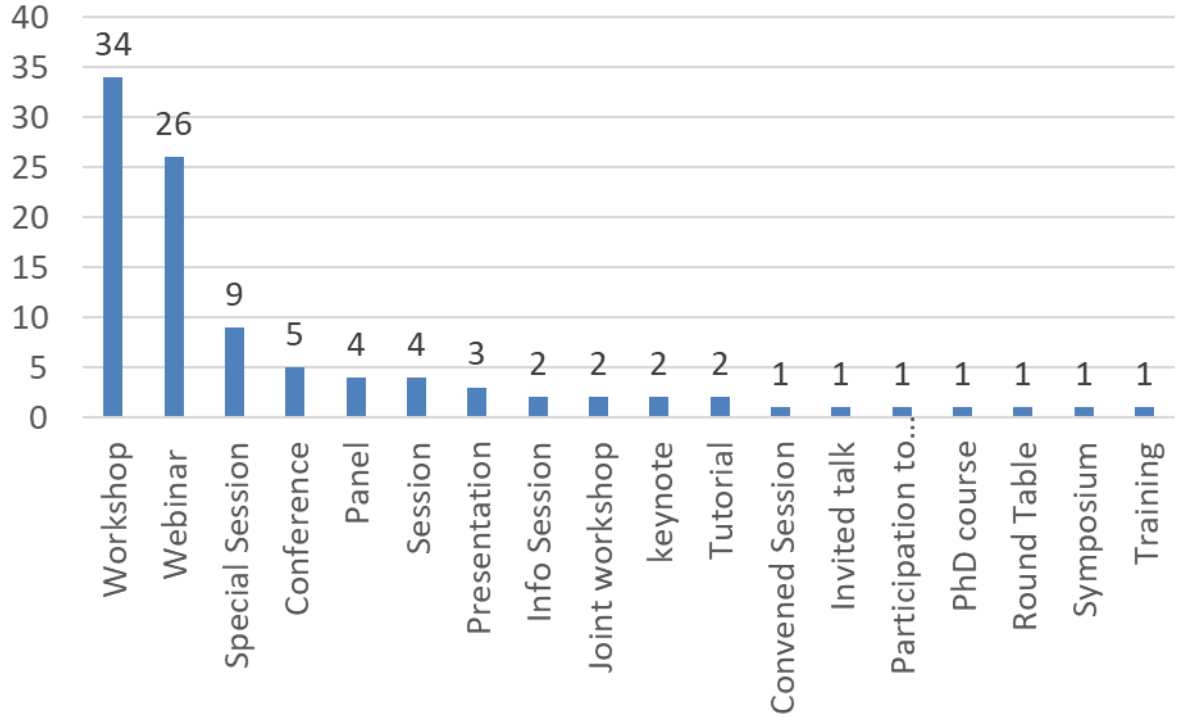

Figure 48: Type of events organized by Call 1 projects in 2023

Question 2: How many events (webinars, workshops, sessions, panels, keynotes), NOT organized by your project, has your project supported/contributed to?

This question targeted the number of 3rd party events featuring the contribution of SNS JU projects. The total number of events supported or contributed by Call 1 projects were 314 (Figure 49). Stream B was the leading stream with supporting /contributing to 189 events. This was followed by Stream D (45), Stream A (34), Stream C (23) and CSA projects (23).

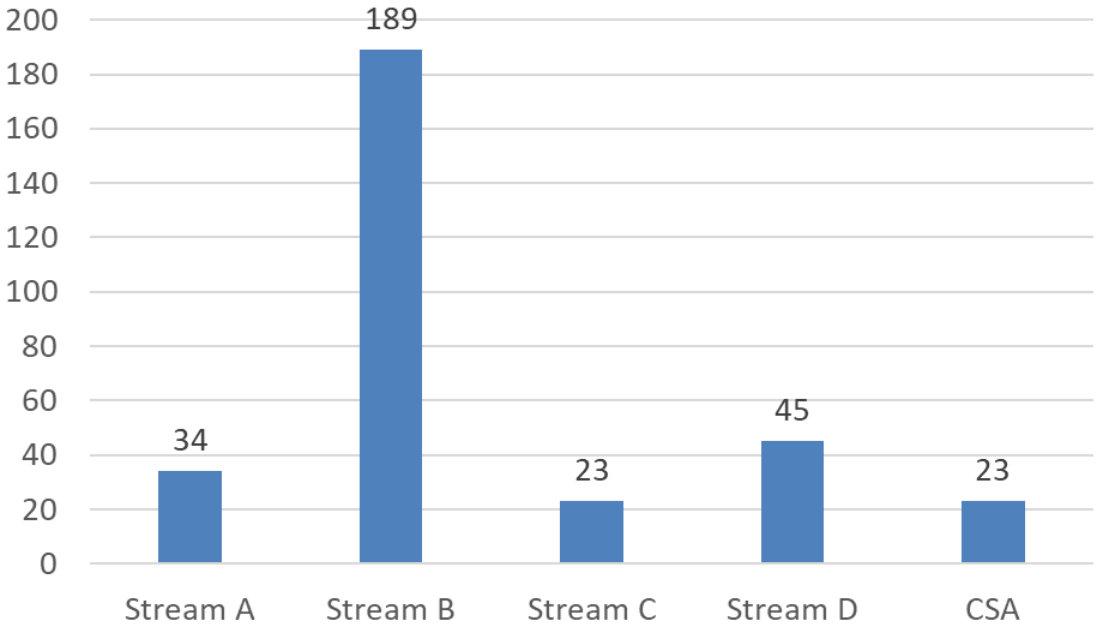

Figure 49: Number of events that Call 1 projects supported / contributed within 2023

Zooming-in into the type of events supported/contributed (Figure 50), the majority of the events are conferences (70), followed by Workshops (49) and Panels (33).

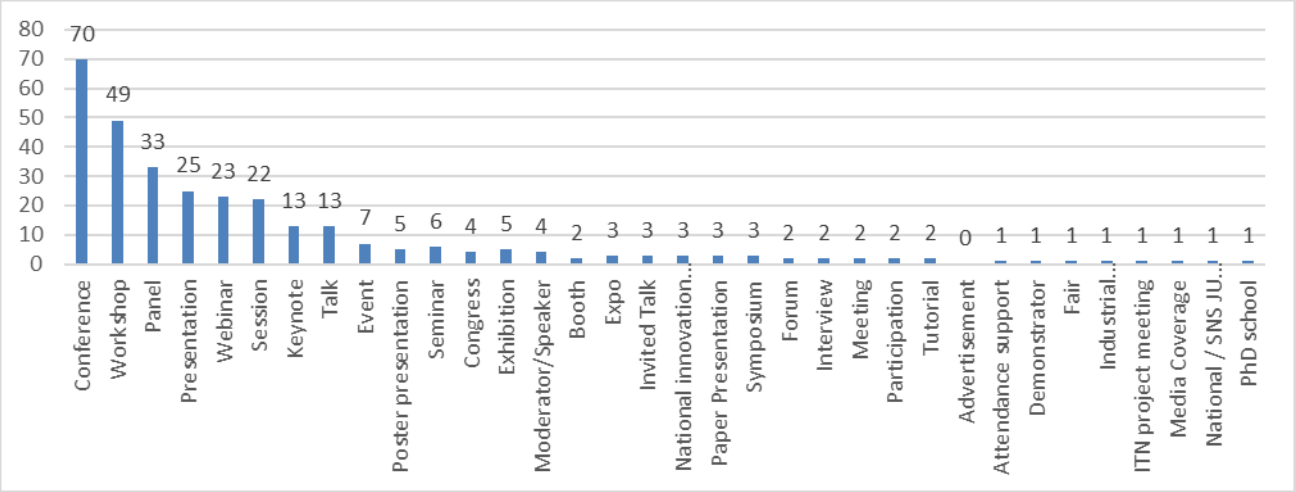

Figure 50: Type of events supported / contributed by Call 1 projects in 2023

Question 3: How many peer-reviewed journal/magazine articles has your project authored?

This question aimed to capture the peer-reviewed journal/magazine articles authored by Call 1 projects. These also included publications resulting from collaborations among SNS projects and/or as the outcome of SNS SB, TB or WG activities, resulting in an achieved technological consensus solution.

As depicted in Figure 51, the total authored peer-reviewed journal/magazine articles from Call 1 projects were 129. Stream B is the leading stream with authoring to 93 peer-reviewed journal/magazine articles. This is followed by Stream A (25), Stream C (6) and Stream D (5).

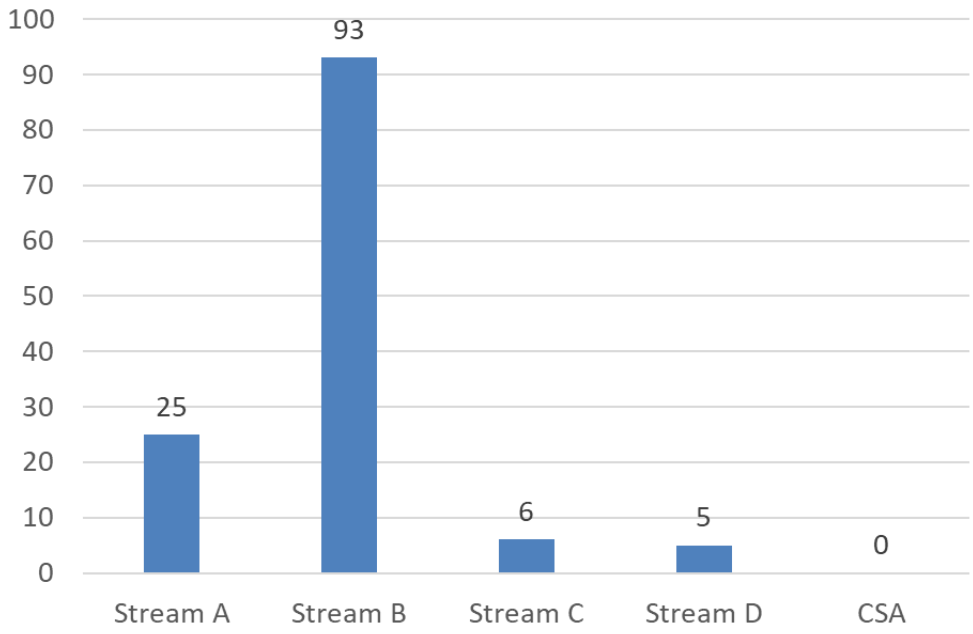

Figure 51: Number of peer-reviewed journal/magazine articles.

Question 4: How many conference papers has your project authored?

The purpose of this question was to capture the number of Conference Papers published by Call 1 projects during 2023. As depicted in Figure 52, the total number of conference papers authored by Call

1 projects during 2023 is 230. Stream B was the leading Stream with 146 authored conference papers followed by Stream A (51), Stream, C (15) and Stream D (8).

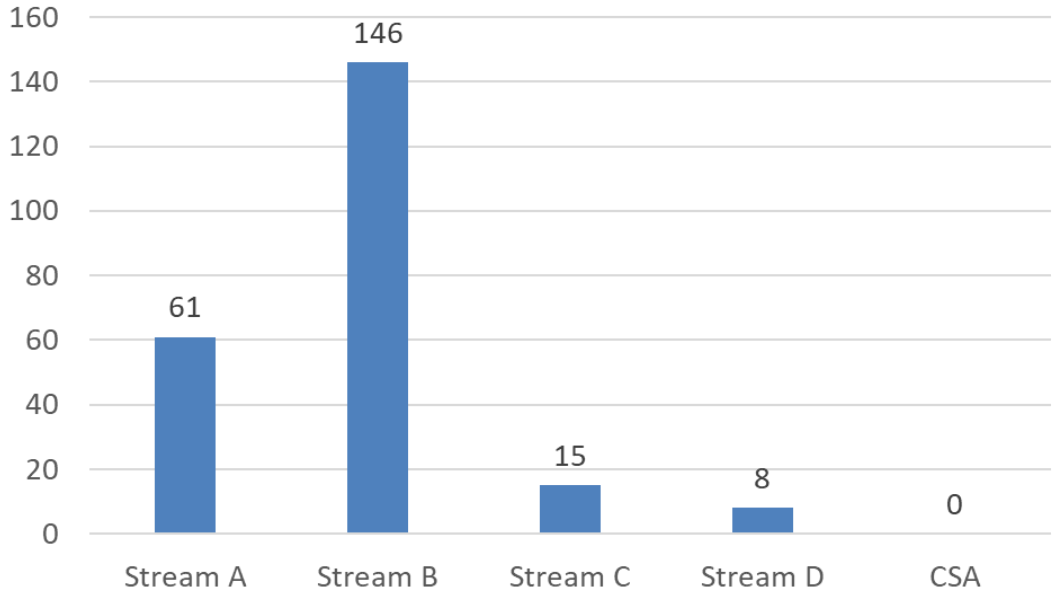

Figure 52: Conference papers that Call 1 projects authored within 2023

Question 5: How many book chapters has your project authored or contributed to?

Based on the responses in this question, the total number of book chapters authored or contributed by Call 1 projects was 2, all coming from Stream A projects. More specifically the following two book chapters have been authored:

1) TinyML for Edge Intelligence in IoT and LPWAN Networks - Embedded Intelligence in Internet of Things Scenarios: TinyML Meets eBPF [2].
2) Resource Management for Cloud Computing - eBPF and XDP Technologies as Enablers for Ultra-Fast and Programmable Next-Gen Network Infrastructures [3].

Given the early stage of SNS JU projects in 2023 (merely their first year in operation), the low number of book chapters authored within 2023, is not a surprise and this metric is expected to increase as the project work matures.

Question 6: How many whitepapers has your project authored or contributed to?

Figure 53 depicts the total number of whitepapers featuring Call 1 projects either as authors or contributors, which were 14 in total. Stream A and B projects contributed or authored 4 whitepapers each. This is followed by Stream D (3), Stream C (2) and CSA (1) projects.

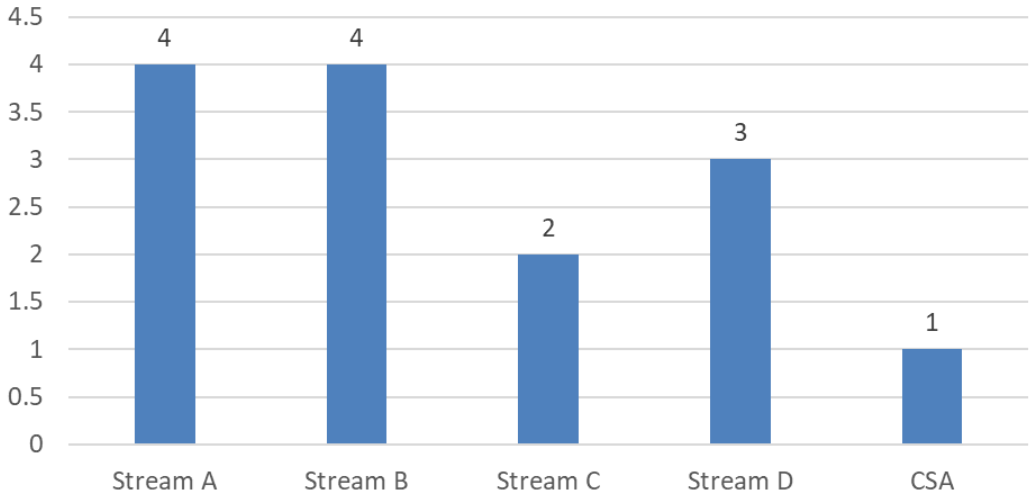

Figure 53: Whitepapers that Call 1 projects authored or contributed to within 2023

Question 7: How many contributions to standards organizations have been submitted by project partners, stemming directly from project related activities?

With this question, Call 1 projects were asked to provide their contributions to standards organisations stemming directly from project related activities. As depicted in Figure 54, the total contributions to standards organisations from the projects were 308. Stream B has the most contributions to standards with 219 contributions, followed by Stream D (45), Stream C (28) and Stream A (16).

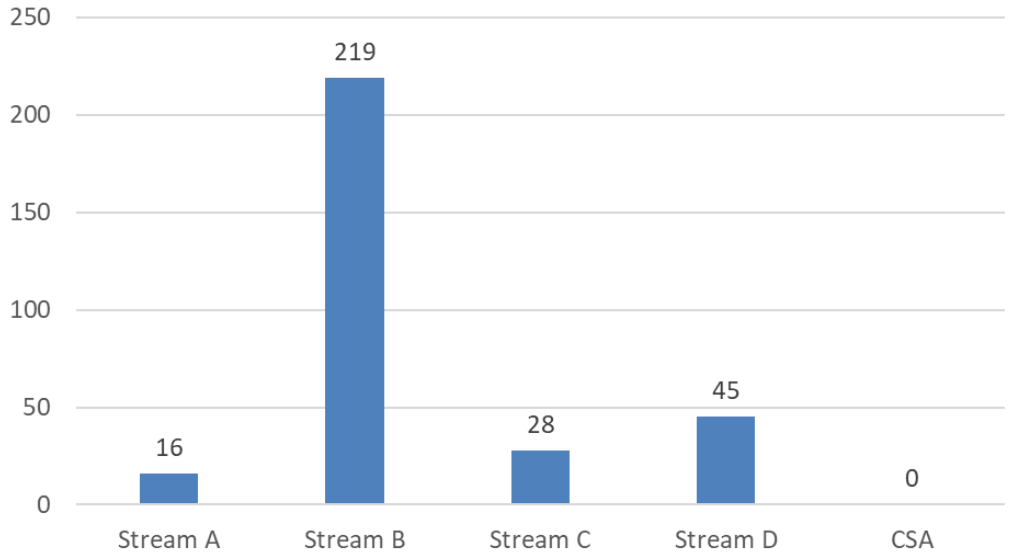

Figure 54: Contributions to standards organizations bodies by Call 1 projects in 2023

Figure 55 showcases the top 10 ranked standardisation bodies / groups that Call 1 projects have contributed to: The highest-ranking standards bodies is 3GPP SA5 (74), followed by 3GPP SA3 (25), 3GPP SA2 (21), 3GPP RAN2 (16), IETF (13), IETF Ops Area (11), ITU/SG12 meeting (10), ETSI ZSM (9), ETSI (9), 3GPP SA1 (6).

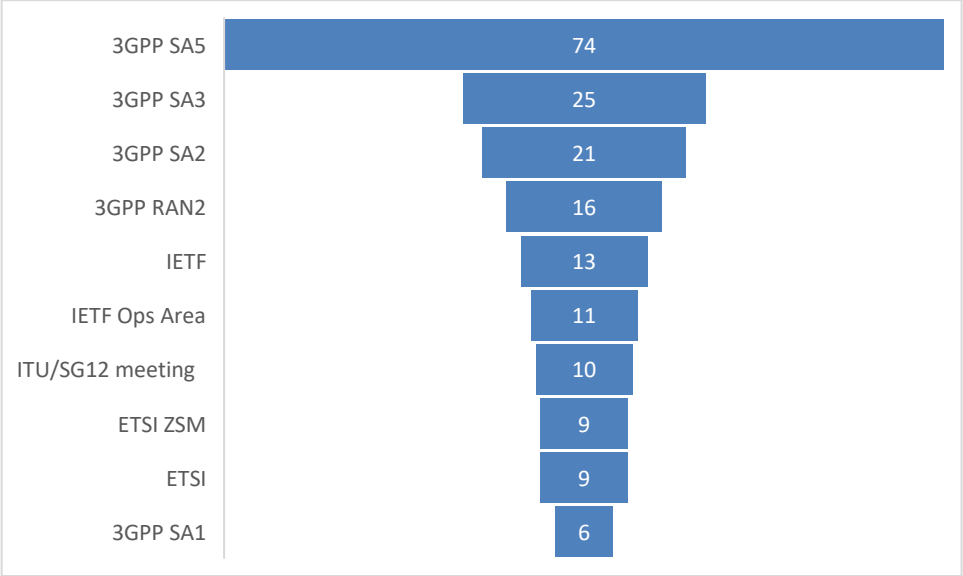

Figure 55: Top 10 standards organizations bodies that Call 1 projects have contributed in 2023

Question 8: How many IPR (patent) applications, stemming directly from project related activities, have been submitted by project partners?

Figure 56 depicts the total number of Intellectual Property Rights (IPR = patent) applications from Call 1 projects within 2023, which is 32. The majority of the IPR patent applications come from Stream B (31) projects, followed by Stream A (1). Stream C and D did not submit any IPR applications, as they focus mostly on experimentation, rather than technology development.

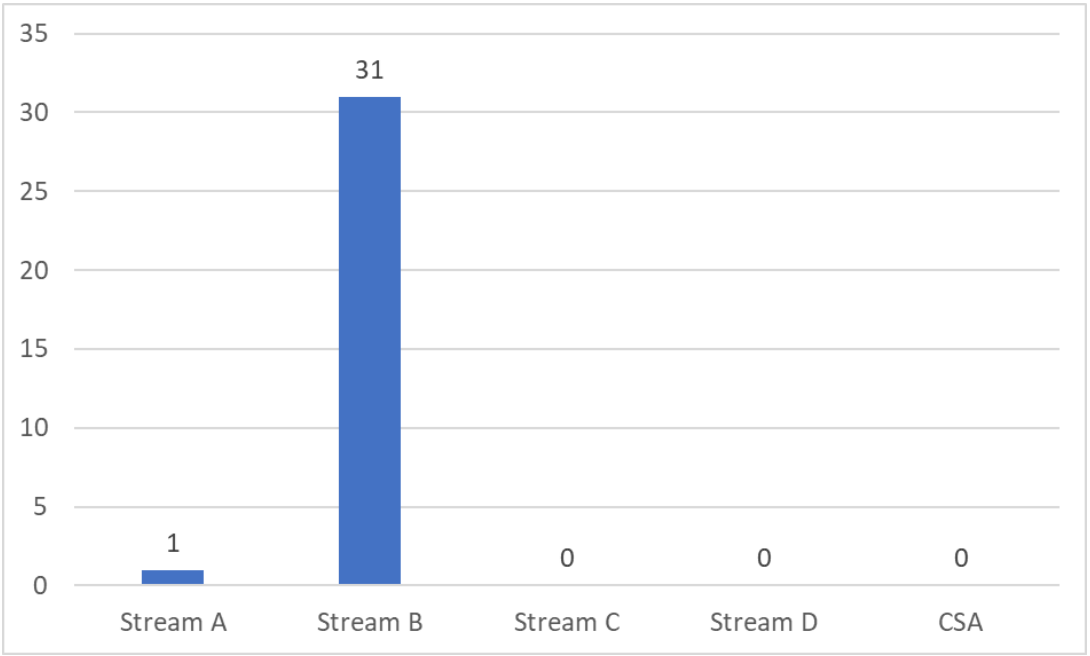

Figure 56: Call 1 projects IPR applications within 2023

Question 9: How many Proof of Concepts (PoCs) (TRL3) and/or Lab Tests (TRL4) has your project executed?

Figure 57 provides the analysis of Proof of concepts in 2023 within the SNS JU, by Call 1 projects. In total, 46 Proof of Concepts (PoCs) (TRL3) and/or Lab Tests (TRL4) have been executed. Stream D is the highest contributor to Proof of Concepts (PoCs) (TRL3) and/or Lab Tests (TRL4) with 33 entries, followed by Stream B (11) and Stream A (2).

In several cases, projects commented remarking that activities are still ongoing activity for their projects.

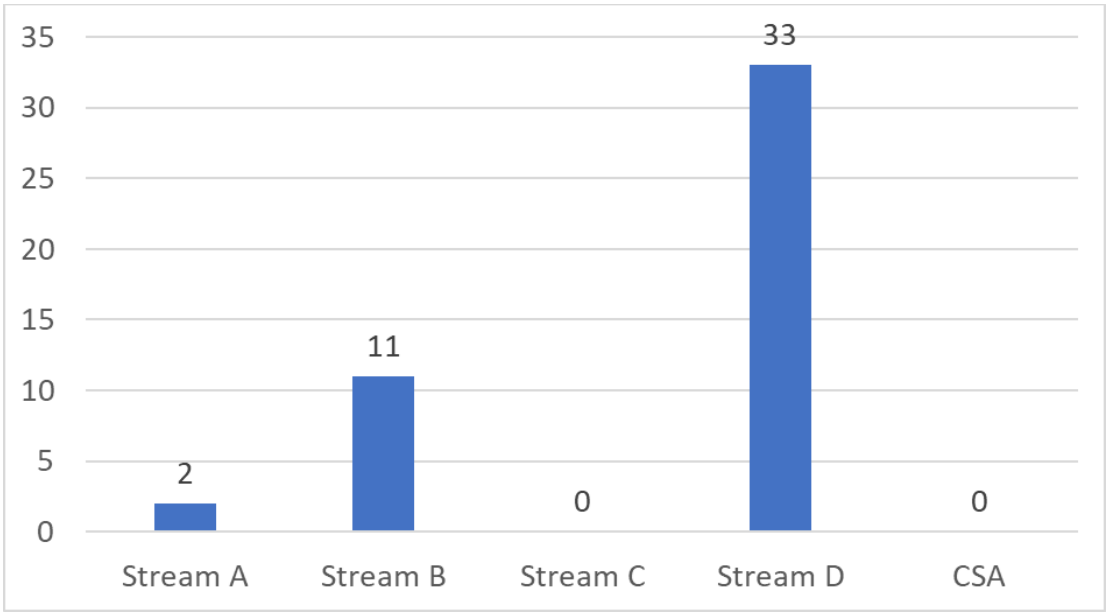

Figure 57: Call 1 projects PoC/Lab Tests execution in 2023

Question 10: How many Trials (TRL5/6) or Pilots (TRL7) has your project executed?

Figure 58 provides the analysis of Trials and/or Pilots in 2023 within the SNS JU, by Call 1 projects. Overall, Call 1 projects have executed 25 trials and pilots in total. Stream D has executed the highest number of trials and pilots with 13, followed by Stream C (10), and Stream B (2).

Projects that have commented mostly mentioned that this is an early phase for their project to execute trials and pilots.

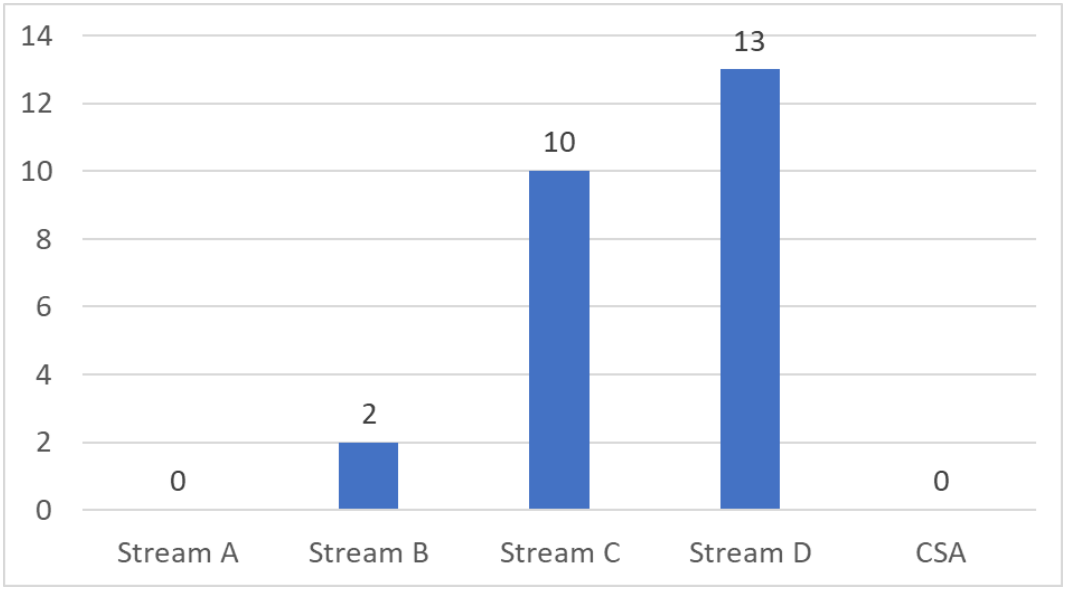

Figure 58: Call 1 projects trials / pilots execution in 2023

Question 11: How many open-source solutions has you project made use of?

Figure 59 depicts the use of open source-solutions in 2023 by Call 1 projects. In total, Call 1 projects have used 132 open-source solutions. Stream B has the highest open-source solution usage with 52. This is followed by Stream D (33), Stream C (27), Stream A (20).

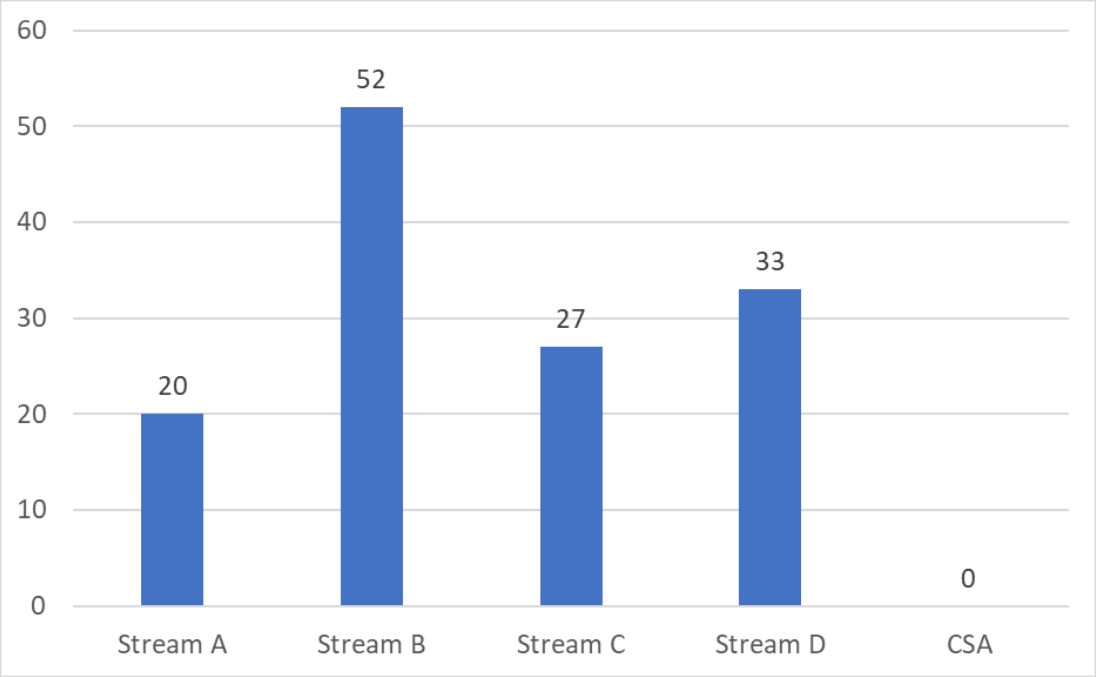

Figure 59: Open-source solutions distribution – Usage within Call 1 projects per Stream, in 2023.

Investigating the top ranked open source solutions that Call 1 projects have made use of (Figure 60), Open5GS is ranked first (8), followed by Kubernetes (4), OpenSlice (3), Prometheus (3), Openstack (3), ELCM (2), FexRIC (2), Free5GC (2), Sionna (2), srsRAN (2), Docker (2), UERANSIM (2).

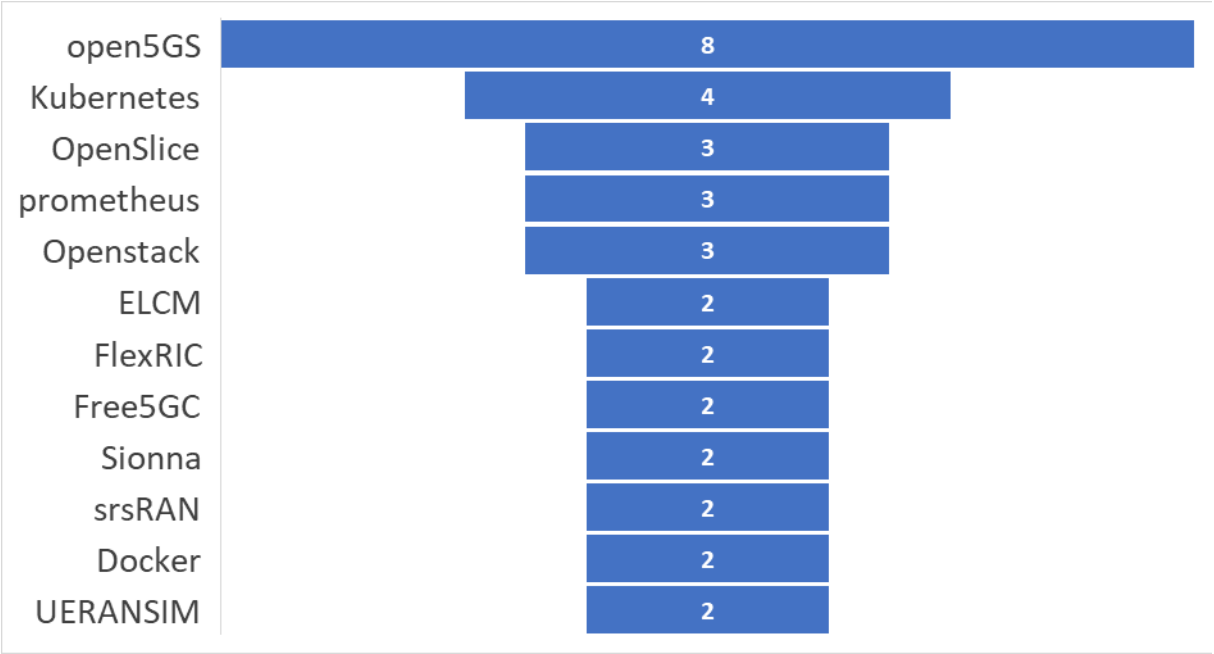

Figure 60: Open-source solutions that Call 1 projects used in their projects, in 2023

Question 12: How many open-source contributions has your project generated & submitted and how many were accepted in the relevant communities?

Figure 61 depicts the number of contributions to open-source organizations by Call 1 projects. In total, Call 1 projects have submitted 29 open-source contributions and 23 of them have been accepted. Most open-source contributions came from Stream B with 14 contributions (10 accepted). Stream A submitted 7 open-source contributions (5 of them were accepted), while Stream C and D have the same submission and approval number, both with 4 submissions of open-source contributions, all of which were

approved.

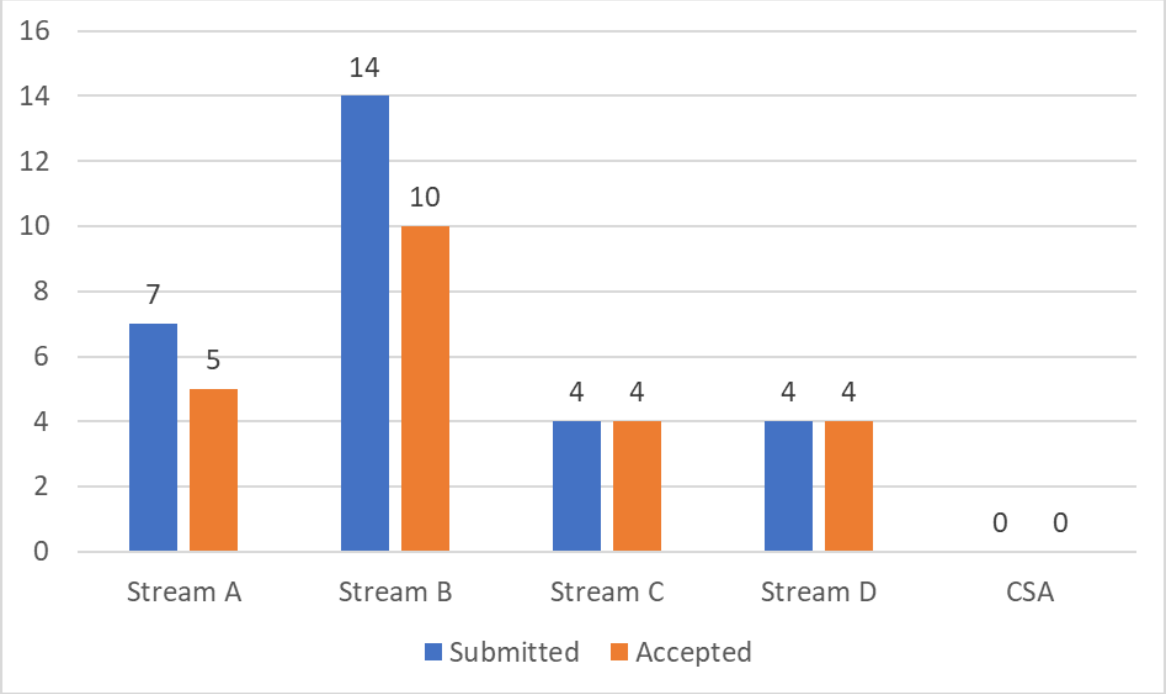

Figure 61: Call 1 projects open-source contributions submission and their acceptance rates within 2023

Question 13: Has your project experimented with Energy Efficiency (EE) solutions?

Only 5 projects have experimented with energy efficiency solutions from Call 1within 2023. As depicted in Figure 62, 26 Call 1 projects' experiments do not explore energy efficiency solutions. Some projects commented that they are currently running simulation studies, which will later result in additional EE solutions. In other instances, they declared that measurements are pending or are expected in period 2 of the project.

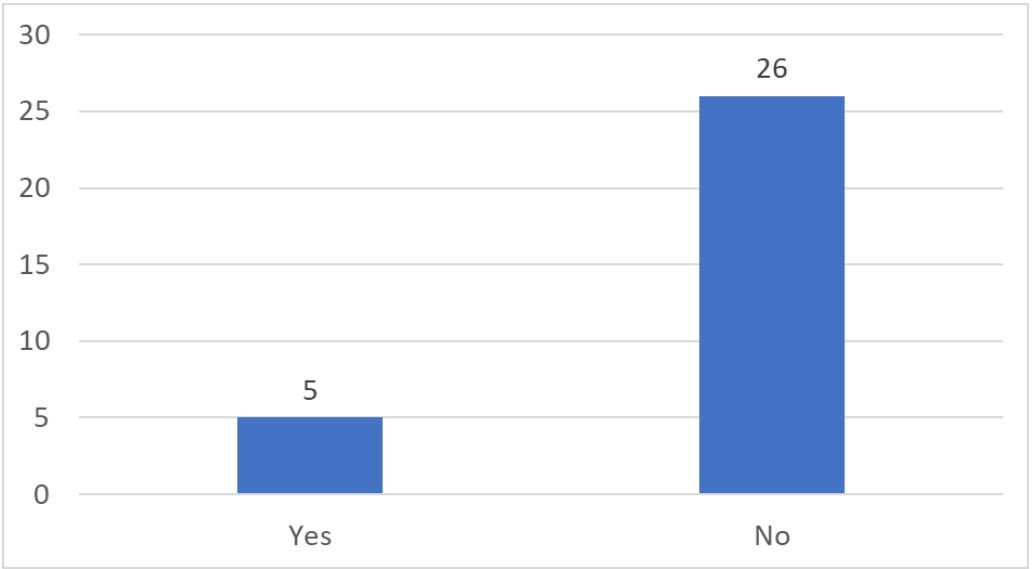

Figure 62: Call 1 projects that have experimented with Energy Efficiency (EE) Solutions in 2023

Question 14: High-risk research: 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?

In terms of High-Risk Research experiments, outcomes were grouped to increase risk range visibility,

according to the metrics below, representing risk ratios in terms of budget share:

- % 0 - %,25
- %,25 - %,50
- %,50 - %, 75
- %, 75 - %, 100

As showcased in Table 2 below, the highest number of projects (7) are running high-risk research using between 0 and 25% of their budget. These are followed by 4 projects that are running high-risk research between %25 - %50 and 4 other high-risk projects %50 - %75. No project is currently running high risk research project between %75 - %100.

Table 2: Call 1 projects and their High-Risk research within 2023.

Risk % in Terms of Budget Share	Project Number	Risk Topics
%0 - %25	7 Projects	Human-machine interfaces, quantum architecture, RF power transfer, zero-crossing modulation, enhancing radio protocols, mobility, intent-based management, security, intelligent radio design, energy-neutral protocols, defining use cases, requirements, and architectures for RIS and THz systems, developing cross-layer algorithms, energy-efficient network architectures, and security solutions.
%25 - %50	4 Projects	AI-driven management and orchestration frameworks, scalable and secure data sharing, energy-efficient AI models, network control frameworks, and the development of new transceivers, network protocols, security frameworks, and hybrid RAN/Core functions.
%50 - %75	4 Projects	Novel hardware solutions for ultra-high capacities with ultra-low power consumption, 6G architectures, wireless transmission, time synchronization, edge cloud solutions, and security-by-design, sub-THz systems, ultra-short transmissions, and RIS enhancements.
%75 - %100	0 Projects	

Finally, a question was asked to the projects to understand their largest pain points during their first year of operation, and to investigate whether they were able to resolve them.

Question 15: What obstacles/ challenges did you face during your first year of operation? Were you able to overcome/resolve them?

To properly organise the received answers in this question, two groups have been defined: 1) Managerial obstacles/challenges 2) Technical obstacles/challenges.

Managerial obstacles/ challenges

These obstacles mostly refer to admin and managerial challenges that some projects faced, without however receiving a large amount of such input, meaning that most projects were able to navigate these challenges. Some characteristic examples are:

- Human resource recruitment. Difficult to find qualified engineers in the B5G/6G and ethics expert in research area.
- Change in the Technical Management of the project.
- Delays in deliverable completion due to internal discussions.
- The management and organization of the first Open Calls for Stream D project.

- Since UK was not associated at the time, and they needed to apply for their government funding, this situation created some delays in certain activities.

Technical obstacles/ challenges:

These obstacles refer to specific technical difficulties that some projects faced, however they seem very specific in nature, and do not apply generally to all projects. According to feedback, most of these challenges were able to be resolved. Some characteristic examples are:

- Quantum-safe cryptographic algorithms have particular requirements in terms of computing and storage resources, as well as timing constraints.
- The integration of the various project components requires the identification of common interfaces and integration points.
- The applicability of some AI models in other environments/testbeds is limited.
- Achievement of high accuracy in modelling the Blockchain interactions through Markov chain approaches.
- Identification of the appropriate semantic communication techniques that fit in the scope of the project.
- Definition of the quantum key distribution simulator aspects to achieve high precision.
- Achieving good performance in terms of throughput for the in-lab 5G testbed.
- The complexity of the Photonic Integrated Chips implementing the transmitter are receiver modules.
- Subsystem fabrications issues/delays.
- Meaningful datasets for AI use, to be later openly published.
- Lack of hardware implementing baseline approaches.
- The novel concepts with sub-THz over PMF and dual frequency ¨tandem¨ approach, where many basic questions were essentially still open at the beginning of the project.
- The co-design of the communication system and transmission approach with innovative HW does create extra complications as they need to progress in parallel with inter-dependencies, and multiple technological disciplines need to establish models to ensure progress at different abstraction levels and find a common language.

2.5 KVIs Landscape in SNS

For 6G systems, any assessments of technology development and use must be expanded with Key Values (KVs) from environmental, social, and economic domains. KVs specify high-level human and planetary goals, e.g., the UN SDGs[9], for 6G use cases and technologies. Positive and negative impacts are assessed on aspects such as energy and material consumption, human safety and availability, social exclusion or inclusion, and innovation opportunities.

KVs and their indicators, Key Value Indicators (KVIs), play a crucial role in shaping and monitoring the vision and objectives of the SNS 6G initiative. KVIs encompass a broader perspective by aligning technological advancements with societal, economic, and environmental priorities. In the context of 6G, KVIs emphasize goals such as energy efficiency, digital inclusion, enhanced user experience, and economic impact. This requires projects to anticipate and articulate how both realistically and practically 6G can create positive impact at several levels.

Europe, through the innovative work taking place within the SNS JU, is spearheading the effort to establish KVs and KVIs, as integral components of the 6G system, to be part of any discussion on 6G

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

alongside KPIs and other requirements. This section summarises the different initiatives working on KVs and KVIs within the SNS JU ecosystem and their current status.

Efforts to build a consensus around KV and KVIs are ongoing within the 6G-IA Societal Needs and Value Creation (SNVC) Sub-Group, the SNS Test, Measurement and Validation (TMV) sub-Working Group on KVIs, and specific initiatives from the Hexa-X-II (WP1) and the 6G4Society projects.

Benefitting from this work, SNS projects have engaged with KVIs. Projects started to define KVIs, evaluate them, and act based on the results. Most projects are still in the assessment phase, meaning they lack sufficient evidence that their KVI measurements are both effective and accurate in showing the intended impact.

The approaches to address KVIs vary widely across SNS projects. This is highlighted in the 6G4Society D1.1 "Societal aspects in 6G Technology" [4]. Some projects draw on Global SDGs as a starting place, many start from the list of undefined values in the 5G PPP, others try to analyse and mimic what was done in other projects. Other projects have launched in-depth research as to 6G strategy and sustainability policy. Others assess impact areas to consider what a vertical might prioritise as impacts. Some projects struggle with where to focus due to a lack of use cases or stakeholders. Projects without use cases often work from abstract policy values as a starting place for their KVI analysis.

The benefits of engaging with Key Value Indicators (KVIs) can be summarized as follows:

- Improved Understanding: Projects are gaining a deeper understanding of the importance of KVIs, clarifying why they need to engage with them, and assembling collaborative teams to do so.
- Initial Engagement and Validation: Projects are starting to engage concrete KVIs, with many completing their first round of measurement, assessment, and validation.
- Exploration of Formats and Measures: Projects are testing a variety of formats and measurement methods for KVIs, laying a strong foundation for future KVI development. These include KVIs as KPIs, enablers, or subjective expert opinions.
- Clarification of Assumptions: There's a growing awareness of the differences in assumptions about KVIs—such as their goals and target audiences—and the values they prioritize. This is sparking crucial discussions that will help establish a consensus-based framework.
- Proactive Engagement with Social Value: The necessity of engaging with KVIs is prompting projects to be more proactive in considering social value and sustainability.
- Diverse KVI Coverage: Projects are addressing a broad range of Key Values and KVIs, even if some values are only addressed by one or two projects.
- Opportunity Beyond Technical Design: There's an increasing realization that KVIs offer opportunities to rethink not only technical design choices but also business priorities and use case definitions.

However, projects are still facing challenges in engaging with KVIs:

- Notably, projects highlight significant obstacles among which: measuring KVIs, too theoretical KVIs - and then less effective, particularly for projects with lower technology readiness levels (TRLs) or mapping KVIs to Key Performance Indicators (KPIs), difficulty in bridging the gap between theoretical aspirations and practical application, difficulty in prioritising KVIs.
- Another key challenge not otherwise noted is that de-centralised nature of much KVI work, with different actors taking on different components of the KVI puzzle, each working hard to further the initiative.

Work is focusing on KVIs as tools fostering responsible and ethical innovation by aligning technological progress with societal needs, improving public acceptance of 6G, and guiding developers to focus on societal impacts.

Societal Needs and Value Creation (SNVC) group initiatives

The Societal Needs and Value Creation (SNVC) subgroup of the Vision work group of the 6G-IA was formed to fuse knowledge and experience from EU funded research projects from external experts and from the ICT industry. SNVC method of work is based on long-lasting multilateral conversations and iterations between the participants representing the ICT ecosystem.

The 6G-IA SNVC Group focused on the concept of KVIs [5] as a method for analysing the values-related outcomes stemming from ICT developments. It also developed a structured framework tailored to the ICT research and development sector. This framework is aimed to be a tool for research projects to address social challenges in technology design and development phases and to identify and estimate value outcomes from technology use. It also aims at assisting policy makers to establish value-related targets and set requirements and conditions for ICT developments.

The framework comprises five steps, starting from the use-case related identification of values to the assessment of value outcomes. The analysis starts from the Key Values (KVs). The analysis of those KVs results in the formulation and selection of KVI metrics, reflecting a top-down approach in the value selection.

Test Measurement and Validation (TMV) WG initiatives

The TMV Working Group (WG) is one of the four SNS JU WGs, focusing on fostering commonalities among SNS projects with a strong interest in the development of test and measurement methods, test cases, procedures, and the formalization and validation of KPIs and KVIs. The TMV WG actively engages with SNS projects, promoting the adoption of common KPIs and KVIs across the program. As part of its activities, the TMV WG has formed a dedicated subgroup that focuses specifically on estimation and validation methodologies for KVIs. The sub-group is currently conducting a survey on KVIs, reaching out to SNS projects to gather insights into the key values they prioritize, examples illustrating these values, and their relevance to ongoing work. The survey received responses from eleven projects, providing an initial overview of various KVs identified. To analyse these findings, the collected data was compared with KVs defined by Hexa-X-II and the 6G-IA, referencing three comprehensive lists of KVs.

The top four KVs identified so far are Societal Sustainability, Environmental Sustainability, Economic Sustainability, and Trustworthiness. The survey also highlights that KVIs are broadly inclusive, covering most verticals, thereby demonstrating their potential to comprehensively address diverse societal and industrial needs.

5G PPP Hexa-X and SNS Hexa-X-II WP1 approaches on use cases

The 5G PPP Hexa-X and SNS Hexa-X-II projects are the European flagships for 6G research and development. Hexa-X introduced the concept of KVIs in 2021 (Hexa-X D1.2 [6]) as part of the WP1.

Hexa-X-II further iterated the sustainability aspects of 6G technologies and use cases emphasizing the social, economic and environmental domains. The WP1 team undertook a challenging initiative to transform the complex and multifaceted process of defining KVs and KVIs into a practical, step-by-step methodology that can be effectively implemented within the time constraints of research projects. This effort was complementary to the framework established by the SNVC WG.

The methodology for end-to-end systematization in Hexa-X-II emphasizes 6G use cases and associated Human and Planetary goals. 6G use cases are described and a sustainability analysis is carried out identifying KVs, both positive and negative impact (also denoted handprints and footprints) [7][8]. The Hexa-X-II 6G use cases and associated positive and negative KV impact is documented in [8]. For the 6G use case specific KVs, indicators must be identified, i.e., use case KVIs. In addition, the methodology and analysis lead to 6G enabler KVIs. A 6G use case KVI is a qualitative or quantitative indicator used to assess a KV impact of a use case. A 6G enabler KVI is a qualitative or quantitative indicator to assess the KV impact of the technical enabler, i.e., the technology applied to the 6G use case. A 6G enabler KVI may or may not be mapped to existing or new KPIs. The purpose of KVI is to gauge the impact from the execution of a use case in terms of social, economic and environmental outcomes[6][7][8] for these definitions of KVIs).

In Deliverable D1.3 [8], Hexa-X-II laid the groundwork for ensuring social acceptance of 6G and provided an analysis of the challenges and risks involved in achieving environmental, social, and

economic sustainability for 6G technologies, networks, and solutions. The Hexa-X-II representative 6G use cases were studied in detail to identify challenges that must be addressed to deliver handprints while minimizing footprints. The deliverable also identified potential risks associated with these challenges, which, if not addressed properly, could hinder the evolvement of 6G and its solutions, and not the least, disturb KV handprints or fuel footprints.

6G4Society work on KVIs

The 6G4Society project is actively working to ensure that societal, environmental, and economic values are deeply integrated into the design, development, and adoption of 6G technology, bringing a strong sustainability perspective to technological advancements. A key expected outcome of the project is the development of sustainability indicators, building upon KVIs for broader public validation and potential downstream exploitation at the regulatory level.

The project's work is centred around three main pillars: adopting a comprehensive approach based on the three dimensions of sustainability, emphasizing the significance of KVIs, and addressing issues of acceptance and acceptability, supported by active public engagement.

The project issued its D1.1 on "Societal Aspects in 6G Technology: Concerns, Acceptance Models, and Sustainability Indicators" [4]. The work on values focused especially on the current effort of SNS projects in incorporating key values into 6G technological development. D1.1 also outlines a set of 10 actions needed to establish the Key Sustainability Indicators (KSIs) framework, which forms a subset of KVIs. Recommendations were made for further clarifying the goals and process by which values are translated into action for 6G, acknowledging the different ways value can be understood and become part of technology, and assessing the current activities within SNS projects working with KVIs. Consistently, the work has produced a guideline for KVs and KSIs.

Key challenges in how to approach KVIs were discussed at the 6G4Society workshop on "Embracing KVs and KVIs: How can SNS projects drive sustainable change?" [10] organised by 6GSociety and FIDAL projects in October 2024. The workshop underscored the need for actionable, context-specific KVI frameworks to bridge the gap between theoretical aspirations and practical application. Based on the results collected during the event, and laid out more in detail in this report, a roadmap was defined with activities that have been designed to address project's concerns and hopes in approaching KVs and KVIs in their work.

Other Projects Initiatives (non-exhaustive list)

Several SNS projects, began presenting key outputs during a webinar held in May 2024 [11]. During this event, six families of use cases and eight barriers to 6G migration were identified, addressing challenges such as network coverage and data exposure.

The concept of KVIs has made significant progress despite different approaches. The identification of KVIs by many SNS projects is currently ongoing. A summary for each project's work on KVIs is provided in Table 3.

Table 3: KVI related work of selected SNS JU projects

Project	KVI related Work
TrialsNet	As part of TrialsNet activities, both KPIs and KVIs are being defined and measured to validate the use cases that will be implemented in the trials [9]. Preliminary measurement activities have been carried out for nearly all use cases, depending on their level of maturity and in various contexts. The collected data will be analysed and evaluated to achieve two objectives: first, to identify potential limitations of current network

[10] https://smart-networks.europa.eu/embracing-key-values-and-key-values-indicators-how-can-sns-projects-drive-sustainable-change-an-interactive-workshop-jointly-organised-by-6g4society-and-fidal/

[11] https://smart-networks.europa.eu/event/sns-stream-b-d-projects-webinar/

	technologies; and second, to assess the level of user acceptance for the proposed applications.
TARGET-X	TARGET-X has developed a standardized use case description accompanied by a catalogue of requirements for all verticals and has identified the societal benefits achievable through these use cases, expressed in terms of KVIs. A total of ten KVIs have been identified. • For the Improvement of Safety-Related Aspects, three KVIs are defined: o Work accident rate in manufacturing, o Work accident rate in construction, and o Absolute number of prevented traffic accidents. • For the Transparency About Ecological Impact, six KVIs are outlined: o Global Warming Potential, o Water consumption, o Ozone depletion, o Photochemical ozone formation, o Depletion of abiotic resources (minerals and metals), and o Depletion of abiotic resources (fossil fuels) • For Digital Inclusion, one KVI is identified: Digital literacy. o Equations will be formulated for each KVI under each goal for every vertical, establishing a unified framework for evaluating all TARGET-X use cases
FIDAL	The FIDAL project has established a well-defined process for identifying KVs and KVIs. The team is actively collaborating with use case stakeholders to determine specific KVs, identify relevant indicators aligned with these KVs, and develop methodologies to effectively measure the identified KVIs.
IMAGINE-B5G	The IMAGINE-B5G project has developed its own methodology for identifying KVs and KVIs. Open call projects in three calls have been invited to suggest and assess KVIs for their use cases. This effort successfully resulted in the identification of 14 platform KVIs, 8 generic KVIs applicable to verticals, and over 31 sector-specific KVIs. The metrics are gathered through a combination of automated collection using facility tools and manual input via forms and questionnaires.
DETERMINISTIC6G	DETERMINISTIC6G leverages on work performed by the TMV and the SNVC Working Groups and also by the Hexa-X-II project. It is currently investigating the usage of KVIs in automated control plane mechanisms. For the Exoskeleton use case in an industrial context, the Key Value identified is personal health and protection from harm. while KVIs are reduction of the costs for the care of work-related injuries and reduction of number work-related injuries.
ORIGAMI	The ORIGAMI project has also addressed the KVs and KVIs by categorizing KVs into two distinct groups: (i) use case-specific and (ii) architectural. Each KVI has been clearly defined and will be systematically

	measured. Performance and progress will be carefully monitored and evaluated to ensure comprehensive insights are obtained.
PRIVATEER	PRIVATEER partners provided a list of KVIs in deliverable D2.1 "6G Threat Landscape and Gap Analysis" [10] and included relevant references and indicative values for each specific use case and system requirements.
SAFE-6G	Based on an analysis of key documents released by the TMV and SNVC Working Groups, the SAFE-6G project developed an Excel file consolidating all KPIs and KVIs, along with target values for certain ICT projects. Additionally, the project created reference templates for both KPIs and KVIs in alignment with the specifications outlined by the working groups. SAFE-6G places particular emphasis on the Level of Trust (LoT) KVI. Unlike static metrics, the LoT reflects the dynamic interplay between the KPIs of SAFE-6G's core functions, which are designed to adapt to the evolving needs and trust requirements of network users. The LoT as a KVI is closely tied to the performance of the framework's five core functions: safety, security, privacy, resilience, and reliability. These functions are orchestrated using advanced (X)AI/ML techniques, ensuring a user-centric approach to fostering trustworthiness in 6G networks.

3 Monitoring & Analysis Framework Updates 2025

One of the objectives of SNS OPS project is monitoring, evaluation and reporting on the progress of the SNS JU projects and the "Monitoring and Analysis Framework" constitutes one of the main pillars to accomplish this objective. This framework is intended to be used during SNS OPS lifetime and beyond (by follow-up CSA projects), so that a consistent record of SNS JU results can be obtained, offering tracking and comparability. The SNS Questionnaire is circulated in annual editions, which are updated and upgraded based on lessons learned every year. This section provides an explanation and the motivation behind the updates for the 2025 edition.

As part of its structure, SNS JU announces new calls since its establishment and this approach will continue until the closure of the programme. The timeline of current SNS JU projects is shown below. As of December 2024, Call 1 and Call 2 projects (63 projects in total) are active, while an additional 16 projects from call 3 contractually started in January 2025.

- SNS Call 1 - 35 Projects, started January 2023.
- SNS Call 2 - 28 Projects, started January 2024.
- SNS Call 3 - 16 Projects, started January 2025.

As new R&I projects join the SNS JU family on an annual basis, targeting different technologies and approaching solutions at different maturity levels (as the SNS JU progresses in its next calls), it becomes critical to adapt the questionnaire every year, to reflect the contemporary focus of research and to ensure that all achievements of older and newer projects are properly documented. In order to monitor and analyse the improvements in those projects, an approach with two separate questionnaires has been devised.

1. A questionnaire for newly started projects: Contains questions that are targeting the new projects starting every year covering technology, vision and marketing related aspects, and mostly addressing intentions (as the projects are barely starting, so there are no accomplishments to show for).
2. A questionnaire for ongoing projects: Contains questions regarding SNS JU programme level KPIs such as events the projects organized, publications, contributions to standards / IPRs / Open-source and their Trials / Pilots and regards actual accomplishments of the projects during the past calendar year.

Since the establishment of the framework, it has been decided that the input from the projects will be captured and collected periodically for the progress reporting. The first questionnaire was sent out to all Call 1 projects in 2023 as an excel file attachment via email. In the following year (2nd edition of the questionnaire) an online tool was implemented to facilitate data collection and post-processing in a more professional manner.

According to previous years' experience, SNS-OPS made some improvements in the 2025 edition of the questionnaire to increase the efficiency of the results achieved and also to lower the effort necessary by project managers to respond. The main changes implemented compared to previous questionnaire versions can be summarize below:

1. The reduction and merging of questions to facilitate the project representatives and lower the effort threshold necessary to complete the questionnaire.
2. The alignment with the EC portal formatting for the ongoing questionnaire, to minimize duplication of effort from project representatives.
3. The alignment with 6G4Society experts, to better formulate KVI relevant questions.
4. The updates on the online implementation to allow for better user interaction (e.g., ability to download the questionnaire in pdf format, sending a copy of responses to SNS OPS questionnaire drivers) and to facilitate post-processing.

This online questionnaire is updated and upgraded on an annual basis, to reflect the focus of the newly starting projects (according to the annual SNS JU WP) as well as to implement updates based on lessons learned from previous editions of the questionnaire.

Before the questionnaire is sent out to the projects, this information is provided to the SNS Steering Board (SB), Technology Board (TB) and Working Groups (WGs), to assist with project results tracking and grouping of relevant projects (according to interest).

The results of the questionnaires are always shared with the entire SNS community, and the key findings and insights presented in a dedicated open webinar. This input is crucial for the SNS programme and for its future management and success. The previous webinars and the relevant material providing the analysis and insights from the previous editions of the questionnaire can be found via the SNS JU Website:

- [2023 Edition] SNS-OPS Survey Results on Technical, Vision and Market aspects of Call 1 SNS Projects[12].
- [2024 Edition] SNS-OPS Questionnaire Results of Call 1 & 2 SNS Projects 2024[13].

[12] https://smart-networks.europa.eu/event/sns-ops-survey-webinar/

[13] https://smart-networks.europa.eu/event/sns-ops-questionnaire-results-webinar/

4 Building 6G SNS Momentum

This section discussed how the input received from the projects as well as insights from activities of the private side (6G-IA WGs, etc.) and common actions with other projects are used to analyse the current status of the SNS JU, build additional momentum and awareness for the activities of the SNS JU researchers and drive the development of the follow-up SNS JU Work Programmes.

4.1 Call 2 (2023) Gap Analysis

The Gap Analysis within the SNS OPS project plays a crucial role in aligning the goals, technologies, and verticals addressed by selected SNS projects with the high-level objectives set by the European Commission (EC) and the SNS JU. This process aggregates inputs from diverse sources, including the SNS OPS framework, CSA projects like SNS ICE, 6G-IA members, and NetworldEurope SRIA 2024. These inputs enable a detailed comparison of the projects' progress and focus areas against the broader strategy, ensuring adherence to the EC and SNS JU roadmap. The Gap Analysis also considers global developments in 6G standardization, regulatory policies, and technological trends, facilitating timely adjustments to keep the EU competitive in the global research and innovation ecosystem. A detailed definition of the gap analysis was provided in deliverable D1.2 [11], along with a schematic representation that is repeated in Figure 63, to facilitate the understanding of the reader.

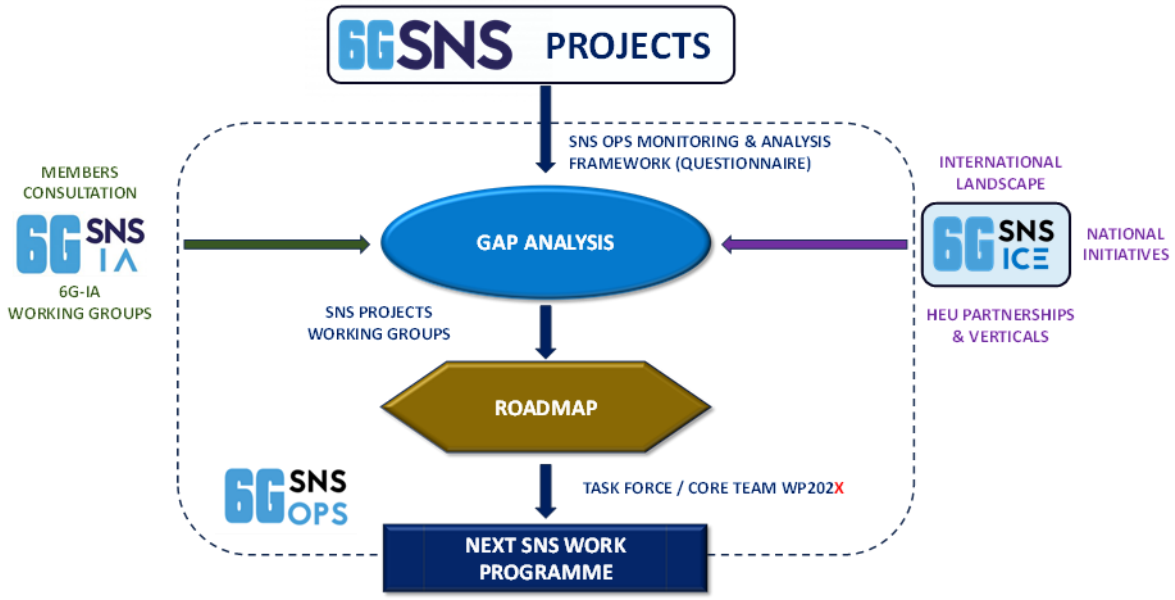

Figure 63: SNS OPS Gap Analysis & Road-mapping process

A key aspect of the Gap Analysis is its reliance on the SNS OPS Monitoring and Reporting framework, which collects data through standardized tools like the SNS OPS questionnaire. Insights gained from this process include detailed information on technologies, use cases, enablers, KPIs, and network aspects addressed by ongoing projects. These insights, combined with the targeted outcomes of Call 2 projects and global 6G R&I updates, are fed into the Task Force/Core Team (TF/CT) responsible for designing the next SNS Work Programme. This iterative feedback loop allows the TF/CT to identify gaps in current strategies, refine future calls, and ensure that the EU remains a leader in critical technological domains.

Based on the analysis of the focus areas of the Call 2 projects presented in section 2, it can be determined that ***all main objectives of the SNS JU R&I Work Programme 2023 are being addressed by the selected projects***. More specifically, the following challenges and objectives are being addressed:

- Reinforced European leadership in 6G technologies: This objective is addressed as multiple and diverse technologies are being developed by the call 2 projects, focusing on network aspects as well as devices and services.
- Disruptive high value applications: This objective is being addressed via the large variety of innovative use cases being addressed by the projects and their evaluation/validation using the standard as well as new tailor-made KPIs.
- Sustainability leadership & green transition: This objective is being addressed via the intense work of the majority of call 2 projects on sustainability aspects (economical, environmental, societal) and the broad coverage of key UN SDGs by the projects, as well as by the contributions towards a sustainability framework and the efforts to define and further develop suitable Key Value Indicators (KVIs) for each Use Case.
- Advancements in Micro-electronics: The cooperation with Key Digital Technologies (KDT)/Chips JU and the commission of three call 2 projects focused on developing micro-electronics solutions for telecoms networks, addresses this objective.
- Fostering International Collaboration on 6G & work towards a single 6G standard: The commission of the first international collaboration SNS JU project (EU - US) and the significant weight that call 2 projects place on a broad representation in international Standards Developing Organizations (SDOs) and pre-standardization working bodies, indicate that this objective is on track to be achieved.
- Innovative business models: the detailed answers and specific insights shared by projects on the Market section of the SNS OPS questionnaire, indicate that there is a well-thought-out process behind the definition of their use cases, that will lead to the development of innovative business models.
- Validate and reduce the introduction risk of candidate 6G technologies: The commission of additional Stream C and D projects under call 2, with close collaboration with the call 1 projects contributes towards the achievement of this objective.
- Provide Vertical Industries with accessible and Open experimentation platforms and show the applicability of technologies in their sectors: The vast engagement of vertical stakeholders in call 2 projects in various roles (including experimenters via Stream D projects), as well as the active engagement and development of vertical use cases in more than 10 different vertical sectors, indicates that SNS JU stakeholders are on their way of achieving this objective.
- Harmonise the usage of multiple test platforms: The commission of a Stream C project tasked with federating such platforms has covered this objective.
- Validate SNS KPIs (and KVIs) in the context of very advanced digital use cases implemented through Large-Scale Trials and Pilots (LST&P): This objective has been further advanced with the commission of two additional Stream D projects in call 2 targeting specific vertical sectors and extending the experimentation data base with additional T&Ps and experimenters.

The results of the above gap analysis have been taken into account along with the rest of the information and insights shared in this document, for the creation of momentum for the SNS JU and the design of the Work Programme 2024, as explained in the rest of this section.

4.2 NetworldEurope SRIA status overview

4.2.1 Introduction

NetworldEurope (NWE) [12] is the leading institution addressing the challenges posed by the increasing integration of ICT into society. With a diverse network of nearly 1,000 stakeholders (spanning SMEs, large industries, academia, and other key players), NWE seeks to establish a shared vision for the future of a connected Europe. To this end, NWE collaborates with the 6G-IA and maintains strategic partnerships with various European and international organizations, such as the Alliance for AI, IoT and

Edge Continuum Innovation (AIOTI)[14], the Networked European Software and Services Initiative (NESSI)[15], the European Cyber Security Organization (ECSO)[16], and the European Telecommunications Standards Institute (ETSI)[17] amongst others. These collaborations aim to develop a comprehensive Strategic Research and Innovation Agenda (SRIA) for communications and services [13].

4.2.2 Impact of the SRIA

The SRIA's immediate impact is seen in the European research Work Programme of SNS JU [15], a collaboration between the European Commission and the 6G IA. Beyond SNS, the SRIA is expected to influence other European Work Programmes, both at the national level (where numerous European countries are actively funding national 6G initiatives) and at the international level, including Horizon Europe and other Joint Undertakings/Public-Private Partnerships.

As a forward-looking blueprint for the development of communications and services, the NWE SRIA provides a deeply technological vision that can be explored across various dimensions, technological domains, and application areas.

4.2.3 Development Timeline of the NWE SRIA 2024

The update process for the NWE SRIA 2024 was formally initiated during the Visions for Future Communications Summit (VFCS 2023), held in Lisbon on November 7–8, 2023. Figure 64 depicts the agreed timeline for the development of the NEW SRIA documents. Key milestones for the NWE SRIA Technical Annex, include:

- December 1, 2024: Completion of the first version of the NWE SRIA Technical Annex.
- December 20, 2024: Completion of the public consultation.
- February 15, 2025: Final version of the NWE SRIA Technical Annex, incorporating feedback from stakeholders.

The updated Technical Annex will serve as a foundation for developing the NWE SRIA Whitepaper. Key milestones for the NWE SRIA Whitepaper include:

- December 15, 2024: Release of the first draft.
- February 01, 2025: Completion of the public consultation.
- February 28, 2025: Final version of the NWE SRIA Whitepaper, incorporating feedback from stakeholders.

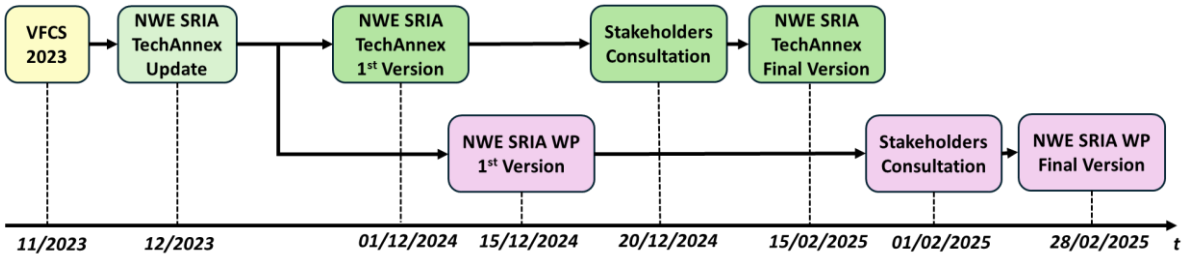

Figure 64: NetworldEurope SRIA 2024 documents being developed

[14] https://aioti.eu/

[15] https://nessi.eu/

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

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

4.2.4 The NWE SRIA Technical Annex and Whitepaper

This sub-section shortly describes the two documents that are being developed according to the timeline in the previous figure. These documents are available on the NetworldEurope Webpage[18].

4.2.4.1 NWE SRIA Technical Annex

The NWE SRIA Technical Annex discusses concepts and technologies essential for developing innovative services. The diversity of technological domains required for future communication infrastructures highlights the relevance of multiple innovation domains for European Research. In this document, there are nine different domains, each one of them with a set of identified research challenges:

- **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 addresses network protocols and network services interfaces. This chapter is a novel introduction over the previous NWE SRIA 2022 [13] document and as such the whole content is completely different from the previously published content on the SRIA.
- **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.

New highlights in this SRIA2024 version include the following:

- A **new Chapter 3 - Fundamental Enablers for Future 6G Systems** - this is a new chapter dedicated to networking basic blocks, including protocols and interfaces.
- **Enhanced versions** of all SRIA2022 chapters and the **introduction of new subchapters** in:
  - Chapter 5 - Software and AI Technologies for Telecommunications.
  - Chapter 7 - Optical Networks.
  - Chapter 8 - Non-Terrestrial Networks and Systems.
  - Chapter 10 - Future Emerging Technologies (this later one incorporating some new futuristic scenarios).

[18] https://www.networldeurope.eu/sria-and-whitepapers/

4.2.4.2 NWE SRIA Whitepaper

The NWE SRIA Whitepaper is a separate document relying on the SRIA Technical Annex. This document has a different target audience being oriented towards interested stakeholders and not only technical experts. The whitepaper provides the overall system vision for 6G, including expected performance improvements for the future.

4.3 SNS Road mapping

SNS OPS partners are orchestrating and organising strategic activities to capture and promote the European view on 6G and the achievements of the 6G SNS (at projects and programme level) and are also monitoring the development and impact of these results on the evolution of 6G in Europe and worldwide, over the period of life of the 6G SNS initiative. The dedicated efforts of SNS OPS team have made it possible to deliver the comprehensive and well-structured SNS / 6G Reference Roadmap captured in Figure 65. This achievement reflects the team commitment and expertise, providing a clear vision to guide future developments in 6G technology. The intermediate draft versions were discussed and enriched through specific interactions with (among others) 6G-IA Board Members, EC-SNSO Officers and 6G-IA Vision WG Members developing the 6G-IA Vision WG White Paper "European Vision for the 6G Network Ecosystem" [14].

The SNS agenda is actively progressing; Call 1 and 2 projects are already up and running full speed, first Call 1 projects to contractually end in 2025, while Call 3 projects contractually started beginning of 2025. Call 4 was initially expected to close in April 2025. Calls 5 and 6 are scheduled by 2027. This timeline is fully aligned with the roadmaps of both 3GPP and ITU, and with agendas published by international associations, other SDOs/OSCs and ecosystems/fora, paving the way for development and commercialisation starting in 2029/2030. As captured in the Roadmap, both EU 6G Observatory and EU 6G Pioneer Award are under further EC consideration.

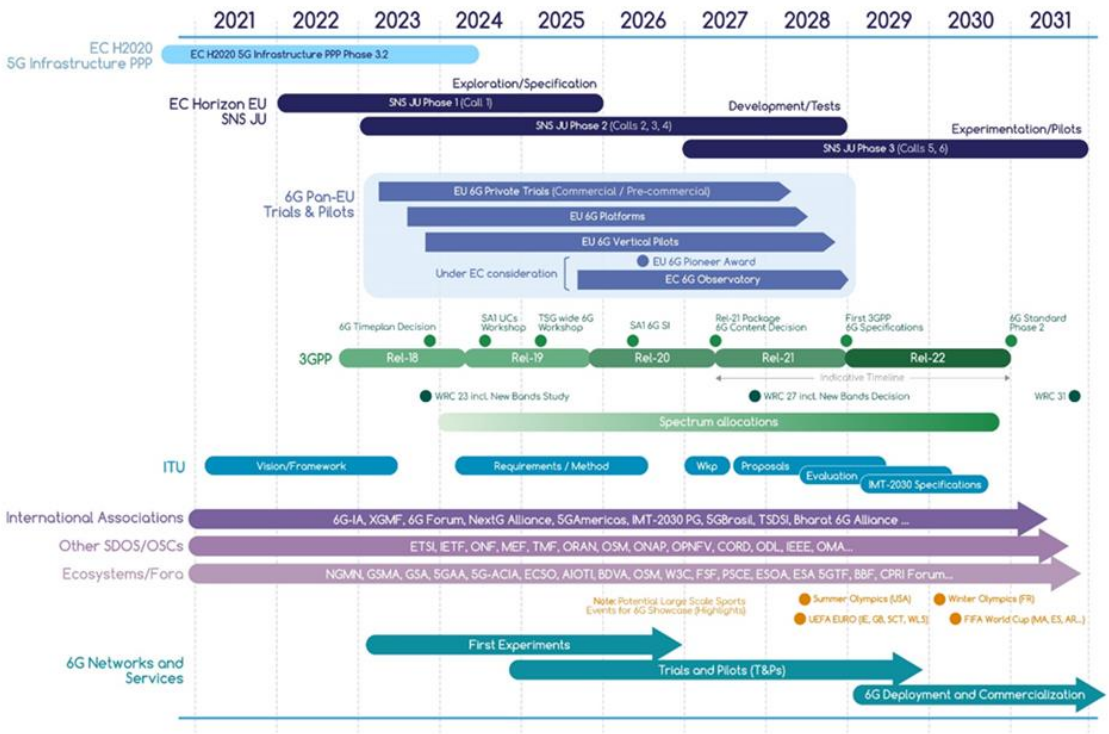

Figure 65: SNS / 6G Reference Roadmap (Version 1.0)

This Reference Roadmap constitutes an excellent platform for overall synchronisation and brainstorming within the SNS Community and also much broadly with overall stakeholders in EU and in other Regions. The Roadmap was first presented during the 6G-IA presentation during the 5G-ACIA meeting organized on 03-05.12.24 in Nuremberg, Germany, and was very well received. It is expected

that the Version 2.0 will be developed and released in the course of 2025, considering all latest up-dates from SNS and from the overall 6G international development perspectives.

4.4 SNS Work Programme and future calls

This Section is detailing the Work Programme CT/TF actions and related SNS OPS support related to the development of the SNS Work Programmes, focusing on SNS WP 2025 in this deliverable (deliverable D1.2 included details related to the definition of the SNS WP 2024), considering the SNS Portfolio and Projects coverage assessment (including Gap Analysis), the SNS Roadmapping and the SNS Vision, and further developing the overall SNS momentum. As described in the SNS OPS GA, the focus of the Task 1.4 is the following "*Based on the gap analysis of the phase one SNS projects against the SNS work programme, this task will distribute information for potential participants in future SNS calls as to what is needed and what would/should be encouraged for future calls in terms of a pre-structuring model for the open calls. It will be supported by a campaign of presentations and discussions with the target communities with the clear ambition of stimulating a set of high-quality relevant proposals, involving all necessary players, for future SNS calls.*". The Section explains how 6G-IA members and Community stakeholders are further contributing to / engaging with the SNS definition and implementation.

Leveraging SNS Call 1, Call 2023 and Call 2024 Work Programme definition experience, the WP 2025 definition started first with the 6G-IA Board Strategy Meeting organized on the 29th and 30th of January 2024 in Brussels and addressing (among others) the evolution of SNS and the forthcoming definition of SNS WP 2025-26-27. Further synchronization/brainstorming sessions were organized and the first 6G-IA Board Task Force (TF) / Core Team (CT) online meeting was organized on 13th of March 2024. The overall draft WP 2025 definition was very rapidly engaging TF/CT and EC-SNS Office (SNSO) interactions, starting with the first TF/CT – EC/SNSO online meeting organized on 21st of March 2024. The overall definition represented a very huge effort, spanning from March 2024 to November 2024, including 37 TC/CT online meetings, 13 TF/CT – EC-SNSO online meetings, 4 TF/CT - 6G-IA Board online meetings, 2 6G-IA Members Consultations, 4 EC-SNSO – States Representatives Group (SRG) / 6G-IA Office online meetings, 6 face-to-face focused Impact Assessment and Facilitation Action (IAFA) Workshops in Brussels and 1 focused Stream C – Stream D online Workshop.

Over the complete period March-November 2024, the TF/CT included participants from the 6G-IA, the EC and the SNS Office.

The WP 2025 definition started with the overall brainstorming on the overall WP 2025-26-27 ambitions and targets, including research and innovation / innovation actions on (not exhaustive list) (1) Low TRLs enablers (balance between SNS lover TRLs and higher TRLs Projects), (2) Wireless Communications and Signal processing, (3) Communication Infrastructure Technologies, (4) Secure Service Development and Provision, (5) Microelectronic / Front-End Module (FEM), (6) Service Platform / Open Source and (7) Trials & Pilots (T&Ps). The potential orientations for International Cooperation projects were also discussed from the start of the WP 2025 definition.

The initial draft WP 2025 / Options Paper pre-definition was including the major components of the WP, the overall target was to define before October 2024 the overall detailed targeted objectives and scope for each Stream/Strand and also the possible enrichment of the overall pre-definition, considering (1) the 6G-IA and EC-SNSO priorities up-dates (March-November 2024), (2) the further detailed understanding of SNS Call 1 projects portfolio and the step by step mature SNS Call 2023 projects portfolio understanding (March-October 2024), (3) the first awareness of the SNS Call 2024 selected proposals portfolio understanding and respective gap analysis (August-October 2024) and (4) the technical inputs from the NetworldEurope SRIA 2024 that was under development during 2024. The SNS Call 2 Projects Introduction Webinars were organized on 07th of March 2024 and 14th of March 2024 and brought more detailed information on Call 2023 projects portfolio[19][20]. The SNS OPS

[19] https://smart-networks.europa.eu/event/introducing-the-call-2-sns-projects-part-1-of-2/

[20] https://smart-networks.europa.eu/event/sns-webinar-introducing-the-call-2-sns-projects-part-2-of-2/

Questionnaires also clearly helped the detailed understanding of the overall Call 1 and Call 2 Projects portfolio coverage.

The draft WP 2025 definition was progressed step by step during April-May 2024 with multiple consecutive versions (15+) until Version V1.0, regularly enriched with new inputs and proposed updates/grades from TF/CT and EC-SNSO. Considering previous WPs definition experience and leveraging the very valuable 6G-IA Microelectronic Workshop organized on 16th of October 2023 in Brussels, 6G-IA Board / Office decided to organize and implement 5 specific thematic IAFA Workshops in Brussels focused on (1) Photonics (10th of April 24) (2) NTN (11th of April 2024), Security (12th of April 2024), Wireless (15th of April 2024) and Service/Cloud (16th of April 2024). The purpose of the IAFA Workshops was to identify future strategic directions for the SNS JU for the years 2025 to 2027, starting with the NetworldEurope SRIA as the basis of 6G related technological topics. The Workshops reports have been approved by the 6G-IA Board and served as input to relevant WP 2025 Streams / Strands and as a starting point for the WP 2026-27 discussions. Regarding technological roadmaps and synergies, a summary of the results from the Workshops has been captured in the SNS WP 2025 and is reminded hereafter:

- Microelectronics for Europe and Chips JU synergies: The Workshop has led to the definition of a Strand on "Front End Module" (FEM) that combines digital, RF, and packaging technologies to reach a reconfigurable, multi frequency, versatile front end for 6G, i.e., including prioritized spectrum, and capable of interference mitigations. It is proposed to run this Strand over the next Work Programmes, with WP 2025 being the first iteration, with a potential of transfer towards the Chips JU pilot line in due time.
- Cloud computing technologies and 3C Networks: The Workshop has led to the definition of short and medium-term activities for both: a) cloud solutions and b) service provisioning. The key findings of the Workshop include: a) that Europe should focus on open-source solutions to reach faster the target for European-wide accepted solutions, b) Target the standardization of the results so that future solutions will abide by the European rules for security, privacy, sustainability, etc., and c) Identify synergies among European funding instruments to maximize the impact of their activities and shorten the delivery of well-studied and tested solutions.
- Photonics and Photonics PPP synergy: The Workshop has identified further R&I work on multiple aspects of photonic technology, covering especially architecture/protocols for space links, access or backhaul use-cases, integration wireless and optical, optical sensing as support for services, quantum over fibre as main targets. These should be also developed in the context of sustainability (low-energy demand) and optical processing including AI capabilities.
- NTN and Space component: Lots of activities on 5G/6G are running through ESA, national Agencies and programmes, such as the Union Secure Connectivity Programme (IRIS2), which allows for the provision of commercial services by the European private sector. SNS is strong in facilitating bridges between the space and terrestrial community and current space contributions towards standardisation are planned through running SNS projects. In that context the Workshop has identified a "TN-NTN" unification Strand, with WP 2025 being the first iteration. It targets reuse of similar protocols and technologies in both the TN and NTN segment where feasible, moving beyond the integration stage reached with 5G, and reusing test and demo capabilities of ESA, if appropriate.
- Wireless: The Workshop has identified further R&I work on multiple aspects of wireless technologies (MIMO evolutions, physical layer technologies), on 6G RAN system aspects also covering topics in the upper midband spectrum (on top of below 6G, mmWave and THz), spectrum sharing/RAN co-existence, hardware development aspects and AI/ML and semantic communications related aspects.
- Security: The Workshop has identified further R&I work on multiple aspects of security-related technologies, such as SecOps, Secure AI, Physical layer security, secure service exposure, resilience and recovery, post quantum cryptography, DCS/CC, new paradigms e.g., deception MTD), evaluation certification metrics, CTI, supply chain/OSS/safe code etc.

The first draft WP2024 6G-IA Members Consultation, including Questionnaire, draft Orientation Paper (to be reviewed by 6G-IA Members) and Workshop Reports (for information of 6G-IA Members) was

launched on 07th of May 2024 with initial deadline for Consultations Answers on Friday 17.05.24, shifted to Friday 24.05.24.

The TF/CT Members analysed the overall set of 6G-IA Members inputs (51 contributions received - 15% of all 6G-IA members, 19% of full members - 94% of those who responded had read the draft orientations). There was clear acceptance of the proposed orientations in the draft WP 2025 with specific valuable feedback/perspectives, raised questions and proposed orientations. All were appropriately taken into account for the further development of the WP 2025.

The draft WP 2025 Version 1.0 was released on 27th of May 2024 and communicated as input to the EC-SNSO – SRG meeting n°1 organized on 3rd of June 2024 in Antwerp collocated with EuCNC & 6G Summit 2024. The very valuable discussion during the SRG meeting validated the status of the draft WP definition and the raised questions and feedbacks were taken into account for the further detailed definition of the WP.

TF/CT Members used the opportunity of EuCNC & 6GS 2024 in Antwerp to further synchronize on-site with SNS community, including among other 6G-IA Members and to further address the lessons learnt from the first Consultation analysis. Beyond the different technical perspectives related to Stream B, very interesting and valuable progress was achieved concerning both Stream C (Platforms) and Stream D (T&Ps) orientations. It was then decided to organize a dedicated 6G-IA Stream C – Stream D online Workshop on the 27th of June 2024, restricted to two Representatives per Streams C and D Projects. Specific questions/points were defined/addressed as input to the meeting, targeting to much better understand the current C and Ds Projects status, progress, issues… and best define the forthcoming targeted draft WP2025 Stream D Projects:

- Questions for Stream C Projects:
    - What are the major technological solutions you will deliver by the end of your projects?
    - Have Stream B projects contributed to or used your project infrastructure?
    - Considering your modular and open-source approaches, how easily can these solutions be integrated into future Stream D projects?
    - What assets of your project will be reusable by other projects, and how?
    - Do partners from your project consider further developing the solutions mentioned above, and if yes, in the context of SNS or other frameworks?
    - How many external entities have used your project tools until now, and which ones?
- Questions for Stream D Projects:
    - Have you used previous assets from other (previous) projects in your project, and where did they come from?
    - Based on your experience, how easy is/will it be for Stream D projects to integrate solutions developed by Stream B and C projects?
    - Have you integrated Stream C infrastructures into your Stream D Trials? If yes, did you face any difficulties, and how did you deal with them?
    - What are the business perspectives of the vertical services you are developing?
    - How do you think SNS Stream D projects can increase the participation of key European vertical stakeholders in their activities?

The answers from Stream C and D Projects and the overall Workshops discussion/brainstorming clearly enriched the further definition of the WP 2025 Stream D Expected Impact and Scope.

The dedicated 6G-IA Consultation Analysis Webinar was organized on the 08th of July 2024, to present the overall analysis and engage into further interactions with 6G-IA Members, including live Q/As. The Webinar included the presentation of the Consultation key lessons learnt and the proposed orientations towards draft Version 2.0. As highlighted above, all valuable inputs from the Consultation and related Webinar were appropriately taken into account for the further development of the WP 2025.

The draft WP2025 definition was further progressed step by step during June-July 2024 with multiple consecutive versions until Version V2.0, still regularly enriched with new inputs and proposed up-dates/grades from TF/CT and EC-SNSO. The draft Version 2.0 was released on 22nd of July 2024 as input to the second 6G-IA Members Consultation (document attached to the Consultation). The second draft WP2025 6G-IA Members Consultation was launched on the 22nd of July 2024 with the initial deadline set for the 30th of August 24, which was extended to the 04th of September 2024.

The TF/CT Members analysed the overall set of 6G-IA Members inputs (59 contributions received - 16% of all 6G-IA members, 22% of full members - 96% of those responded that they have read the draft orientations). As for Consultation n°1, there was clear further acceptance of the proposed orientations in the draft WP 2025. The specific valuable feedback/perspectives, raised questions and proposed orientations were considered for the development of the WP 2025.

In addition to the 6G-IA Members Consultations, the TF/CT Members also defined, as was the case for the draft WP 2023 and WP 2024 definition with the SNS Call 1 and Call 2023 PMs Survey, the SNS Call 2024 PMs Survey. The SNS Call 2024 Projects Assessment Questionnaire was targeting to assess the technical coverage of the Call 2024 projects (predecessor of the SNS OPS Monitoring and Analysis framework to assist with the gap analysis).

The questions raised to SNS Call 2024 B01-01/02/03/04/05, C01-01 and D01-01 projects Coordinators were focused on the following core basis:

- Table 4 below contains a set of topics under scope in this call. Please distribute a total of 20 points (cumulative total) according to the relevance your project plans to give to that specific topic. The higher the number, the more work you project plans to do here.
    - Specific WP 2024 - B01-01/02/03/04/05/06, C01-01 and D01-01 list.
- Final comment: Please provide any final comment or important area in your project that was not considered?

The SNS Call 2024 Coordinators survey analysis was discussed in TF/CT and in TF/CT – EC-SNSO context and was bringing specific up-dates on the SNS Call 2024 projects portfolio scope and coverage, This Coordinators Survey contributed to the overall SNS OPS Questionnaire detailed in this Deliverable and provided the necessary input to perform the required Gap Analysis.

The draft mature WP2025 definition was then further progressed and converged in September-October 2024, with multiple consecutive versions (10+) until Version V3.0, still further regularly enriched with new inputs and proposed up-dates/grades from TF/CT and EC-SNSO. Concerning International Cooperation, there was EC-SNSO orientation to shift International Cooperation to WP 2026-27. The draft Version 3.0 was released on the 17th of October 2024, following the latest remaining TF/CT-EC-SNSO up-dates/grades. EC-SNSO included the specific Security Conditions and released the final version 3.0 sent to SRG/MSs Members on 06th of November 2024. Again, the draft Version was very positively received / discussed during the SRG online meetings, the main interactions/discussions being focused on the Security Conditions. The final version was officially published by EC-SNSO on 21st of December 2024 and it included the following Summary depicted in Table 4. It must be noted that due to the further EC-SNSO discussions on the implementation of the Security Conditions, the released WP 2025 did not initially include the information on the Call 2025 Proposals submission deadline.

Table 4: SNS Call 2025 Streams and Strands summary

Streams / Topics	Call 2025 Topic Budget (in M€)
HORIZON-JU-SNS-2025-STREAM-B (RIA)	
01-01: Advanced Architectures Systems and Technologies	15.0
01-02: Advanced IoT and Device Technologies	9.0
02: Wireless Communication Technologies and Signal Processing	21.0

03-01: 6G NTN-TN Unification/Integration	8.0
03-02: Higher Speed Optical Access Networks and future end-to-end Packet Optical Network Architecture in 6G	8.0
04-01: Smart Security / Security Services	8.0
04-02: Reliable Services Operation	8.0
05: Microelectronic – Front-End Module (FEM)	12.0
HORIZON-JU-SNS-2025-STREAM-C (RIA)	
01: 6G Telco Cloud and Service Provision enablers	15.0
HORIZON-JU-SNS-2025-STREAM-D (IA)	
01: SNS Trials and Pilots (T&Ps) with Verticals	24.0
Total (M€)	**128**

Following the completion of the WP 2025 definition, the 6G-IA Office organized specific Workshops debriefing online meetings in December 2024, with the target to synchronize with Workshops participants, highlighting the selected orientations for final version of the WP 2025 and also briefly addressing the potential follow-up actions for the forthcoming SNS WP 2026-27 definition.

6G-IA, EC-SNSO, SNS OPS, SNS ICE and 6GStart CSAs were/are very actively contributing to develop the overall SNS / Community momentum (as detailed in the related CSA Deliverables and in the 6G-IA and SNS webpages). As explained in the previous Sub-Section, the SNS momentum is also further grown step by step thanks to the overall work and actions related to the SNS Work Programmes and Calls definition and implementation, including among others through specific 6G-IA Members Consultations and WPs/Calls Webinars. The definition of the Call 2025 participation conditions, related to IKOP and restricted calls to a certain level of the budget, also led to the clear development of the 6G-IA Membership (more than 360 members).

Concerning the SNS WP 2024 / Call 2024 definition and implementation, the SNS Call 2024 brokerage Event organized on the 25th of January 2024 was one key event to further develop the SNS Momentum.

The NetworldEurope SRIA 2024 actions also broadened the overall SNS / NetworldEurope Community and further raised awareness of the SRIA / SNS WPs development. The SRIA 2024 "Technical Annex" developed during 2024 was released for Consultation on the 11th of December 2024. Based on the received feedback, an extended version of the "Technical Annex" (long document) has been released as well as a SRIA 2024 White Paper (short document)., as detailed in the previous SRIA sub-section.

Concerning the SNS WP 2025, the 6G-IA Brokerage Event has been organized on 29th of January 2025, included 50+ 6G-IA Members presentations pitches. Additionally, an SNS Call 2025 Information Session will also be organized (past March 2025). In parallel, several Information days are also organized in the different Members States, to also contribute to raise at National level the awareness of the SNS Programme and Calls, possibly engage more organization into SNS projects and 6G-IA and synergize SNS with the National 6G Initiatives. The SNS Call 2024 Projects Introduction Webinars organized on 14th of February 2025 and 17th of February 2025 also reinforced and developed the SNS momentum from 6G-IA Members and Community.

Last but not least, the SNS Brokerage Platform[21] is further used and promoted in the different SNS Calls, The Platform offers very valuable service to the 6G-IA members and overall SNS community, with the key functionalities (1) Submit a proposal idea, (2) Submit your expertise, (3) Browse proposals/ideas and (4) Browse profiles. The platform shows information about potential proposals that stakeholders may wish to contact and also show expertise offered by potential participants that stakeholders may wish to invite to join their consortium.

[21] https://sns-brokerage.eu/

As a summary, the SNS momentum has been further steadily growing and there is a clear plan/path for further growth in the coming years (until the end of SNS), which will enable the engagement of even more stakeholders with SNS activities. The tools and framework developed by SNS OPS and the tight collaboration with the other CSA projects, the SNSO and the running projects themselves (via the SNS Steering Board, Technology Board and Working Groups) play a significant role in the maintenance and further growth of the SNS momentum. The monitoring and analysis framework of the SNS OPS and its produced results and insights (latest version of which was presented in this deliverable) play a pivotal role in better understanding the work, scope and coverage of the running SNS projects and provide the necessary input for the gap analysis. These results and insights are fed back to the community and the TF/CT working on the next version of the SNS WP and support the organization of several events to bring the community together and to disseminate the work and direction of the SNS JU.

5 SNS Vision updates

The European 6G SNS vision is undergoing a significant revision based on extensive stakeholder consultation including key organizations and associations, industrial and academic stakeholders, peer-associations, other global regions, and scientist of multi-disciplinary backgrounds. This update aims to summarise the latest findings from SNS JU projects and analyse evolving societal, business, and policy considerations that are essential to avoid shortcomings of previous generations and to deliver a network of networks, meeting the needs of society as a whole.

SNS OPS D1.3 [8] presented the SNS roadmap/status for the SNS JU in June 2024, after the first one and a half year of running SNS projects. Later, the updated 6G-IA Vision and Societal Challenges Working Group (VSC WG) white paper [14] – system perspective re-affirms previous findings and several of the identified orientations are valid for the SNS JU, and further support is needed in R&I activities by the SNS and its potential follow up in the future. Key findings are also aligned with the 6G-IA Strategic white paper from September 2023 [16] . It is important to also mention the European Commission white paper on Connected Collaborative Computing (3C) [17] and make a point that all these documents point to the same direction. Furthermore, 6G-IA has also recently released a position paper on 6G security, which further emphasizes the need for secure, reliable and resilient solutions [18].

In section 5.1 a recap of the SNS Vision process is provided, reflecting the broader sense of “vision”, which take the future 6G System as the primary focus. Section 5.2 provides an update on latest (ad-hoc) input by SNS OPS industry stakeholders, while 5.3 provide key points from prominent vision papers (as mentioned above), while section 5.4 provides reflections and analysis by the SNS-OPS project on the foreseen further potential impacts and directions.

5.1 Recap of vision process and outlook

The Vision process and outlook were comprehensively treated in SNS OPS deliverable D1.3 [8] and a short summary follows here. Figure 66 shows how relevant actors, stakeholders, and other inputs have been involved in shaping the SNS 6G Vision. It was formulated based on consultations within the EU and Associated Countries, and with strong involvement from the private sector. The industry perspectives were mainly expressed via the NetworldEurope ETP and the 6G-IA. Together with high level EU policies formulated in the Digital Europe and Horizon Europe programmes, this was the basis for the SNS JU SRIA followed by the creation of annual work programmes. Parallel to this the 6G-IA through the Vision and Societal Challenges Working Group (VSC WG) provides the industry vision of 6G.

The update of the SNS Vision is based on updates of the mechanisms above. In November 2024, the 6G-IA VSC WG released an update of the white paper “European Vision of the 6G Network Ecosystem” [19], while NetworldEurope opened the 2024 edition of the Strategic Research and Innovation Agenda (SRIA) for public consultation in December 2024 [20].

In D1.3, we discussed the outcome of the information collection and suggested a way forward for the European 6G SNS Vision. By collecting inputs from multiple stakeholders containing both public and private sector views, a complex picture is presented. This comprises several comprehensive technical advancements and strict targets within domains as architecture, use of AI, integration with existing and upcoming technologies, spectrum, interoperable networks and services, and how to leverage new HW components.

The 6G SNS Vision does not only include technological aspects; societal, business and policy aspects play a critical role. This includes sustainability in all the three domains (social, economic, environmental) and, hyper-reliability, security, privacy and resilience. It is our belief that D1.3 did add value to the 6G SNS Vision update process and the final outcome of the EU Vision whitepaper itself.

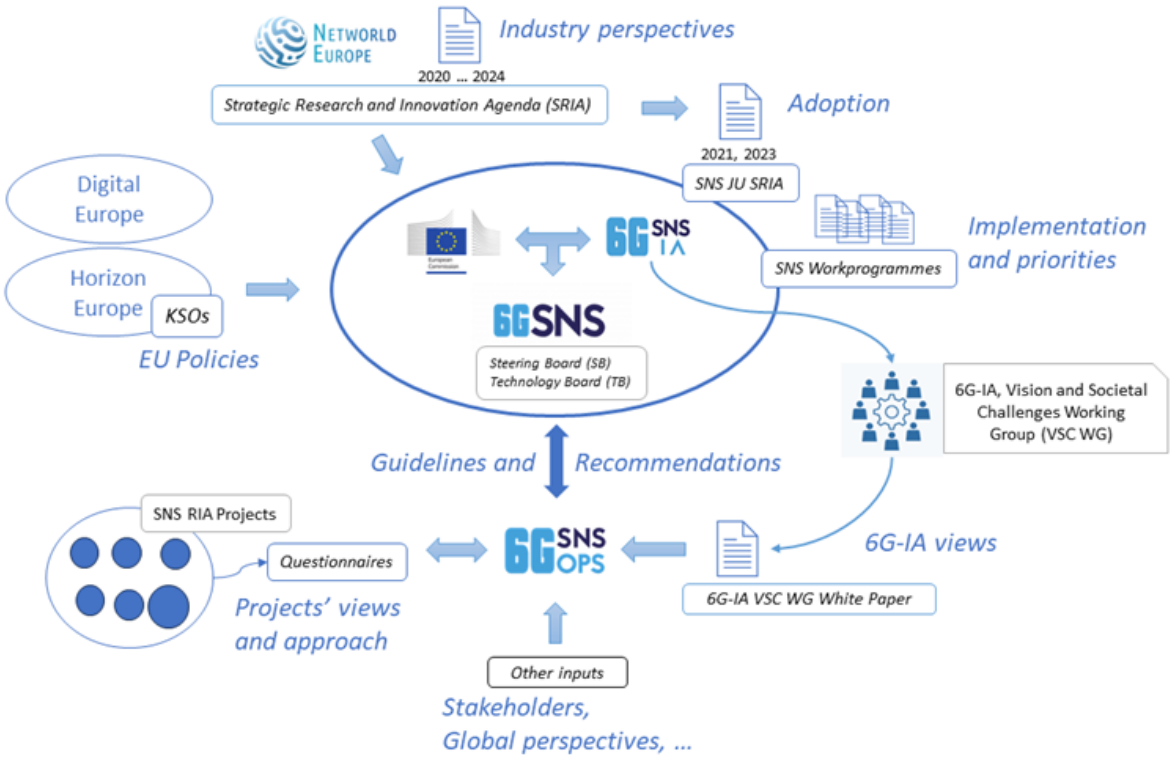

Figure 66: SNS Vision and Programme process, stakeholders and reference documents [8]

The *Societal Needs and Value Creation* sub-group of the 6G-IA VSC WG established an initial approach to the KVs and KVIs. Their baseline methodology has been used by the SNS JU (projects, WGs, sub-groups, including 6G-IA) to follow up the overarching societal targets and objectives., as detailed in the corresponding KVIs sub-section

The scope and definition of 6G system and services offered is work-in-progress. For example, the SNS JU expert community is working towards a 6G system that will integrate beyond connectivity services or service enablers. However, beyond connectivity services can also be adjacent (over-the-top) and complementary, an approach that 5G can benefit from. The transition from Beyond 5G (B5G) networks to 6G smart interoperable networks and services requires a focus on technological, as well as on societal, business and policy aspects, to avoid shortcomings of previous generations and to deliver a network of networks meeting the needs of the entire society.

The key elements that will drive the transition towards 6G SNS are HW components (strengthened by a potential collaboration with e.g. CHIPS JU); Interconnected Networks, Cloud Continuum, and Services; Ecosystems, Sustainability and Societal Aspects; Novel Technologies; and AI/ML-enabled Functionality.

Based on this, D1.3 put forward some key observations on fundamental needs:

- Convergence and new customer needs.
- Service orientation, both horizontally and vertically.
- Security, Privacy, Resilience and Liabilities in complex infrastructures [22]
- Facilitating ecosystem enablement, evolution and sustainability.
- A strong collaborative expert community.

The further SNS vision process update will be followed up in the SNS CO-OP CSA as part of the strategic activities maintaining a dialogue in the wider European 6G SNS community to promote the European Industry view on 6G and the achievements of the 6G SNS initiative and projects. Available

[22] Cf new EU directives like Cyber Security Act, Cyber Resilience Act, Cyber Solidarity Act, NIS2 (for a high common level of cybersecurity across the Union).

information from SNS JU projects, EU and global stakeholders, global organizations and associations, and 6G-IA members will be collected and critically analysed. A deeper analysis of the impact and potential future directions is elaborated in section 5.4.

5.2 SNS OPS industry members views update and status

As summarised in section 5.1, the previous deliverable D1.3 took on-board the early efforts on roadmap and vision from the SNS Community inputs (by the broad range of stakeholders), which formed a vision on the fundamental needs for 6G research. In this section, we will take this further to incorporate a number of complementary SNS OPS industry member perspectives. SNS OPS industry members include key stakeholders from European vendors and operators. Thus, their views for 6G priorities and trends are of importance. These views are also cross-checked against the overall European priorities captured in white papers, questionnaires, and other stakeholder Working Groups efforts that have taken place since D1.3 was delivered. These efforts have resulted in a gathering of a more clear and detailed vision on the key challenges and clear trends of 6G research and innovation to be addressed next, especially from the perspective of vendors and operators to achieve maximum impact in the marketplace. It should be noted that while the technology focus is still very aligned with the SNS JU phases and work programme portfolio, the views of the vendors and operators, telecommunications service providers in particular, are taken in the context with the current transformation of their companies to become more fit for the future. This transformation occurs while dealing with (at least a partial) lack of investments into meaningful and holistic commercially driven innovation activities, and lack of technology platform maturity and operational experience for the needed operational scale.

Based upon this stakeholder engagement, the following areas are highlighted by SNS-OPS to drive the SNS vision forward to drive the last phase of SNS JU, and even for FP10:

- 6G is driven by societal needs; It is important for EU stakeholders to address these needs and provide reflections on how they will drive priorities and roadmap from the public telco operator’s perspectives.
- Ensure a smooth migration from 5G to 6G by supporting an evolved 5G core network (5G CN) for 6G and multi-RAT spectrum sharing for efficient interworking.
- Work for a simplified yet flexible and modular 6G architecture to adapt to future evolutions and deployment cases, avoiding complexity and cost for simpler and less demanding contexts.
- Develop solutions aiming at common denominators applicable for various vertical sectors.
- Enable support of beyond communication services (e.g., sensing, compute offloading, etc.) to be provided by the 6G system.
- Provide exposure and network programmability through APIs, considering interoperability in both on-net and off-net service and device endpoints.
- Ensure ubiquitous network connectivity through integration of diverse connectivity options, e.g., TN, NTN, mesh, etc.
- Develop 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).
- Mainly focus on lower frequencies and mid-band and consider higher frequencies only for specific solutions e.g., backhauling.
- Enable the native AI support in 6G networks - develop frameworks to support full network automation and provide AI as a service solution.
- Support network disaggregation through open lower layer split (LLS).
- Enable the operation of the cloud continuum by providing edge cloud solutions (that may be based on open-source initiatives) and define open interfaces to hyperscalers and service providers.
- Support an end-to-end security and privacy preservation framework that is aligned with the

European principles / policies.

- Enable new technologies, frameworks and processes to industrialize EU certifications (and maintenance cycles) of 6G related infrastructures, products and services (cf ENISA EUCC, EUCS and EU5G schemes).
- Improve European capabilities to develop 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.).

Section 5.4 will present these in more detail as it outlines the impact and potential directions forward to roadmap the SNS stakeholders' work to lay out the next steps for the SNS community.

5.3 Updated European industry position and 6G SNS vision

This section aims to capture the industry position towards 6G networks and services. The main industry view is expressed through 6G-IA, who is the voice of European Industry and Research for next generation networks and services with more than 360 members. 6G-IA has recently released the above-mentioned 6G Vision White Paper [19]. This document, together with the updated version of NetworldEurope SRIA will drive the evolution of the smart network and services in Europe. Furthermore, it is important to look back on the 6G-IA Strategy position paper [16], and the newly released position paper on security [18], as well as the whitepaper on ecosystem business modelling [21]. Sustainability is also a major topic, covered by a corresponding 6G white paper from December 2024 [22]. All these are discussed in more detail below. Key Societal Values (KVs) and Key Value Indicators (KVIs) will provide a framework to anticipate and later to measure the actual impact of 6G SNS technologies and services and ensure alignment with broader societal goals.

Central to this updated vision are some key fundamentals.

- Sustainability is not a peripheral concern but a foundational principle encompassing environmental, social, and economic dimensions, going beyond mere energy efficiency improvements.
- The vision emphasizes a holistic approach for the transition from 5G to 6G, aiming for a comprehensive "network of networks" that provides services beyond traditional connectivity.
- AI and Machine Learning are integral to the vision, permeating all aspects and layers of future 6G networks including smart and multi-disciplinary architecture paradigms. This momentum is driving integration with existing and upcoming technologies such as NTN, UAV, cloud continuum, immersive experiences, physical awareness, fully connected worlds, C-V2X, collaborative robots, digital twins or trusted environments [23].
- The convergence of ICT technologies and evolving customer needs are pushing demand for solution-as-a-service offerings, where enabling technologies, cloud & virtualization, exposition of network assets in a platforming approach, and advanced connectivity are opening up new opportunities.
- Given the geopolitical and societal challenges, hyper-reliability, security, privacy, trust and resilience at all network layers are paramount and require coordination and alignment among stakeholders.

Consequently, fostering a thriving 6G ecosystem requires new frameworks and methodologies for collaboration and co-creation, and a diverse and skilled community of experts within the SNS JU is essential to drive innovation and achieve the vision's goals. A strong focus on service and innovation, both horizontally across networks and vertically towards specific customer segments and ecosystems, combined with communication that focuses on the value delivered to customers and society, is critical.

As a result, the 6G-IA VSC WG released the update of the white paper "European Vision of the 6G Network Ecosystem" [19] providing more mature insights into key technologies, architectural trends, and business enablers, as well as a deeper understanding of use cases and a holistic societal perspective, offering a refined 6G SNS vision and an overarching roadmap for the future. This new version also focusses on the ongoing global efforts to develop and standardize 6G networks. It highlights the

importance of creating *a unified 6G vision*, driven by key stakeholders worldwide, towards a single global consensus. The anticipated technological advancements are outlined comprising *security, AI, energy efficiency, and ubiquitous coverage*. Furthermore, the socio-economic considerations in 6G development, including *energy efficiency* and *sustainability* goals are discussed. The white paper also outlines the six use case families with their KPIs which have been developed and defined in various SNS JU projects, like the flagship Hexa-X-II project. In this context, five key points of a "*6G-enabled Services Vision*" are introduced:

- Foster transition from 5G to 6G to sustain and enhance 5G innovations.
- Address potential shortcomings of 5G in areas that may have been underdeveloped, e.g., with respect to support of vertical industries.
- Integrate new service capabilities with an emphasis on interoperability and service continuity.
- Propose interconnected and interoperable smart networks ensuring seamless interconnection and interoperability among network providers, beyond just connectivity.
- Define sustainable 6G ecosystems prioritising sustainability and encompassing environmental, social, and economic aspects through a new business ecosystem approach.

In the white paper, technological enablers are categorised in a set of concrete areas. An updated division is provided on the forthcoming 6G architecture where the focus is on potential innovations and current 5G limitations. The major differences between 6G (IMT-2030) and 5G (IMT-2020) are outlined. Finally, the white paper emphasises the need for *a unified global standard* for a resilient telecommunications ecosystem, which is supported by industry groups, associations, and open-source communities.

In 2023, 6G-IA released the position paper "Key Strategies for 6G Smart Networks and Services" [20] describing the key strategic priorities for Europe in relation to smart networks and services. In this document, the following areas were considered and analysed:

- 6G Technological Sovereignty which includes a) components and microelectronics, b) open SNS solutions, c) cloudification and distributed computing, d) network intelligence, e) security, privacy and resilience and f) knowledge base.
- *Sustainability* which captures all aspects of environmental, societal and economic sustainability.

The key observations and recommendations for European research in the document are summarized as follows:

- Technological sovereignty on components and microelectronics: To ensure that supply chains for products, components, materials and know-how are diversified through the identification of synergies with related EU Partnerships.
- Technological sovereignty on open SNS solutions: To ensure that the results from current activities are capitalized, to reach sound and widely accepted conclusions assuming a technology-neutral regulation pursuing the most suitable and efficient solutions for the European stakeholders.
- Technological sovereignty on cloudification and distributed computing: To ensure Interoperability between cloud infrastructures enabling different independent cloud infrastructures that are separately optimised for a specific task or market. Additionally, it is important to identify open-source activities that will allow European solutions to eventually acquire a global role in a market that is currently heavily dominated by non-European stakeholders.
- Technological sovereignty on network intelligence: To meet the need for a globally accepted framework where AI/ML will be benchmarked and validated. Additionally, appropriate training data sets, open solutions and well selected standardised interfaces are needed to support such a framework, formalize stakeholders' responsibilities and to allow interconnection and interoperation of AI, digital twins and other intelligent components across different stakeholders.
- Technological sovereignty on security, privacy and resilience: To create a collaborative

environment for key public and private forces to cover the complete range of needs from research activities, develop security solutions in critical hardware and software modules and foster solutions that will conform to European policies, legislation and certification schemes by meeting European values.

- Technological sovereignty on knowledge experts' base: To contribute towards a timely integration of the knowledge produced by SNS R&I activities in the educational process at the European level and measures to grow the base of experts in Europe.
- Sustainability: To develop a framework that will serve for the quantitative evaluation of solutions designed to support environmental, societal and economical sustainability measured by key value indicators.

These key strategic areas are still valid in 2025. This is also supported by 6G-IA VSC WG white paper [19] (see above), which captures not only the identified priorities from the 6G-IA members but also the work and priorities of the SNS JU projects, like the flagship project Hexa-X-II.

Further, *security, reliability, privacy and resilience* has become more important due to increased geopolitical tensions. 6G-IA Security WG released the position paper "Innovative Approaches for 6G Security" in January 2025, highlighting the following key pillars currently covered by SNS JU projects [18]:

- Innovative security frameworks like AI-driven architectures for dynamic and continuous trust evaluation (zero-trust) and adaptive security organization optimizing vertical and horizontal needs and introducing a holistic trustworthiness framework.
- Decentralized and adaptive solutions in resource management and analytics putting privacy-first.
- Advanced technologies for future-ready networks includes AI enhanced physical layer security to combat jamming and eavesdropping threats, and post-quantum cryptography and federated learning for anomaly detection.
- Scalable and zero-touch approaches include automation, network digital twins (NDT), AI model validation, and service optimization, as well as integrating software-defined perimeters and zero trust architectures for adaptable and efficient security management.

There are gaps in the current B5G and 6G security landscape which already has been identified to some extent, and current initiatives forms a foundation for a secure, user-centric, and resilient 6G ecosystem

Another key topic for the European industry is sustainability, and the VSC WG released the update of the white paper "Sustainability of 6G: Ways to reduce Energy Consumption" in December 2024 [22]. The white paper identifies the main challenges in the area of operational Sustainability of 6G. It is contrasting the consensual 6G vision of the European Industry and the expected evolution of services and the mobile ecosystem with the lessons learnt from 5G, in the sense of the main energy consumers and the reasons for the latter. Trying to address these challenges, it identifies several candidate enabling technologies and more general approaches for energy consumption and carbon dioxide emission reduction and possible current research and standardization gaps, to be considered in the future work on the way towards more sustainable 6G.

This white paper lays out a possible path towards more sustainable 6G operations along the following concrete recommendations for technological advances:

- Agree on a small set of *universal, ICT-suitable energy consumption and carbon emission metrics*, fit for cooperative ICT service provisioning characterized by multitenancy, open interfaces as well as service and system composition.
- Continue investing into successful optimization work, both on system and service energy efficiency, supported by explicit full-service-scope *green KPIs*. The whitepaper underlines the high saving potentials of dedicated energy efficiency measures, yet it also identifies intrinsic limitations of the latter facing the expected increase in loads.
- Improve the maturity of our profession by measuring and providing data on energy consumption and carbon footprints, i.e., ecodata, of current systems and services. *We need reliable, agreed*

benchmarks today to be able to improve systems and services in the future.

- Introduce native, integrated, service-level energy consumption metering capabilities in 6G.
- Create an agreed industry methodology for the *attribution* of measured ecodata to the service instances responsible for them at each level of service usage and resource abstraction.
- Specify trustworthy, *per service session ecodata exchange* (forwarding, aggregation) among the (sub)service providers and users involved into a (sub)service function chain.
- Position *service user involvement* as a new green technology family, consisting of service user awareness, service user incentivization and service user enablement. *Raising service user awareness is key to greening 6G*.

The 6G industry community continues to recommend a customer focussed approach when innovating, developing services, and pursuing business opportunities in the evolving 5G and 6G enabled markets. In the 6G-IA whitepaper on ecosystem business modelling [21], Industry4.0 pain points are the starting point for applying the 5G and beyond (5G/B5G[23]) ecosystem business modelling methodologies and frameworks. In the 5G/B5G, and later 6G ecosystems, providers must collaborate to create value for users, customers, and each other, while individually extracting revenues based on the services they provide vertically and horizontally. The whitepaper analyses ecosystem roles and configurations and exemplifies business models and their key characteristics and differentiators. Based on such analyses, key stakeholders must consider how to orchestrate the start and continuation of a thriving 5G/6G ecosystem, and the impact of their strategic choices on other roles in the ecosystem.

Finally, it is also imminent to recognize the European Commission (EC) initiative and push towards what has been pitched as 3C Network (3CN for short). The EC white paper from February 2024 [18] recognizes that "Computation is no longer bound to dedicated computing environments such as data centres. Instead, it has become embedded and ubiquitous in almost everything. This will allow to combine on-device edge with the rest of the broad range of edge computing categories and different types of cloud services in collaborative computing environments". Furthermore, a major concern is that "the different sectors are fragmented and, as well as lacking scale, they do not have a common approach to the innovation necessary to deliver next generation connectivity and computing. Thus, as well as orchestration in the technical sense, these sectors require close collaboration in order to succeed."

The EC provides the following vision, and encouragement:

> "We need to ensure that these innovations are implemented in the EU and safeguard our economic security and prosperity. In particular, it is of key importance that EU industry has sufficient technology capacity in key parts of the digital supply chain and is able to reap economic benefits in the most attractive parts of the digital value chain. The goal is to foster a vibrant community of European innovators, creating the "Connected Collaborative Computing" Network ("3C Network"), an ecosystem that spans semiconductors, computational capacity in all kinds of edge and cloud environments, radio technologies, to connectivity infrastructure, data management, and applications."

The above analysis illustrates that the SNS OPS work and findings are aligned and included in the overall updated R&D framework either in 6G-IA white papers (where a significant number of 6G-IA members and SNS JU projects contribute) or in the results of the SNS JU projects. Moreover, it is apparent that the European private side view and the EC priorities for 6G networks are also well aligned.

5.4 Impact and potential directions

All the above visions, recommendations, positions, and targets are fully aligned with the latest views of key European stakeholders as captured in D1.3, in sections 5.1, 5,2 and 5.3, and the SNS plans as depicted in section 4.4 above. However, continued broad vision-oriented analysis, and more collaborative work is still needed to ensure that the ongoing European R&I activities in the various areas of SNS JU will achieve impactful results. We observe that this is true also in the broader scope, where

[23] This includes smart networks and services enabled by 5G and beyond connectivity capabilities.

we need further considerations of the 5G-6G SNS industry ecosystem, as provided and suggested below.

In this section, we complement the above as further observations, recommendations, and potential directions are identified for the various stakeholders to consider in the preparations of the subsequent phases of the SNS JU, and even for FP10.

The SNS vision has evolved and pointed at technological and architectural challenges, however, also acknowledging that stakeholders' and customers' needs, barriers, and motivations and geopolitical aspects affect the path forward.

A common observation is that the **5G and in particular the 5G Standalone (SA) Core has not matured** and been deployed at the expected speed. As a result, the variety of the smart network services (e.g. roaming, and beyond connectivity services) enabled by 5G and cloud native technologies have not commercially matured as expected, and the go-to-market for such services and enablers have been delayed. Hence, many stakeholders see 5G as currently not living up to initial expectations, and there is a whole lot of 5G enabled potentials that are so far untapped. Unleashing, facilitating, and driving the full potential of 5G, through common, standardized service abstractions, models, and APIs is important for the telco industry at large, ensuring 5G RoI, and a better positioning of the industry prior to and in support of a successful 6G standardization and a stronger European SNS industry journey. Thus, for various aspects an evolutionary approach from 5G advanced to 6G is expected.

Another point is that **6G's evaluation will not be exclusively a technological one**. This will be a challenge for the industry ecosystem. The main responsibility seen from the technological perspective, is to make it as easy as possible to invest in, deploy and operate, and sell (as a service) SNS technologies. This will be done through continuous support of a sensible standardization process for a limited set of options, interoperability, modularity, and compatibility. 6G' success will be evaluated on its level of monetization, verticals' engagement and overall ecosystem growth. Thus, in the final SNS JU phase, there must be more focus on understanding the common and overarching risks and pain points of the industry, and how operators and industry can facilitate the strengthening and evolution of the end-to-end SNS multi-stakeholder ecosystem for joint benefits.

In this context, **the 3CN vision as introduced by the EC is important**. The industry should further develop the vision, identify more refined objectives and requirements, and place the 3CN concepts into a European approach to multi-stakeholder service provisioning and operations, along with the SNS Vision. In alignment with the public side, the 3CN elaborated vision should ensure that the European policies and directions translate into concrete objectives and requirements, developing a holistic roadmap taking the various stakeholder perspectives into consideration. This vision, directions, and the corresponding roadmap must include a strong approach to security, privacy, robustness, as well as a holistic approach to sustainability. In light of the above, the following list of recommendations should be considered for the way forward:

- Synergies between related Horizon Europe partnerships need to be further strengthen in various areas of 6G, (e.g., micro-electronics, photonics AI, HPC, etc.) to ensure that configurable and generic hardware platforms will efficiently support key 6G technological trends (e.g., virtualization, softwarization, native AI support, etc.). The key target would be to move from R&D activities to high-TRL pre-commercial solutions that could be developed in pilot lines. Synergies will also be needed to explore longer-term evolution, such as hardware upgradability to support the extension of equipment usage duration.
- Further support activities related to open SNS solutions, where the development of openly accessible pan-European platforms could be used to transparently verify the performance of the developed solutions and enable reproducibility, repeatability and reliability of claims.
- Prioritize and support European solutions for telco-cloud that conform to European values, legislation for data security and privacy. These solutions should be based on open, interoperable and multi-provider cloud infrastructures.
- Develop an end-to-end multi-stakeholder platform where European stakeholders can deploy native AI solutions, agree and use a common list of training data sets for benchmarking and testing AI/ML algorithms. This work could be also used to define open solutions and

standardized interfaces that could enable the interconnection and interoperation of intelligent components across different stakeholders.

- Create a collaborative environment of key public and private stakeholders to form a cooperation framework from R&D activities to policies targeting the creation of new products and services that adhere to European priorities.
- As the SNS JU is producing new knowledge for smart networks and services, a new framework is needed to pass this knowledge into the education process (i.e., Universities and Research and Technology Organisations (RTOs)) to increase the knowledge basis of experts on 6G topics.
- For the successful engagement of the vertical industries and the planning of future SNS R&I WPs, it is important to organize dedicated face-to-face and electronic workshops with key vertical associations and key European vertical stakeholders. These workshops should constitute the future Impact Assessment and Facilitation Action activities (IAFAs). The scope of these workshops will be to identify the key priorities of the verticals, in terms of services, technical requirements from the underlying network, their needs in terms of KVIs, while also recognizing the current market issues. These workshops should also consider the lessons learned from the existing SNS JU projects (especially Stream C and D projects).
- Complementary to the IAFAs with vertical sectors orientation, new IAFAs may be conducted with a focus on aligning the relevant 5G/6G SNS industry stakeholders to drive developments of the common future multi-stakeholder interoperable smart network services (cf. 3CN, and more), including capturing insights on current stumbling blocks, pain-points, and challenges. These IAFA activities may then evolve into a permanent European Ecosystem Forum on Interoperable Networks and Services Provisioning, facilitated by or in collaboration with future SNS JU CSA.
- On security, privacy and resilience, considering in particular the perspectives and challenges on multi-stakeholder services and operations and taking into account the recent geo-political environment, to ensure sovereignty and GDPR enforcement for EU data and networks, principles of liabilities delegation and control should be enforced between stakeholders including Verticals versus 6G infrastructures.
- Sustainability should be treated as an integral part of the 6G network design, alongside the technical specification requirements and should contribute to meeting key societal needs and the United Nations Sustainable Development Goals. To this end, a comprehensive scheme of KVIs and a clear framework for their definition, evaluation and analysis is deemed necessary to be established during the 6G standardization process. Sustainability on its three dimensions (environmental, social, economic) also needs to continue to be a cross-cutting concern of future SNS projects, both for the design of the technology and associated infrastructures and their operation, and for the development of 6G-powered usages enabling the sustainability of verticals and society. Tighter collaboration with representatives from these verticals and society should be applied to this end, up to co-development. Flexibility in the design of future systems according to different levels of sustainability priorities should be explored.

Recognizing and driving the industry according to such directions will require further insights and knowledge (also research based), complementary to today's SNS JU projects and activities, supporting a customer, demand, outcome, and mission-oriented approach. The corresponding research and innovation agenda and topics can complement a technology and supply driven approach. In this way, the SNS JU can enrich the current scope, including a stronger approach in support of a future 5G-6G SNS end-to-end provisioning ecosystem.

The work conducted by the SNS-OPS Task 1.3 and the SNS Vision update will be handed over to SNS CO-OP and followed up in the context of this SNS JU CSA.

6 Conclusions

In this Deliverable, the final results of the SNS OPS WP1 activities on Assessment and Planning have been presented. They reflect the work done and results achieved in the second year of the project.

The largest part of the Deliverable addresses the progress assessment in SNS projects of Call 1 and the evaluation of the plans and expected results of Call 2 projects. As in the year before, the questionnaire to new projects has been structured into technical, vision and market aspects. For the Call 1 projects in turn, the aim was to capture their progress towards the SNS programme level KPIs. The analysis revealed that excellent progress has been achieved by Call 1 projects in their first year with e.g., 308 contributions to Standards and 32 patent applications. Also, the plans for Call 2 projects show that they are in line with SNS objectives and priorities. They will complement and strengthen the efforts of Call 1 projects according to their specific priorities. For the next iteration of the project monitoring that is already ongoing at the time of preparing this report, some adaptations have been made to the questionnaire and process to increase the value of the results and to make answering for projects and processing for the CSA more efficient.

For 6G systems, any assessments of technology development and use must be expanded with Key Values (KVs) from environmental, social, and economic domains. Several projects and groups in SNS are active on that. The approaches to address KVIs vary widely across SNS projects, which can be seen as an asset as such a complementary approach, has the potential to capture and measure KVIs yielding a more comprehensive end result.

The Deliverables has also reported on the activities for building SNS momentum and the design of the Work Programme 2025. This activity includes a gap analysis performed mainly based on Call 2 plans but also taking other initiatives and evolutions into account, which most prominently is NetworldEurope with its SRIA, whose latest edition has been completed in February 2025. SNS OPS partners have orchestrated and organised strategic activities to capture and promote the European view on 6G and the achievements of the 6G SNS (at projects and programme level) and have also monitored the development and impact of these results on the evolution of 6G in Europe and worldwide. SNS OPS has also strongly supported the building of the SNS Workprogramme 2025, which has been reported in great detail in this Deliverable.

Finally, SNS OPS has supported the revision of the European 6G Smart Networks and Services (SNS) vision, based on extensive stakeholder consultation including established key organizations and associations, industrial and academic stakeholders, peer-associations, other global regions, and scientist of multi-disciplinary backgrounds, also including specific feedback from the industry partners in SNS OPS. All presented visions, recommendations, positions, and targets are fully aligned with the latest views of key European stakeholders and the SNS plans. However, continued broad vision-oriented analysis, and more collaborative work is still needed to ensure that the ongoing European R&I activities in the various areas of SNS JU will achieve impactful results.

With this Deliverable, the work of SNS OPS on Assessment and Planning has come to an end, but the work will continue in the follow up CSA SNS CO-OP project.

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