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Lead editor	Didier Bourse (ALUI)
Authors	Kostas Trichias (6G-IA), Arda Gureller (EAB), Per Hjalmar Lehne, Hanne-Stine Hallingby and Håkon Lønsethagen (Telenor), Jessica Carneiro (AUS), Claudio de Majo (TRUST-IT), Jim Clarke and Micheal Crotty (SETU), Didier Bourse (ALUI), Pierre-Yves Danet (6G-IA), Rui Aguiar and José Cabaça (IT-Aveiro), Carole Manero (IDATE)
Reviewers	Colin Willcock (NSN) and Pierre-Yves Danet (6G-IA)
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Abstract

This Deliverable presents the first period assessment and planning report, summarizing the SNS monitoring and analysis framework, detailing the analysis of the SNS Phase 1 projects answers to the first questionnaire (technical, vision and market), addressing the SNS roadmap and summarizing the overall definition of the SNS Work Programme 2024.

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Executive Summary

One of the objectives of the SNS OPS CSA is to monitor, evaluate and report the progress of the SNS JU projects. To this end, SNS OPS has developed a comprehensive **monitoring and analysis framework** that has been and will continue to be used to systematically monitor, analyse and document the technological Key Performance Indicators (KPIs) and societal Key Value Indicators (KVIs), as well as other relevant work aspects of SNS JU projects. The KPIs and KVIs of the SNS Phase 1 projects were the basis to build the framework. The **first questionnaire** has been sent to the 33 Phase 1 projects and included 29 questions which were structured in three sections (technical, vision and market). All answers were analysed and a dedicated 6G-IA / SNS OPS webinar was organized on 23/11/23 to present the key findings and insights. The questionnaire to be sent to SNS Call 2023 (Call 2) projects in 1Q24 has been revised, leveraging the first questionnaire experience and how the projects achievements will be qualified and quantified, detailing the targeted SNS metrics methodologies and data collection. In addition, a **questionnaire with an additional set of question** has been developed that will be sent to Call 1 projects. This is intended to get more details on the actual progress of project activities after them having completed their first year.

The monitoring and analysis framework, the related gap analysis and roadmap definition constitute an **important process within SNS** which allows for the comparison of the goals, addressed technologies and verticals of the selected projects of each Phase against the EU and SNS-JU high level goals. Such comparison offers insights with regards to the "adherence to the plan and strategy" of EC and the SNS JU, and constitutes valuable feedback towards the Task Force / Core Team (TF/CT) of experts working on the follow-up SNS JU Work Programmes

This Deliverable D1.2 provides a detailed analysis, conclusions and plans concerning the first assessment of the Phase 1 projects scope and coverage.

Concluding from the **first questionnaire analysis**, the **technical section** responses show that all specific objectives (SO) of the SNS Work Programme (WP) are well matched by the Phase 1 projects. Moreover, a healthy balance and complementarity is detected among the projects, ensuring that *each SO will be addressed by more than one project* and with different levels of scrutiny. From the received responses it can be observed that *Energy Efficiency* is the most popular KPI which 87% of the R&I projects of Phase 1 plan to address. This is followed by *Positioning (accuracy)* and *Reliability* KPIs. There seems to be a trend towards Ultra-Reliable Low Latency Communications (URLLC) research, that will allow for faster and more reliable communication. User Experienced Data rate and Peak Data rate, seem to be the least popular among Phase 1 projects. The projects are looking also at additional KPIs including resource allocation/update, dynamic service chain expansion and capacity efficiency.

In terms of technological focus, *System network architecture and control* is the most addressed topic within the SNS Phase 1 projects. Such a choice makes sense as the investigation of the 6G network architecture in this early stage of research is a reasonable approach and is also in line with the SNS WP. Regarding what technological enablers the projects will work on or make use of, *Artificial Intelligence (AI)* and/or *Machine Learning (ML)* is by far the most popular enabler. 87% of R&I projects will make use of it, followed by orchestration of *Virtual & Cloud Native functionalities (VNF/CNF*.

Regarding what use cases / applications the projects will support, *Digital Twin applications* is top-ranked, addressed by 20 projects. This followed by *Manufacturing/Industry 4.0* and *Multi-sensory Extended Reality* applications. 31 of 33 projects expressed that their use cases and solutions developed and experimented will be replicable and accessible to future experimenters which is of particular interest to Stream C and Stream D projects.

A previous question revealed that the use of AI/ML functionality is almost universal within the SNS Phase 1 projects, as the vast majority will make use of it. Regarding what network/system part or service AI/ML will be used for, most of the Phase 1 projects plan to use AI/ML functionality on the *network management & orchestration layer*. Other areas ranked 2nd and 3rd are *RAN* and *Security*.

Most projects will *validate the technologies developed* in *lab tests*, *simulations* or *advanced testbeds*. Large scale trials are rather at the lower end and are done mostly by Stream D which was expectable in this early stage of the programme. Due to the early stage of the projects, there was only few information provided on dates and locations of testbeds and trials. The *end user equipment* used for testing are mostly

mobile phones, but also IoT sensors and CPEs.

One of the key targets of the SNS programme and related SNS projects is clearly related to the engagement of verticals sectors and SMEs. *Requirement provisioning* is the main engagement method employed by Phase 1 projects to engage vertical sectors. *Device adoption for trialling* and *end-user testing* are other forms of verticals' engagement, showcasing both a significant attention for existing vertical equipment in trial instances. Regarding SME involvement, SMEs are mainly involved as project consortium partners. Some projects also indicate that SMEs are specific technology suppliers, while others promote SME participation through Open Calls.

Most of the projects address *energy efficiency*. The majority of the projects focus on *Design of specific algorithms for energy efficiency*. This is followed by *Device side* and *RAN plane* options, indicating a healthy variability of application of energy efficiency mechanisms.

In terms of SDO impact, the majority of the projects plan to contribute to 3GPP (28 out of 33 projects), while a similar number of projects foresees contributions towards ETSI groups (27 out of 33 projects), but also further standardisation bodies are targeted.

The **vision section** analysis summarizes the responses and learnings from the Phase 1 projects regarding how the vision of the programme and its various sub-topics is addressed. Regarding *societal challenges*, the analysis showed that the focus of the projects is on technology challenges, like *advanced 6G ICT solutions for vertical industries*, and to *accelerate the development and deployment of advanced infrastructures*. This aligns well with the responses observed for the technical questions and with the scope of the SNS Work Programme. The *societal values* addressed ranks *Sustainability and Energy consciousness* at the top. *Native AI* and *Trusted technology* also have high scores. It shows that the first wave of SNS projects have adopted and understood the importance of having sustainability as a key value for shaping 6G. Societal acceptance of AI is a key issue and is connecting with both ethical and trust questions. *Key Value Indicators* (KVI) reported by projects were matched with the Key Values (KVs) table proposed in the 6G-IA White Paper: "What societal values will 6G address". *Economical sustainability and innovation* is dominating above the others, while there is little match on e.g. *Cultural connection* (none) or *Personal freedom* (none).

In terms of how project contribute to the 6G Vision, the responses show that all projects are conscious about *European leadership* and *Contribution to standards*. There is medium focus on *AI*, *Sovereignty and security*, and *Competence.*

As stated above, sustainability is considered by the projects essential for B5G/6G networks. The SNS Work Programme explicitly promotes four specific UN Sustainable Development Goals (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)*. The analysis revealed that the Phase 1 projects have these four SDGs on top of their priorities.

The initial EU stakeholders' vision of what 6G should be led to the SNS programme creation. This initial vision, in general terms, is now being worked on in articulation with multiple projects that were contracted and are being led by the community. SNS OPS makes use of several mechanisms and forms, including Working Groups, questionnaires, related initiatives as e.g. NetworldEurope and its Strategic Research Innovation Agenda (SRIA), etc. This is a cyclic process in which the community is involved and impacts the community and technical groups through the issued reports and results.

The analysis of the **market section** of the SNS OPS questionnaire gave a few interesting insights on the market outlook. Two important trends, perhaps contradictory, refer to the evolution of the market in the next few years: *market fragmentation* versus *rise of a few dominant industrial players*. The fragmentation of the market would be mainly due to the modular architecture that would foster the emergence of new players covering the value chain. Contrariwise, the rise of a few globally dominant enterprises emerging from current incumbents could be linked to the predominance of use-cases requiring the establishment of private networks in most vertical sectors, generating new business opportunities for MNOs.

In terms of *technologies expected to play an important role in the telecommunications market* in the coming years, *AI-based solutions* are predicted to be a game changer for the delivery of high-level and more efficient services. *Energy efficiency solutions* and *Dynamic/zero-touch network management*

solutions are also among the most anticipated innovations to disrupt the market in the coming years. *Industry 4.0/Manufacturing* and *Media/xR* are expected to be the verticals most impacted by the advent of 6G. The ultra-low latency and increased bandwidth in 6G networks, which enables high-speed data processing, coupled with wireless and mobile robotics, are deemed critical for industrial applications.

There are also *obstacles* seen for the deployment of 6G networks. *Deployment costs* are seen as the main obstacle. In particular, some projects indicate the lack of transparency regarding the Return of Investments (RoI). The *lack of demand for unique 6G service*s and *the lack of willingness to allow interoperability* are also seen as notable challenges by 48% and 42% of the projects.

The number of *Key Exploitable Results* (KER) expected to be delivered by projects was widely different among projects. Moreover, each identified very specific results. KERs were thus clustered in three main groups: integration/network technologies, management and security and privacy. Most projects will target medium Technology Readiness Levels (TLRs), i.e., between 4 and 5.

SNS OPS has also actively supported the **SNS Work Programme generation**. One key action in 2023 for the development of the SNS programme was the definition of the SNS Work Programme 2024, and D1.2 also summarizes the related key actions and achievements, including the contribution from SNS OPS and contributing Partners. The draft WP2024 definition was successfully completed in November 2023 and the Call 2024 is now open with deadline for proposals submission on 18 April 2024. SNS OPS is further supporting the development of the SNS / 6G-IA Members momentum and some SNS OPS partners are already engaged in the first pre-definition steps of the forthcoming draft WP2025 definition.

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Abbreviations

3GPP	Third Generation Partnership Project
5G	5th Generation Wireless Systems
5G PPP	5G Public Private Partnership
5GAA	5G Automotive Association
5G-ACIA	5G Alliance for Connected Industries and Automation
AI	Artificial Intelligence
AIaaS	AI as a Service
AIOTI	Alliance for the Internet of Things Innovation
AR	Augmented Reality
BSCW	Basic Support for Cooperative Work
CEF	Connecting Europe Facility
CEPT	European Conference of Postal and Telecommunications Administrations
CPE	Customer Premises Equipment
CSA	Coordination and Support Action
CU / DU	Centralized Unit / Distributed Unit
DIH	Digital Innovation Hub
DPU	Distribution Point Unit
EC	European Commission
ECSO	European Cyber Security Organisation
eMBB	enhanced Mobile Broadband
ERTICO	European Road Transport Telematics Implementation Coordination Organization
ETSI	European Telecommunication Standards Institute
EuCNC	European Conference on Networks and Communications
GHG	Greenhouse Gas
GPU	Graphics Processing Unit
H2020	Horizon 2020
HEU	Horizon Europe
IAFA	Impact Assessment and Facilitation Action
JCAS	Joint Communication and Sensing
KDT	Key Digital Technologies
KER	Key Expected Result
KPI	Key Performance Indicator
KVI	Key Value Indicator
MIMO	Multiple Input Multiple Output
mmW	Millimeter Wave
MNO	Mobile Network Operator

NGO	Non-Governmental Organisation
NPN	Non-Public Network
NTN	Non-Terrestrial Networks
MWC	Mobile World Congress
OBU	On-Board Unit
PCG	3GPP Project Coordination Group
PPDR	Public Protection and Disaster Relief
PN	Public Network
PNI	Private Network Interconnect
PoC	Proof of Concept
PON	Passive Optical Network
PSM	Pre-Structuring Model
R&I	Research & Innovation
RIS	Reconfigurable Intelligent Surface
SB	Steering Board
SDG	Sustainable Development Goals
SDO	Standards Developing Organisation
SNS	Smart Networks and Services
SNSO	SNS Office
SO	Specific Objective
SRIA	Strategic Research and Innovation Agenda
T&P	Trial and Pilot
TB	Technology Board
TF/CT	Task Force / Core Team
TN	Terrestrial Network
TRL	Technology Readiness Level
TSN	Time-Sensitive Network
UAV	Unmanned Aerial Vehicle
URLLC	Ultra Reliable and Low Latency Communications
VNF/CNF	Virtual Network Function / Cloud-Native Network Functions
VR	Virtual Reality
WG	Working Group
WP	Work Package
WP	Work Programme
XAI	eXplainable Artificial Intelligence
xR	Extended Reality
ZTP	Zero-Touch Provisioning

1 Introduction

One of the objectives of the SNS OPS CSA is to monitor, evaluate and report the progress of the SNS JU projects. The SNS OPS WP1 "Assessment and Planning" objectives are to (1) Contribute to SNS strategic R&I orientations, (2) Monitor, evaluate and report about the progress of the SNS JU Phase projects, (3) Review and revitalise the SNS vision, (4) Stimulate future R&I actions ("grow a project pipeline"), (5) Actively contribute in the periodic up-date of the SNS SRIA and (6) Capture and promote the European view on 6G. To achieve these objectives, WP1 is organized in 5 specific Tasks "SNS Progress Assessment" (T1.1), "SNS Roadmapping (T1.2), SNS Vision (T1.3), "Building 6G SNS Momentum (T1.4) and "Metrics Methodologies and Data Collection (T1.5). As detailed in SNS OPS D1.1 "Analysis Framework" [1], WP1 developed the appropriate framework to monitor progress and analyse the technological Key Performance Indicators (KPIs) and societal Key Value Indicators (KVIs) that SNS projects are to achieve. SNS OPS regularly up-dates/upgrades this framework that is and will be used to systematically monitor, analyse and document the KPIs and KVIs, as well as other relevant work aspects of the SNS projects. The KPIs and KVIs of the SNS Phase 1 projects were the basis to build the framework. Section 2 details the SNS OPS monitoring and analysis framework and its on-going evolution. The document also explains how the projects achievements will be qualified and quantified, detailing the targeted SNS metrics methodologies and data collection, as captured in Section 3.

The first questionnaire communicated to the 33 Phase 1 projects included 29 questions and was structured in three sections (technical, vision and market). All answers were analysed and a dedicated 6G-IA / SNS OPS webinar was organized on 23rd of November 2023 to present the key findings and insights. This Deliverable (D1.2) provides the detailed analysis, conclusions and plans concerning the first assessment of the Phase 1 projects scope and coverage, addressing technical, vision and market perspectives, respectively in Sections 4, 5 and 6 of this document.

One key action in 2023 for the development of the SNS programme was the definition of the SNS Work Programme 2024 (WP2024). The Gap Analysis performed on Phase 1 results (prior to the definition of the SNS OPS monitoring framework, done with contribution from SNS OPS partners), the insights extracted and the following discussion with the community and the Work Programme Task Force contributed to the definition of WP2024. The overall definition, including key actions and achievements is detailed in Section 7.

The monitoring and analysis framework, and the related Gap Analysis and Roadmap definition constitute an important process within SNS which allows for the comparison of the goals, the addressed technologies and verticals of the selected projects of each Phase against the EU and SNS-JU high level goals. Such comparison offers insights with regards to the "adherence to the plan and strategy" of EC and the SNS JU, and constitutes valuable feedback towards the Task Force / Core Team (TF/CT) of experts working on the follow-up SNS JU Work Programmes (as detailed in Section 7). The TF/CT may opt to make adjustments to the following Work Programmes to account for smaller or larger deviations from the agreed strategy based on the theme and technologies addressed by the selected projects. The TF/CT is also clearly taking into account the evolution of the overall 6G standardization plans, regulatory plans and policy framework. This feedback loop and available flexibility in the design of the annual Work Programmes is an important element for ensuring that the EU will not stay behind and instead take a leading role in the global Research and Innovation ecosystem in any of the important technological fields and that any potential gap will be quickly identified and addressed.

2 SNS OPS Monitoring & Analysis Framework Evolution

The SNS OPS Monitoring and Analysis Framework has been presented in Deliverable D1.1 [1]. It uses an elaborate questionnaire targeted at SNS JU projects, in order to source critical information from the projects and to extract insights regarding the targeted technologies, use-cases and trials, the overall vision and the market aspirations of SNS projects. Processing such complex input, originating from a large number of projects in order to draw meaningful insights and to distil the most critical pieces of information is not a trivial task. This section explains the approach of the SNS OPS partners to perform the analysis of the received responses.

Moreover, as new R&I projects join the SNS JU portfolio on an annual basis, targeting different technologies and approaching solutions at different maturity levels (as the SNS JU progresses in its next phases / Call by Call), it becomes critical to adapt and up-date/grade 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. The process to evolve the SNS OPS framework is also explained in this section.

2.1 SNS OPS Questionnaire – Input Analysis Overview

The 1st edition of the SNS OPS questionnaire which was circulated to all 33 R&I projects of SNS JU Phase 1 (35 projects in total – of which the 2 CSAs were not addressed), consisted of three sections, Technical, Vision and Market and contained 29 questions in total, that all projects were requested to respond to. More specifically the following breakdown of questions applied for the SNS OPS Questionnaire – Edition 2023:

- Technical Section: 15 Questions in total (11 multiple choice + 4 free text questions).
- Vision Section: 6 Questions in total (4 Multiple choice + 2 free text questions).
- Market Section: 8 Questions in total (4 Multiple choice + 4 free text questions).

Multiple choice questions were selected for cases where a potential answer space could be defined a priori, thus enabling more straightforward post-processing and grouping of responses. However, all multiple-choice questions also allowed for additional responses and comments by the project representatives via the "*elaboration text*" box, which accompanied each multiple-choice question (in free text format). As such, and since all 33 R&I Phase 1 SNS JU projects responded to all the questions SNS OPS partners had to process **a total of 957 responses** (29x33) and to extract useful insights and conclusions.

Additionally, different groupings were considered (e.g., grouping answers per SNS Stream, where it made sense), and verification of answers was also requested by projects (1 additional iteration), which further increased the processing load and complexity.

The analysis performed by the SNS OPS partners follows the methodology presented in Table 1.

Table 1: SNS OPS Questionnaire – Analysis methodology

Question Type	Analysis Item	Explanation
Multiple Choice Questions	Overall Phase 1 results grouping	The first stage of analysis focuses on the overall grouping of the received responses to the multiple-choice questions to establish the general priorities/focus of Phase 1 projects. All project responses are added up, to establish the most popular research directions/ technologies / KPIs / use-cases, etc, according to the possible answer space. The maximum potential score any given answer may obtain is 33, in case all projects respond that they address a specific item / technology / solution. The results are plotted in bar charts, which provide an immediate and straightforward representation of the

		received answers and allow for some immediate high-level insights, such as the most and least popular responses for any given question, whether all topics in the answer space are well covered by Phase 1 projects and whether any potential key answers are not covered (or sparsely covered) by the projects. This first level of analysis, also allows to detect outliers and/or unexpected results, which may indicate the need for further, more in-depth analysis. The Key insights drawn by each of the created bar charts are noted next to the charts.
	Additional insights from elaboration box	The third stage of analysis concerns the responses provided in the "*elaboration text*" box of each multiple-choice question, which usually include either additional answers to the questions (that were not included as possible choices in the initial answer space) and/or comments elaborating on the responses provided. Such input has proven valuable in clarifying some of the answers provided and/or in expanding the possible answer space. In case some of the provided elaboration text by different projects, indicated the same additional response (e.g., another popular option/item that was not included in the initial multiple-choice list), the previously create bar chart for this particular question was up-dated to include this new item[2]. Moreover, completely new graphs/ bar charts may also be created based on the received answers in the elaboration box, to indicate the range of responses received (as is the case with identifying specific standardization WGs that the projects are targeting). In other cases, comments provided in the elaboration text, assist in drawing additional conclusions and insights that could not be drawn solely based on the multiple-choice answers. These insights are also included in the analysis of each question.
	Results grouping per Stream	In certain cases where differentiation in answers is expected based on the Stream each project belongs to, or in cases where additional insights are expected to be gained based on the break-down of the answers on a per Stream basis, such an analysis also takes place. The project answers are grouped per Stream and additional graphs are created, depicting the score of each question per Stream. This analysis provides additional insights and can assist in validating the scope and focus of the selected projects. Additionally, the per-Stream analysis allows for the categorization of the expected results, and facilitates the gap analysis with regards to the targets of the SNS JU Work Programme.
Free Text Questions	Manual grouping of responses	The processing and analysis of free-text responses is considerably more challenging, as different terminology may be used by the different projects. However, valuable insights my still be gained, as the projects have the freedom to elaborate on a certain question. The first level of analysis for free-text questions, is an attempt to create a manual grouping of projects based on their responses, that would allow for a

[2] Such responses are also taken into account for the annual update of the questionnaire, where the questions and possible answers are updated to reflect the project responses and to create a more complete questionnaire for the following edition.

		more straightforward representation (e.g., in the format of a table or graph) of the received answers, and hence could also more easily lead to some key insights. In several cases, this is feasible and allows for the creation of a "bird's-eye-view" of the approach that the projects are taking with regards to a certain issue. As this analysis stage, requires the SNS OPS partners to interpret the received answers, a second stage of validation is required by the projects, after an initial categorization has been performed by SNS OPS partners. The outcome of this categorization is shared again with the project proponents, and they are requested to either validate the SNS OPS understanding of their answer or to provide the necessary corrections.
	Additional individual insights	The second stage of analysis of the free-text questions, regards the received answers that cannot possibly be grouped or categorized. In many occasions, these answers are very project-specific and do not allow for general insights on behalf of the SNS programme, however they do shed light into the specific approach, work, expected results and vision of certain projects. Such individual insights are also valuable and may also point towards potential "hidden gems", or obscure research directions/technologies, which may prove promising. Especially in the initial stages of research (with low TRL), it is important to identify all aspects investigated by SNS projects.

The methodology described in Table 1 was followed for all three sections of the SNS OPS questionnaire, and the results of the analysis along with the key insights emerging from each question are presented in Sections 4, 5 and 6 for the Technical, Vision and Market aspects, respectively.

2.2 SNS OPS Framework Evolution

As previously emphasized, a primary goal of SNS OPS involves the vigilant monitoring, thorough evaluation, and detailed reporting of the progress within the SNS JU projects. To facilitate this, SNS OPS has developed an extensive framework. This framework is meticulously designed to monitor, analyse, and document the progress through both technological Key Performance Indicators (KPIs) and societal Key Value Indicators (KVIs). The KPIs and KVIs established during the SNS Phase 1 projects have been instrumental in shaping this robust framework.

Based on the feedbacks and responses to the first edition of the questionnaire, SNS OPS undertook a comprehensive revision of the questionnaire to ensure its relevance and applicability for future SNS Calls projects. This revision process included a thorough review and adjustment of the questions to better align with the unique status and progression of Call 2023 projects (Call 2), which differ from those in Phase 1. The goal was to create a more tailored and effective tool for assessing and understanding the specific goals, challenges, values, and visions of these upcoming projects, thereby enhancing the accuracy and usefulness of the data collected. The overall process was also improved, considering the following perspectives:

- To ensure ongoing tracking and monitoring of the KPIs and KVIs, the SNS OPS consortium has agreed to distribute the questionnaire on an annual basis. The first quarter of each year has been identified as an appropriate period for communicating the questionnaire. A series of specialized internal meetings was organized to effectively accomplish this objective. Feedback on each existing question has been collected from contributors of WP1 as well as other participants in SNS OPS. This feedback has been meticulously stored and respective actions were undertaken leading to an extensive review and refinement process following detailed

discussions.

- In certain cases, rephrasing of questions and wording clarifications were applied to make the questions clearer and less ambiguous. This also meant providing additional details, defining abstract concepts and making efforts to guide responders more effectively towards focusing on the pertinent market challenges. Where necessary, certain questions were consolidated to enhance clarity and coherence. Moreover, certain questions that did not seem to contribute significant value or provide significant insights from the 1st edition of the questionnaire, were removed. Conversely, new questions were introduced, with a particular emphasis on programme KPIs to enrich our understanding and analysis.
- To efficiently manage and cater to the differing requirements of Phase 1 and Call 2023 projects (Call 2), a meticulous approach has been taken in the documentation process. After the questionnaire review, it seemed obvious that the same questionnaire could not be sent out to projects that have nearly completed already their first year of their operation and to the new projects commencing their activities in January 2024. Consequently, it was decided to develop two separate and specialized questionnaire sections. The first section is exclusively dedicated to Phase 1 projects, designed to accurately track, and record their specific progress and data. Similarly, the second section (structured again in the same three sub-sections) is tailored for Call 2 projects, ensuring that their unique stages of development and specific needs are appropriately documented and analysed. This bifurcation not only streamlines the data management process but also enhances the precision and relevance of the information collected, thereby facilitating a more effective and targeted approach to project assessment and support.
- The first edition of the Questionnaire was prepared and sent out as an Excel document. This worked well but also brought some extra workload to store all responses and manually copying information during the analysis phase. As a result, the updated questionnaires will be available in a user-friendly online format, enabling recipients to respond with ease. Their responses will be automatically recorded and converted into Excel file format, eliminating the need for any further manual processing.

This strategic initiative is designed to collect valuable insights and feedback, which SNS OPS plans to meticulously analyse and exploit by June 2024. SNS OPS partners are committed to a thorough examination of the responses to ensure the extraction of meaningful data and trends. This process is instrumental in shaping our understanding of the projects progress and challenges, allowing the entire SNS community to tailor their respective strategies and support mechanisms effectively.

It has to be noted that a dedicated SNS OPS / 6G-IA webinar [2] was organized on the 23rd of November 2023 to present the key outcomes / analysis of the first edition of the questionnaire, addressing all technical, vision and market perspectives. Similar webinars are planned to be further organized in 2024+ to synchronize the 6G-IA members and overall community on the projects' development.

3 JU Metrics Methodologies and Data Collection

As mentioned before, the results of each annual edition of the questionnaire are set to be reported back to the SNS JU Office (SNSO), providing essential insights into the progress, gaps and future direction of the R&I projects. Moreover, this data will play a central role in populating two online radars. The first radar will display the programme KPIs, offering a visual overview of the SNS achievements and objectives at programme level. The second radar will focus on the technical KPIs targeted by the SNS JU R&I projects, giving stakeholders a clear view of the specific technical advancements and key metrics achieved by the SNS project R&I activities. These radars will enhance transparency and support strategic decision-making within the SNS JU ecosystem.

As the Phase 1 projects are now operational for 1 year, it is important to be able to track their achievements and tangible outcomes, besides their vision and targeted end-results. To that end, additional questions targeted only at ongoing Phase 1 projects (i.e., not Call 2023 projects which started in January 2024) have been added to the SNS OPS questionnaire. These additional questions are designed to help monitor programme-level KPIs and contribute to the SNS Programme KPIs radar. They also aim to provide a more in-depth understanding of each project concrete outcomes, impact, and contributions to the SNS programme. This new set of questions, along with the overall SNS OPS Monitoring framework and data collection methodology described in D1.1 [1] constitute the SNS ***JU Metrics collection methodology***.

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

The questionnaire also delves into the practical application of project work, asking about the number of Proof of Concepts (PoCs), Lab Tests, Trials or Pilots executed, also matching them to the appropriate TRL level, including specifics like location, date, and focus area and the replicability of some use-cases. This also encompasses queries about the usage and contributions to open-source communities, highlighting collaborative and open innovation. Energy efficiency is a focal point, with questions regarding its improvement percentages in experiments or trials. Finally, projects are asked to reflect on the challenges faced during their first year, their resolutions, and how the CSA projects or SNS JU office can assist in overcoming future challenges. The exact SNS JU metrics to be collected are provided and explained in Table 2.

This section of the questionnaire will be addressed to all active SNS projects on an annual basis, targeting the release of the questionnaire by mid-Q1 of each year, the collection of the project responses by the end of Q1 each year, and the availability of the processed results and gained insights before the end of Q2 each year. The processed results and insights will be used to populate the necessary progress and monitoring reports undertaken by the respective operational CSA project and required by the SNS JU office. Moreover, the results of the questionnaire will also be shared with the various working bodies of the SNS, e.g., the Steering Board (SB), the Technology Board (TB), the SNS Project Working Groups (WGs), etc., to facilitate their operation and to provide insights into the aggregate accomplishments of the SNS projects for the previous year. The first edition of this analysis regarding the achieved metrics of the 33 SNS JU R&I Phase 1 projects during their first year of operation (2023), are expected to be available by June 2024.

Table 2: JU Metrics to be collected

#	Question	Unit Of Measurement	Relevant KPI
1	How many ***events/workshops*** has your project ***organised***? What is the approximate number of attendees per workshop?	# of events organized (webinars/workshops, sessions, panels) & approximate number of participants per event.	Outreach

2	How many **events/workshops**, not organized by your project, has your project **contributed to**, i.e., presentation, keynotes, panel, etc.? What is the approximate number of attendees per workshop?	# of events participated (webinars/workshops, sessions, panels) & approximate number of participants per event.	Outreach
3	How many **peer-reviewed journal / magazine articles** has your project authored? What was the main theme of each article (e.g., resource optimization, energy efficiency solution, cybersecurity, data privacy, etc,))? Please indicate whether each publication was the result of collaboration among SNS projects and/or SNS SB, TB or WG outcome, resulting in an achieved technological consensus solution.	# of published journal articles	Scientific Excellence I
4	How many ***conference papers*** has your project authored? What was the main theme of each publication? Please indicate whether each publication was the result of collaboration among SNS projects and/or SNS SB, TB or WG outcome, resulting in an achieved technological consensus solution.	# of published conference papers	Scientific Excellence II
5	How many ***book chapters*** has your project authored? What was the main theme of each chapter? Please indicate whether each book chapter was the result of collaboration among SNS projects and/or SNS SB, TB or WG outcome, resulting in an achieved technological consensus solution.	# of published book chapters	Scientific Excellence III
6	How many ***white papers*** has your project authored? What was the main theme of each publication? Please indicate whether each publication was the result of collaboration among SNS projects and/or SNS SB, TB or WG outcome, resulting in an achieved technological consensus solution.	# of published white papers	Scientific Excellence IV
7	How many ***contributions to standards*** organizations have been submitted by project partners, stemming directly from project related activities? Please indicate all SDOs, bodies and WG that contributions have been made.	# of standards contributions with proper referencing	Impact
8	How many ***IPR*** **(patent) applications** have been submitted by project partners, stemming directly from project related activities? In case any of these patent applications have already been granted, please mention that in the comments and provide the relevant patent information.	# of IPR created (submitted to EPO or other body)	Impact
9	How many **PoCs (TRL3)** and/or **Lab Tests (TRL4)** has your project executed?	## of Tests/ Proof of Concepts (place-date)	Number of Number of

	Please provide a place, date and test focus area, # of end devices and # of vertical stakeholders engaged for each Tests/PoC.		PoCs, Pilots, Trials
10	How many **Trials (TRL5/6)** or **Pilots (TRL7)** has your project executed? Please provide a place, date and test focus area, # of end devices and # of vertical stakeholders engaged for each trial/pilot.	# of large-scale trials (place-date)	Number of PoCs, Pilots, Trials
11	What ***open-source*** solutions has you project made use of?	# and name of open sources used in the project	
12	How many **open-source contributions** has your project submitted and how many accepted to relevant communities? Please provide the key focus of each demonstrated solution.	# open-source contributions	Number of Open-Source Contributions
13	Has your project addressed **Energy Efficiency** in the experiments? If yes, what is the observed improvement of energy efficiency in your experiments/trials (in %)	% increase	Energy efficiency of Telecom. Nets
14	***High-risk research***: Which percentage of activities in your project are related to TRL 1 and 2, which correspond to high-risk research?	% of allocated funding budget to TRL 1 and 2 activities	General
15	What **obstacles / challenges** did you face during your first year of operation? Were you able to overcome/resolve them? Is there anything the CSA projects or the SNS JU office can do, to help you overcome these challenges in the future?		General

4 SNS Technical Progress Assessment & Road-mapping

This section describes the first overall SNS technical progress assessment and road-mapping, summarizing the analysis led by SNS OPS WP1 partners based on the answers received from Phase 1 projects on the technical section of the first edition of the SNS OPS questionnaire. This section also addresses the SNS gap analysis and SNS roadmap and highlights the related HEU partnerships & EU national initiatives, in direct connection with the overall definition of the SNS Work Programmes, described in details in Section 7 for the WP2024.

4.1 SNS OPS Questionnaire – Technical Section Analysis

This sub-section details the analysis and conclusions related to the 15 technical questions raised in the questionnaire.

4.1.1 SNS Project Matching to Work Programme Specific Objectives

Question T1: What is the main planned technology outcome or the key technological improvements targeted by your project?

The responses to this question from all 33 projects from Streams A, B, C, and D 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 can be found in Appendix A. With this information, SNS OPS has categorized all SNS projects in terms of the SOs within the Streams they are addressing.

Based on the responses to this question on technology outcomes, the following 4 tables summarize the SNS projects technology contributions towards the SOs in their respective SNS Streams, quantifying the Primary and Secondary SOs.

Following an initial analysis, SNS OPS requested the projects to verify that the analysis is correct in terms of whether this is their Primary SO and whether these other SOs identified as Secondary are correct and complete (whether any are missing).

Note: **Primary** means that the text provided seemed to indicate that this was the Primary SO that the project was addressing. Secondary means there was something in the response that indicated the project was also addressing this SO but perhaps not as a Primary SO. If the cell is left blank, we didn't find any text in the response about this objective.

Table 3: SNS Project matching to WP Specific Objectives – Stream A

	Stream Name	A-SO1	A-SO2	A-SO3	A-SO4
A1	Green Radio Technology	Secondary	**Primary**	Secondary	Secondary
A2	Ubiquitous Radio Access	Secondary	Secondary	**Primary**	Secondary
A3	Sustainable Capacity Networks	**Primary**	Secondary	Secondary	Secondary
A4	Evolved Architecture for Global Green Systems	Secondary	**Primary**	Secondary	Secondary
A5	Edge Computing Evolution	Secondary	Secondary	Secondary	**Primary**
A6	Trustworthy and Reliable End-to-end connectivity Software platforms	**Primary**	Secondary	Secondary	Secondary
A7	Real-time Zero-touch Service Technologies	**Primary**			

Table 4: SNS Project matching to WP Specific Objectives – Stream B

	Stream Name	B-SO1	B-SO2	B-SO3	B-SO4	B-SO5	B-SO6	B-SO7
B1	System Architecture	4 Secondary	-	1 Primary 1 Secondary	2 Primary	-	1 Primary 1 Secondary	1 Secondary
B2	Wireless Communication Technologies and Signal Processing	5 Secondary	-	1 Primary	-	-	1 Primary	3 Primary
B3	Communication Infrastructure Technologies and Devices	1 Primary 4 Secondary	1 Secondary	-	1 Primary	1 Primary 1 Secondary	1 Primary 1 Secondary	1 Primary 2 Secondary
B4	Secure Service development and Smart Security	4 Secondary	4 Primary	1 Secondary	1 Secondary	-	1 Secondary	-
B5	6G Holistic System	1 Secondary	1 Secondary	1 Secondary	1 Primary	1 Secondary	1 Secondary	1 Primary

Table 5: SNS Project matching to WP Specific Objectives – Stream C

Stream Name	C-SO1	C-SO2	C-SO3	C-SO4	C-SO5	C-SO6	C-SO7
SNS Experimental Infrastructure	3 Primary	2 Secondary	1 Secondary	1 Secondary	3 Secondary	1 Secondary	2 Secondary

Table 6: SNS Project matching to WP Specific Objectives – Stream D

Stream Name	D-SO1	D-SO2	D-SO3	D-SO4
SNS Large Scale Trials and Pilots (LST&Ps) with Verticals	2 Primary 2 Secondary	4 Secondary	1 Primary 3 Secondary	1 Primary 3 Secondary

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 Phase 1 projects. Moreover, a healthy balance and complementarity is detected among the projects, ensuring that each SO will be addressed by more than one projects and with different levels of scrutiny, i.e., providing higher confidence in the drawn conclusions and allowing for cross-verification of results.

4.1.2 Addressed Key Performance Indicators (KPIs)

One of the most important indicators of the work targeted by the projects, are the KPIs that are foreseen to be measured and used for the validation of the performance of the developed solutions/technologies

under various circumstances. There have been several main KPIs that are traditionally used to evaluate the performance of the mobile networks themselves under varying conditions and/or the performance of specific technologies/features. In order to obtain some first insights into the expected KPIs to be measured / delivered by each project the following question was included in the questionnaire, regarding the expected use of the 10 most common network KPIs. Figure 1 depicts the received answers from the SNS Phase 1 projects in a bar graph.

Question T2: Which of the following main KPIs will your project address?

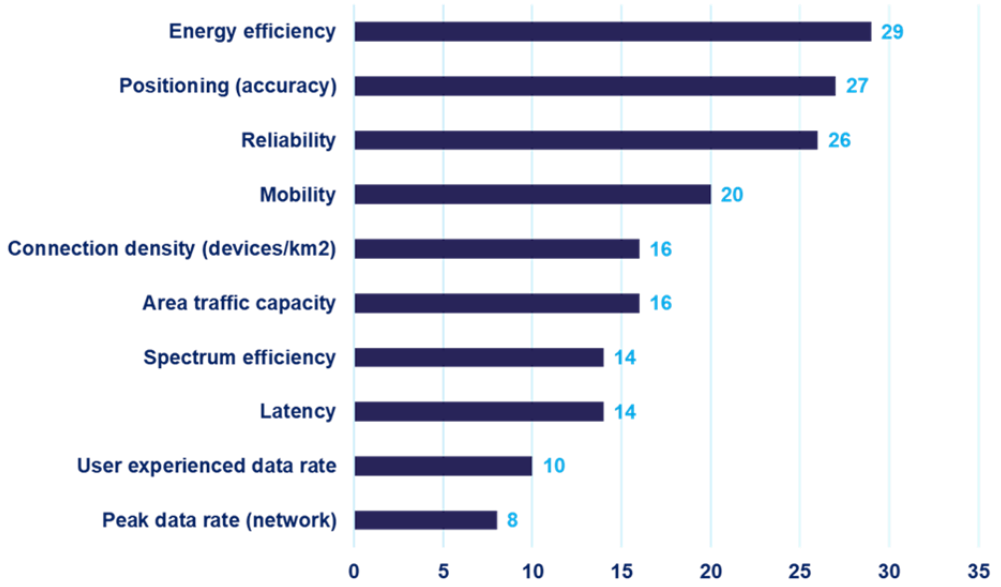

Figure 1: Most popular KPIs addressed by SNS Phase 1 projects

From the received responses it can be observed that *Energy Efficiency* is the most popular KPI which 87% of the Research and Innovation (R&I) projects of Phase 1 are expected to address. This does not come as a surprise as the entire SNS Work Programme 2022 was oriented towards improvements in energy efficiency. Following very closely, *Positioning accuracy* and *Reliability* are also very popular with Phase 1 SNS projects, which seem to investigate technologies that will significantly enhance both these KPIs.

The research effort of the Phase 1 projects seems to cover multiple other aspects and KPIs in a fairly balanced mode, as a good number of projects seem to cover KPIs such as *Mobility, Connection Density, Area Traffic Capacity, Spectrum Efficiency* and *Latency*. These group of KPIs indicate that there seems to be a trend towards Ultra-Reliable Low Latency Communications (URLLC) research, that will allow for faster and more reliable communication, while also enabling the simultaneous service provisioning to a large number of devices with differentiated service requirements.

It is interesting to notice that eMBB related KPIs such as *User Experienced Data rate* and *Peak Data rate*, seem to be the least popular among Phase 1 projects, despite the fact that these type of KPIs seemed to be the top priority during the early stages of 5G network development. This may indicate that since 5G seems to have accomplished to a significant degree its target with regards to Data rates, and eMBB services were the first services to be supported by 5G networks, the interest of the research community is turning to other types of services as the research and development stage of B5G and 6G networks is setting off.

In an attempt to examine additional correlations of work among the projects of the same Stream of SNS, the projects responses were also categorized based on the Stream that each project belongs to. Figure 2 depicts the percentage of projects of a specific Stream that address each of the 10 most popular KPIs. As the number of projects per Stream varies[3], the percentage of projects per Stream is depicted.

[3] Stream A consists of 7 projects, Stream consists of 19 projects, Stream C consists of 3 projects and Stream D consists of 4 projects. An indication of 100% would mean that all the projects of that Stream address the specific KPI.

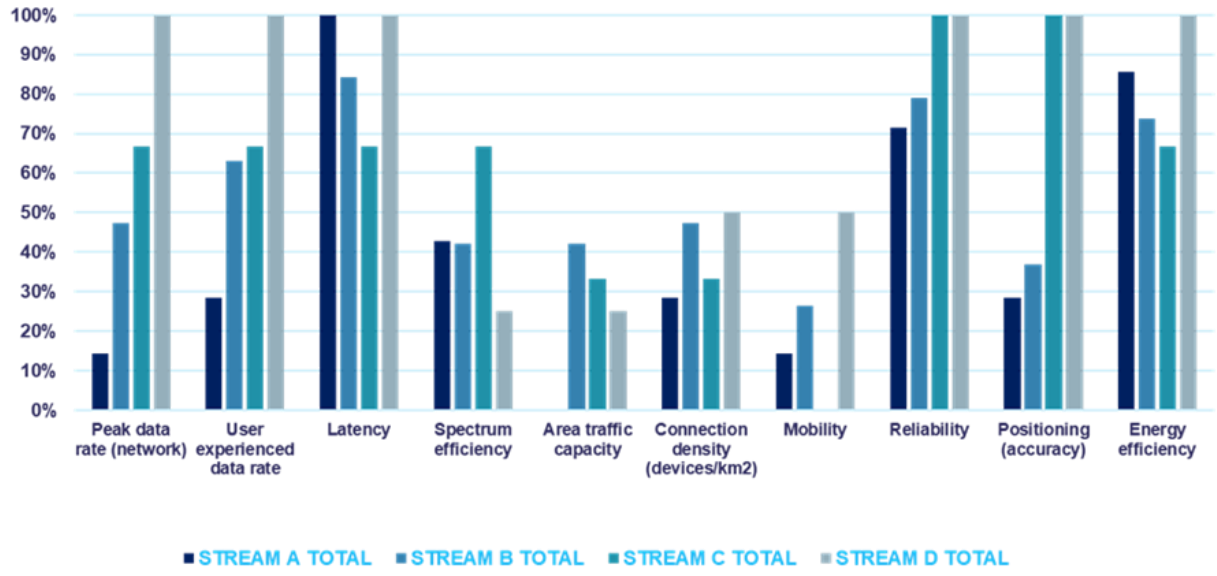

Figure 2: Most popular KPIs addressed per Stream of SNS Phase 1

By examining Figure 2, it can be seen that Stream D projects cover all 10 main KPIs and 6 out of 10 KPIs are covered by every Stream D project. This is a very positive insight, as Stream D projects are onboarding additional experimenters (via their Open Calls) so offering a good variety of KPIs that may be used to validate experimenters' solutions is an important aspect. Stream C projects, which offer the major experimentation facilities, also offer a large variety of KPIs, with only *mobility* not being addressed, as the Stream C facilities of Phase 1 where not focused on such aspects, and specialized facilities are required to cover use-cases with strong mobility aspects.

Overall, it can be observed that *latency*, *reliability* and *energy efficiency* are indeed the most popular, with Stream A and D projects especially addressing them to a large percentage. Stream B projects also provide a good coverage of KPIs, which is nicely distributed among them.

Based on the above presented analysis of the aggregate and the per Stream responses for question T2, the following key insights may be drawn:

Key Insights

- Good coverage of all main KPIs by SNS Phase 1 projects.
- URLLC type KPIs & Energy Efficiency are the most popular.
- There seems to be a shift of interest from eMBB type of services to URLLC type of services.
- Stream C & D projects seem to cover almost all main KPIs (offering them to experimenters)

Besides the above 10 main KPIs, the projects were offered the opportunity to mention any additional KPIs that they will be addressing as part of their activities. These KPIs could be network related or event use case specific. By asking the projects to mention the additional KPIs that will be addressed as part of their activities a good overview of the entire validation space that is relevant for Phase 1 projects may be obtained. The formulation of this question (T3) is shown below, while the results of the received answers by the projects are depicted in Figure 3.

Question T3: Will your project address additional KPIs? If yes, which ones?

The received responses covered a wide space of KPIs, from more generic or network oriented, down to very specific ones, used for the evaluation of specific scenarios or use cases. In total, ***31 additional KPIs*** were mentioned by the Phase 1 projects. Figure 3 depicts the 12 KPIs that were mentioned more than once by the projects (2 times or more) and ranks them according to popularity. It can be observed that *resource allocation* KPIs, along with *dynamic service chain expansion* and *capacity efficiency* KPIs, were the most popular. Additional KPIs were mentioned in several important categories such as cyber-

security, sustainability, service provision timing and more, however the KPIs were so diversified that no straightforward common classification was possible.

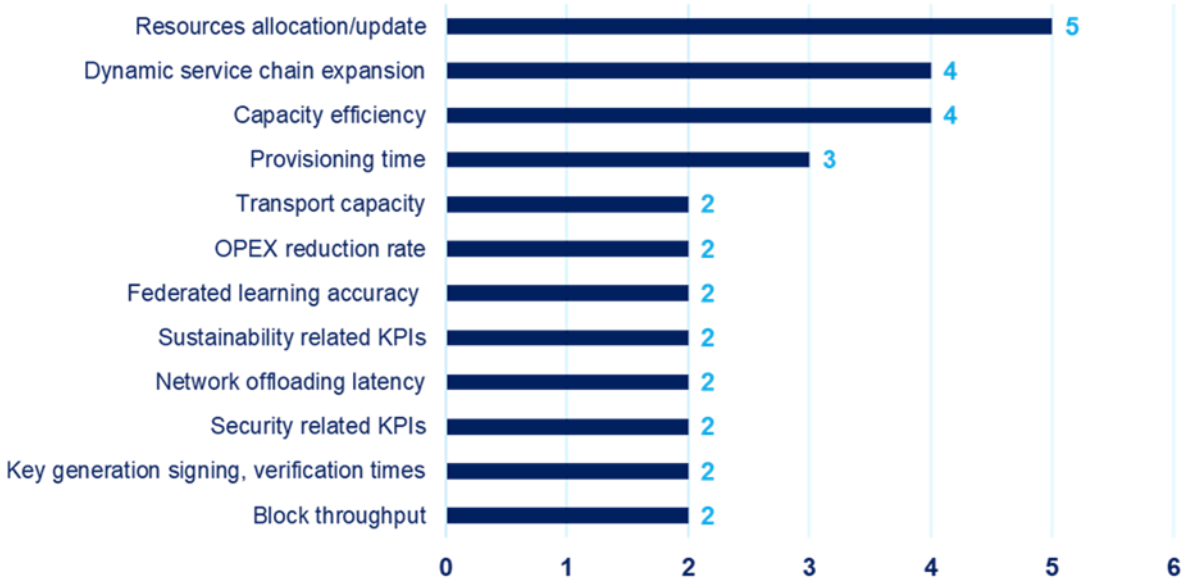

Figure 3: Additional KPIs addressed by SNS Phase 1 projects.

Key Insights

As mentioned before, 19 additional KPIs were mentioned only once by the projects and correspond to very specific fields of research or dedicated scenarios that some of the projects are investigating. These KPIs can be categorized as follows:

- *Security Related KPIs*: cyberattack detection rate, Resistance to adversarial attacks, etc.
- *Sustainability related KPIs*: resource utilization rate/efficiency, signalling overhead, Scalability.
- *Non-Terrestrial Network (NTN) terminal related KPIs*: antenna aperture, power consumption, frequency agility, etc.
- *NTN constellations KPIs*: number of flying nodes, feeder links capacities, link budgets, etc.
- *AI/ML related KPIs*: accuracy, AI training performance, inference latency, AI safety, etc.
- *Determinism related KPIs*: packet delay variation, predictability, etc.

Overall, based on the above analysis of both main and additional KPIs, it can be observed that the SNS Phase 1 projects offer a very good coverage of the main networking KPIs while also offering a large variety of more specific KPIs, thus enabling the testing and validation of a wide range of technologies, features and use cases.

4.1.3 SNS Project Technological Focus

Two questions were asked, in order to get a better understanding of the technological focus of the SNS Phase 1 projects and the technologies, features and mechanisms investigated within each project, along with the precise network or service aspect being investigates. The formulation of the first question focusing on the network aspects and/or technologies being addressed within each project is shown below (T4), while Figure 4 depicts the analysis of the received answers.

Question T4: Which B5G/6G network part / aspect and/or technology will your project address?

By examining Figure 4 it can be observed that *System network architecture and control* is the most addressed topic within the SNS Phase 1 projects. Such a choice makes sense as the investigation of the 6G network architecture in this early stage of research is a reasonable approach, and nicely aligns with the scope of the SNS Work Programme (WP). Four more topics stand out, that attract the attention of multiple Phase 1 projects, namely E*dge & Ubiquitous computing*, *Radio Technology & signal*

processing, *Devices & components* and *Network and Service security*. Once again these four topics align very well with the scope and focus of Phase 1 of the SNS as laid out in the WP, and focus on key aspects that should be investigated in the early stages of research. As such, the Phase 1 projects achieve very good coverage of the main topics of the WP, while the redundancy offered and the different approaches / mechanisms that will be investigated by each project for similar topics, will provide additional insights and opportunities for comparative studies.

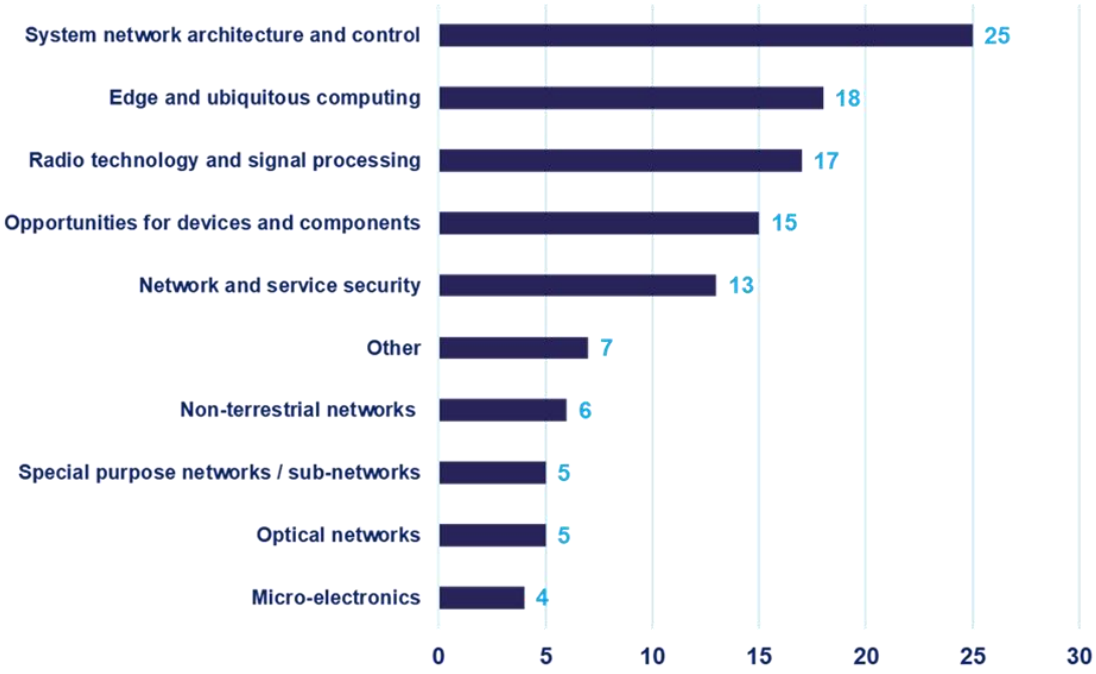

Figure 4: Network parts/aspects and/or technologies addressed within SNS Phase 1 projects

Additional topics of decreasing popularity, are also investigated by the projects, covering more technological sectors, such as *NTN*, *special purpose networks*, *optical networks* and more. The projects also mentioned additional topics of research that are being investigated (not depicted in Figure 4, as they were too specific) such as Digital Twinning approaches, Joint Communication and Sensing (JCAS), spectrum management and more.

The above classification also assists in identifying the less well covered areas by the first wave of SNS projects, which is valuable information for the shaping of the follow work programmes of SNS. In this way, a holistic approach is taken by SNS across all its phases, ensuring that all areas and topics of interest are well covered across multiple phases, ensuring that EU research remains at the fore front of development in all key areas.

A further processing of the responses per Stream took place, in order to establish how the different topics are covered according to the various Streams and their respective scope based on the WP 2022. Figure 5 depicts the analysis of the per Stream analysis of question T4.

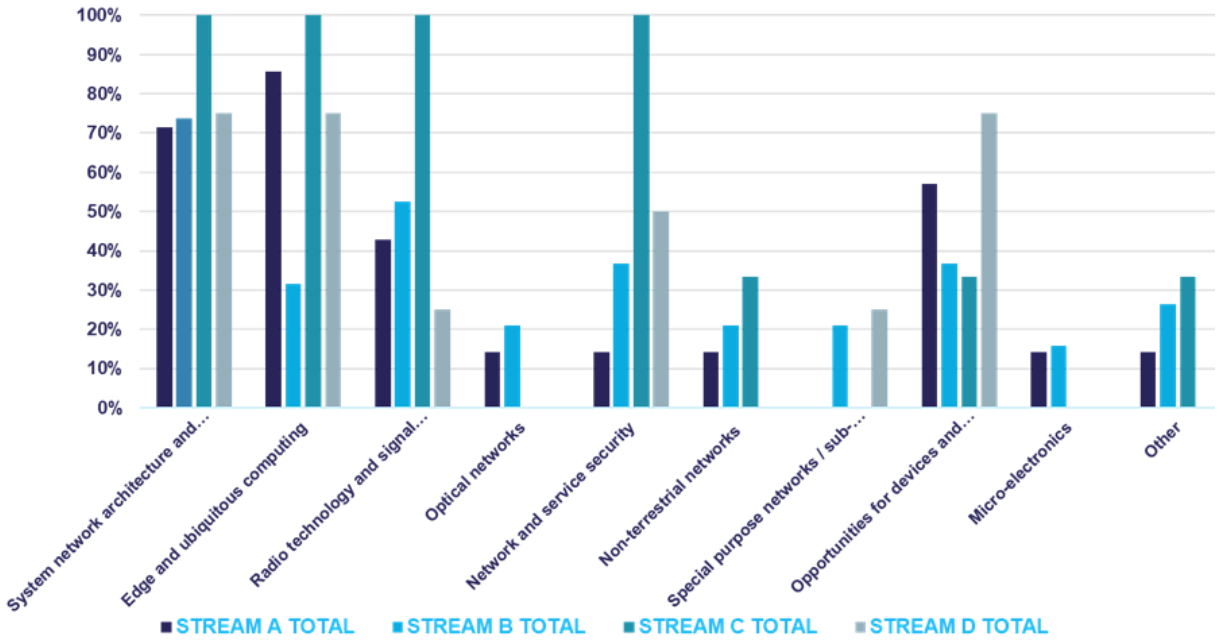

Figure 5: Network parts/aspects and/or technologies addressed per Stream of the SNS Phase 1 projects

From Figure 5, it can be observed that the addressed technologies per Stream nicely follow the respective WP 2022 guidelines and scope for each of the Streams. Moreover, it is interesting to note that all 3 Stream C projects seem to address *Network Architecture*, *Edge computing*, *RAN & signalling* aspects & *Security* issues. Stream D projects cover a broad range of technologies but do not address for the time being *optical networks*, *NTN* and *micro-electronics*. This gap is covered by the dedicated Stream B projects on *NTN* and *optical networks*, while a *micro-electronics* lighthouse project has already been commissioned for WP2024. Finally, Stream A projects also address a wide range of technologies, showcasing good overlap and diversification at the same time.

Based on the above presented analysis of the aggregate and the per Stream responses for question T4, the following key insights may be drawn:

Key Insights

- Good coverage of all major technologies and significant diversification can lead to cumulative and well-rounded insights.
- The distribution nicely matches the SNS-JU Stream focus.
- Identification of less well covered areas provides helpful insights for the creation of the follow up WPs.

Besides the technologies and network aspects being addressed by each project, it very interesting to also discover the exact technological enablers that each of the projects will use for their research and to instantiate their evaluation and validation approaches. To that end an additional question was asked to the projects, to identify the main technological enablers that they will make use of. The exact formulation of question T5 is provided below, while the analysis of the received responses is shown in Figure 6.

Question T5: Which technological enablers will your project work on / make use of?

The analysis of the responses to question T5 clearly shows that *Artificial Intelligence (AI)* and/or *Machine Learning (ML)* is by far the most popular enabler (87% of R&I projects will make use of it), and that Phase 1 SNS projects plan to make heavy use of it, as part of their proposed solutions. This is an expected outcome as AI/ML functionality is indeed one of the main drivers of B5G and 6G technology evolution, and 6G is predicted to offer native AI support. The second most popular enabler is the use and orchestration of *Virtual & Cloud Native functionalities (VNF/CNF)*, which again makes sense as the softwarization and cloudification of the network is expected to be further developed and enhanced in the 6G era.

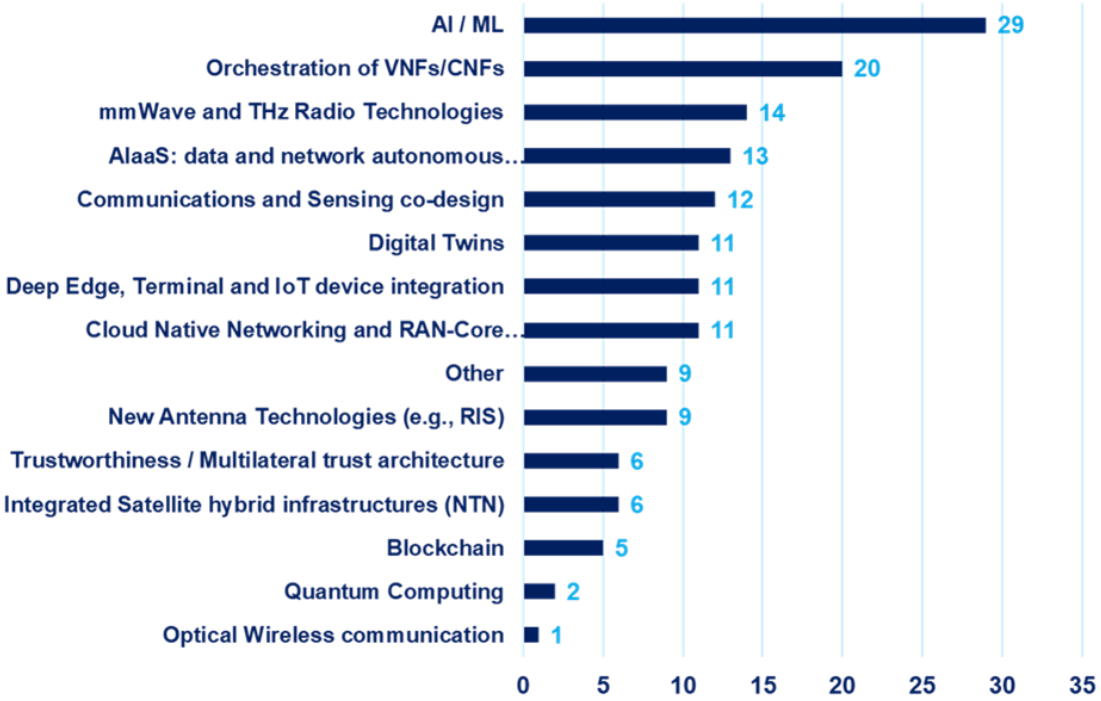

Figure 6: Main technological enablers being used by SNS Phase 1 projects

Several additional enablers are mentioned by the projects, presenting a good coverage of multiple promising technologies and offering research diversification opportunities. Some of the most prominent enablers are *Digital Twinning, mmW & THz technologies, Communication & Sensing co-design, Deep Edge and Terminal/IoT device integration, Reconfigurable Intelligent Surfaces (RIS)* and more. These technologies are indeed in the forefront of global 6G research, and the SNS Phase 1 projects seem to have a good footing to contribute to the global R&D effort with meaningful insights.

Additional technological enablers, such as *NTN, Blockchain, Quantum computing* and more, are used by several projects, but with smaller coverage, as can be seen by Figure 6, while under the *other* category, several very project-specific enablers such as *Cryptographic enablers*, and *Programmable photonic circuits* where also mentioned by some projects. Based on the above analysis it can be concluded that the SNS Phase 1 projects provide a very good coverage of the key technological enablers investigated globally, ensuring EU research remains relevant on the global stage, while also investigating more obscure or service-specific solutions, that may result in significant insights and/or gains.

Once again, in order to identify specific trends within the different Streams, an analysis of the responses per Stream was performed and its results are depicted in Figure 7. Based on the per Stream analysis, it can be observed that all main technological enablers are covered between Stream A and B projects. Moreover, all three Stream C projects make use of AI/ML, mmW & THz technologies, Communication & Sensing co-design and Orchestration of VNFs/CNFs, which are by far the most prominent categories. As such, these enablers will be globally offered to the experimenters that will make use of the Stream C experimentation platforms. From Figure 7 it is also more easily identifiable that optical wireless, quantum computing and blockchain are the three enablers that are not very well covered by Phase 1 projects. Such insights constitute very important input for the definition of the follow up SNS WPs.

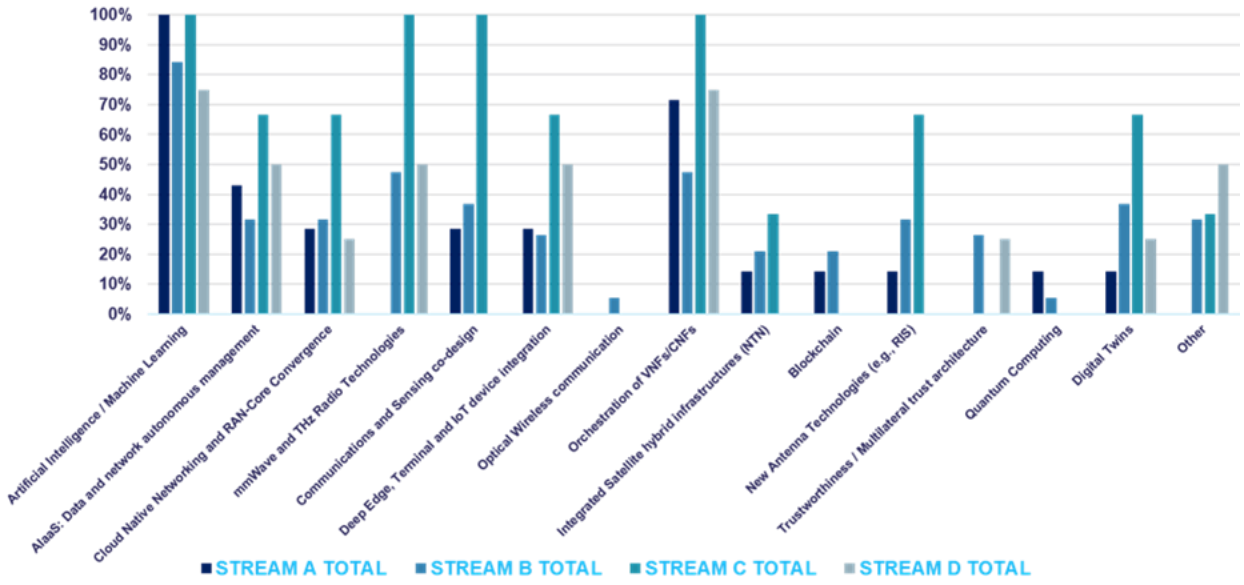

Figure 7: Main technological enablers being used per Stream by SNS Phase 1 projects

Based on the above presented analysis of the aggregate and the per Stream responses for question T5, the following key insights may be drawn:

Key Insights

- AI/ML is used as a global enabler within SNS Phase 1 projects (29/33 projects will use it).
- Use and orchestration of VNFs/CNFs is also a very popular enabler showcasing the importance of network softwarization & cloudification.
- Very good coverage of a broad range of technological enablers observed by SNS Phase 1 projects.
- Additional service-specific enablers will be used, offering possibilities for significant breakthroughs / insights.
- All Stream C projects offer the four main technological enablers to their experimenters.

4.1.4 SNS projects targeted Use-Cases & Applications

Following questions on KPIs and technical/technological scope the questionnaire raised a question on the projects covered use-cases and applications.

Question T6: Which of the following use cases / applications will your project support?

As shown in Figure 8, regarding the use-cases and digital applications supported by SNS JU R&I projects, *Digital Twin* applications are the most largely adopted tool, with 20 projects targeting them. In this context 100% of Stream C projects planning to make use of them, followed by over 70% for Stream D and over 60 for Stream B. These are followed by *Manufacturing/Industry 4.0* applications with 17 results, confirming previous trends of 5G PPP's projects to engage with the manufacturing sector. However, this is mainly popular among Stream C projects with almost 70% total adhesion. The same goes for another traditional vertical – the gaming/entertainment sector – with 14 use cases engaging this vertical through *Multi-sensory Extended Reality* and over 70% of Stream D projects planning large-scale pilots linked to this vertical sector.

Automation is also a central topic with cooperative operation among a group of *Service Robots* presenting 12 use cases, once again mostly popular among Stream D with over 70% of R&I projects planning to adopt these. This is closely followed by *Cyber-physical Systems* and *Intelligent Operation Network* with 11 use cases each and a particular interest among Stream B (about 50%) and Stream A (over 50%) projects, respectively. *Mobility*, *Smart Cities*, *Holographic Communications* and *Healthcare* rank at the same level with 10 use case each. Predictably, traditional vertical sectors such as *Mobility*,

Smart Cities and *Healthcare* are mostly an object of discussion among Stream D projects, with a proposed engagement varying between 70% and 50%, linked to large-scale trials. Predictably, *Holographic Communications* figure in the research agenda of over 60% Stream C projects given their emphasis on experimental infrastructures.

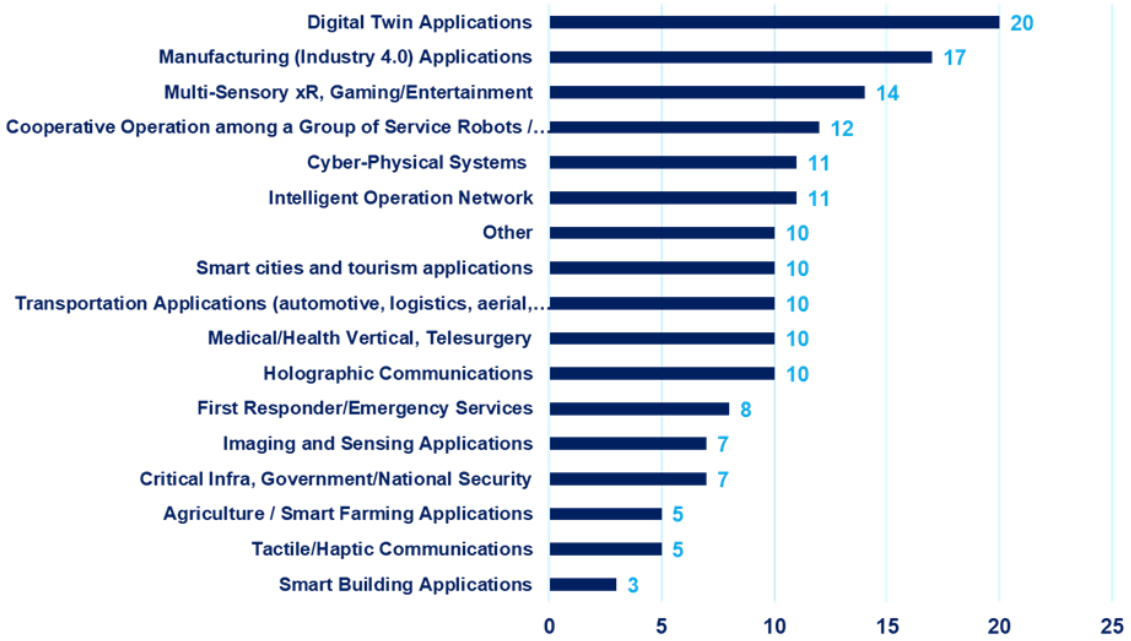

Figure 8: Main vertical sectors/application engaged by SNS R&I projects

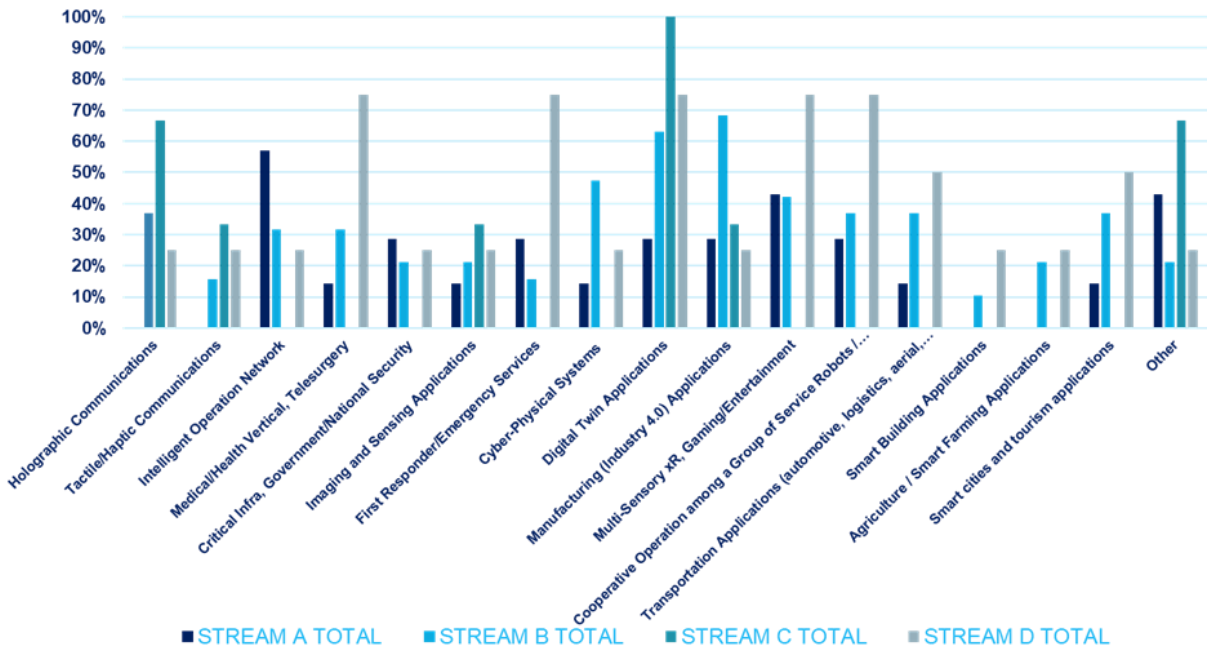

Figure 9: Main vertical sectors/application engaged by SNS R&I projects per Stream

Linked to the healthcare sector, *First Responder/Emergency Services* accounts for 8 use cases, with the same amount of Stream D projects directly interested in it (over 70%). More horizontal use cases such as *Imaging and Sensing Applications* and *Critical Infra Government/National Security* are tackled in 7 use-cases and evenly spread across different project Streams (a rough average of 20%). *Tactile/Haptic Communications* and *Agriculture/Smart Farming Applications* account for 5 use cases each, the first one predominant in Stream B (over 30%) given its emphasis on network technologies while the second one on Stream D (over 20%) given the focus on large-scale trials. For the same reason the 3 use cases

in the *Smart Building Applications* vertical are mostly focused on Stream D, with over 20% of the projects targeting them in their trials. The 10 remaining use cases catalogues as *Other* mainly reflect into over 60% of Stream C projects hinting use cases presumably linked to infrastructure-related applications.

Key Insights

- **Prominent Use of Digital Twins Across Streams**: Digital Twin applications are predominantly used in Stream C (100%), followed by Streams D (over 70%) and B (over 60%), indicating a strong, cross-Stream focus on this technology.
- **Manufacturing Focus in Stream C: Entertainment in Stream D**: Manufacturing/Industry 4.0 applications are a major trend in Stream C (nearly 70% adoption), while the gaming/entertainment sector, particularly through Multi-sensory Extended Reality, is significantly targeted in Stream D (over 70%).
- **Automation and Cyber-Physical Systems**: Stream-Specific Trends: Automation, especially service robots, is a key trend in Stream D (over 70%), whereas Cyber-physical Systems and Intelligent Operation Networks show notable interest in Streams B (about 50%) and A (over 50%).
- **Diverse Verticals with Stream-Specific Interests**: Mobility, Smart Cities, and Healthcare are predominantly topics of Stream D (engagement between 50% and 70%), while Holographic Communications is a significant focus in Stream C (over 60%).
- **Varied Sector Engagement Reflecting Stream Priorities**: First Responder/Emergency Services are largely a focus of Stream D (over 70%). Tactile/Haptic Communications are more prevalent in Stream B (over 30%) due to its network technology emphasis, whereas Agriculture/Smart Farming is more aligned with Stream D (over 20%) for its large-scale trial focus.

In order to take advantage of the results developed by EU funded projects, the Horizon Result Platform[4], collecting all results from projects funded under HEU and providing a filtering tool facilitating the search of specific results, has put in place the replicability criteria that identify those results that have been experimented in some locations and can be replicable in other locations. This replicability and sustainability concept has been studied by one of the AIOTI WG and a white paper has been published [3] together with a tool able to give a replicability level to any use case/solution developed and experimented by a project. As several SNS Call 1 projects have the ambition to develop use cases in order to validate concepts and solutions, one of the questions introduced in the questionnaire deals with replicability, the objective was to better understand the strategy of each project regarding the reusage of projects results.

Question T10: Will the use cases / solutions developed and experimented within your project be replicable? Will they be accessible to other / future experimenters?

It is obvious that Stream C and Stream D projects have to target the development and the experimentation of a number of use-cases, and this is clearly interesting to understand if other projects have also the objective to do so.

The second step will be the creation of a replicability catalogue which will contain the use-cases, their description, the owners and the level of replicability. This catalogue will be used at least by the Digital Innovation Hubs (DIHs) which could pick any solution which fits the end user requirements and replicate it in a region/city with end users.

Looking to the preliminary answers collected on question T10, it is observed that 31 of 33 projects gave a positive response with explanations that can be considered encouraging. When the projects' work progresses, it will be feasible to use the Replicability assessment tool to qualify each solution and give a level of replicability.

[4] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/horizon-results-platform

Based on such indications, it is foreseen that integrators will get a good understanding on the possibility to use a solution in the context of the Digitalisation of the European Industry. Some of the key integrators are the Smart Connectivity DIHs which are members of SCoDIHNet [5], and have indicated that they are expecting this qualification in order to choose the best solution with regards to the end customer needs.

Looking to the explanation given by each project regarding the replicability, a first level of replicability has been assigned, which is subjective and needs further information to give a more accurate level of replicability. Table 7 provides the initial replicability level of each stream as estimated based on the project answers.

Table 7: Project initial replicability level

	Stream A Projects	Stream B Projects	Stream C Projects	Stream D Projects
Replicability Level (RL)	From 50 to 100%	From 50 to 100%	100%	From 50 to 100%

The replicability % is the result of the project responses analysis, it will be validated further on with the use of the Replicability and Scalability assessment tool (under development) which is able to determine more accurately the replicability level of a specific solution.

For those projects who gave a positive answer to this question, the replicability assessment tool will be used to define their respective level of replicability. The replicability is also one of the objectives of the Horizon Result Platform and one AIOTI WG took the lead of this activity with 6G Start contribution in order to define and develop an assessment tool able to identify the level of replicability of a solution. This level is calculated through the answers provided on 33 questions addressing 5 dimensions, namely:

- Technical dimension: 11 questions.
- Data dimension: 6 questions.
- Market dimension: 7 questions.
- Acceptance dimension: 6 questions.
- Regulatory/Policy dimension: 3 questions.

Key Insights

Following the population of the questionnaire, a number of points is allocated to a solution and the following levels can be considered, as depicted in Table 8:

Table 8: Initial replicability levels

High level of Replicability	50 < LR < 74
Good level of Replicability	25 < LR < 49
Low level of Replicability	2 < LR < 24

This initial analysis is very promising, it has to be followed by a deeper study when the use-cases and the solutions will be developed and experimented in order to provide a real replicability level and to populate the replicability catalogue with these new solutions.

4.1.5 Use of AI/ML in SNS Projects

From the project responses to question T5 as depicted in Figure 6, it was observed that the use of AI/ML functionality is almost universal within the SNS Phase 1 projects, as the vast majority will make use of such mechanisms. In order to shed some additional light into the exact envisioned functionality that is targeted by each project with the use of AI/ML, an additional question was asked, attempting to identify the network/system part or service that AI/ML will be used for, within the Phase 1 projects. The exact

[5] https://www.scodihnet.eu

formulation of question T7 is shown below while the analysis of the received responses by the projects is depicted in Figure 10.

Question T7: Will your project make use of AI/ML? if yes, on which part of the system will your project use AI or which AI services will you develop?

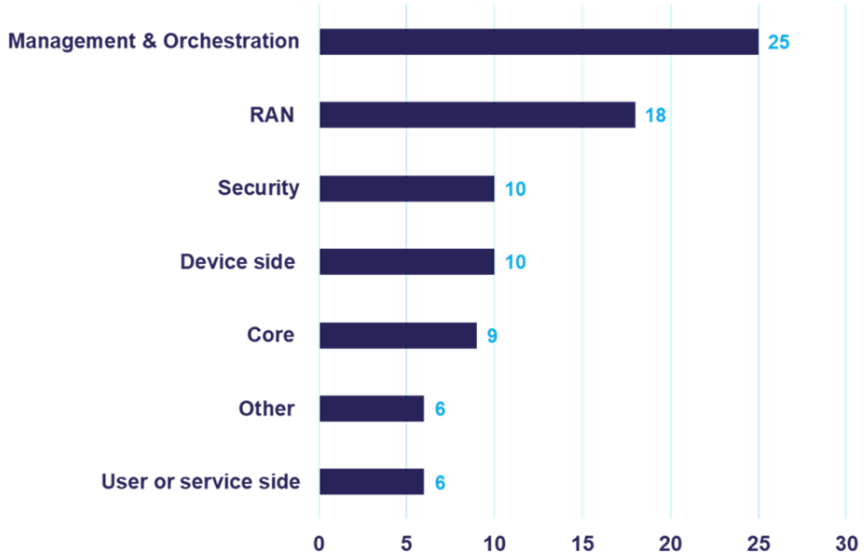

Figure 10: Network/system part or service that AI/ML functionality is used for, within SNS Phase 1 projects

Based on the results depicted in Figure 10, most of the Phase 1 projects plan to use AI/ML functionality on the *network management & orchestration layer*. Such a choice makes sense as already early implementation of various AI-enabled management functions are being experimented with. The second most popular application of AI/ML functionality is on the *RAN* as 18 out of the 33 R&I Phase 1 projects plan to engage in this research. This trend can be attributed to the new RAN technologies such as Reconfigurable Intelligent Surfaces (RIS), Ultra-MIMO, etc. as well as the multiple available spectrum bands (mmW, THz, mid-band, etc.) which make the operation and optimization of the RAN a very complex procedure, where AI/ML could showcase significant benefits. Additionally, AI/ML functions are envisioned to be used to enable or assist *core network* functionality, *security* aspects as well as *device* intelligence and *service* aspects. As such, once again a very broad range of AI/ML applications is going to be investigated by SNS Phase 1 projects.

To further enhance the understanding of the directions of researcher within SNS Phase 1 project and the specific AI/ML enabled functionalities investigated, some projects also offered information on the exact applications of AI/ML. Some of the most prominent examples are:

- Near-real time resource allocation.
- Interference management.
- Predictive scheduling.
- Jamming detection and mitigation.
- Network performance prediction (e.g., predicted latency).
- Intent-based operation.
- Beam forming/tracking management.

Key Insights

Most of the Phase 1 projects plan to use AI/ML functionality on the network management & orchestration layer and AI/ML functionality will also clearly be used for RAN, core, security, device and services. A very broad range of AI/ML applications is going to be investigated by SNS Phase 1 projects.

4.1.6 Targeted Standardization Bodies by SNS Projects

The questionnaire then addressed specific question related to targeted projects standardization.

Question T8: Which standardisation bodies will your projects target for contributions?

Based on the received responses to question T8, as depicted in Figure 11, the majority of the projects plan to contribute to *3GPP* (28 out of 33 projects), while a similar number of projects foresees contributions towards ETSI groups (27 out of 33 projects). Additional standardization bodies are targeted by the projects, such as IETF/IRTF and ITU, which attract the interest of approximately one third of the Phase 1 projects, while other SDOs are not precluded.

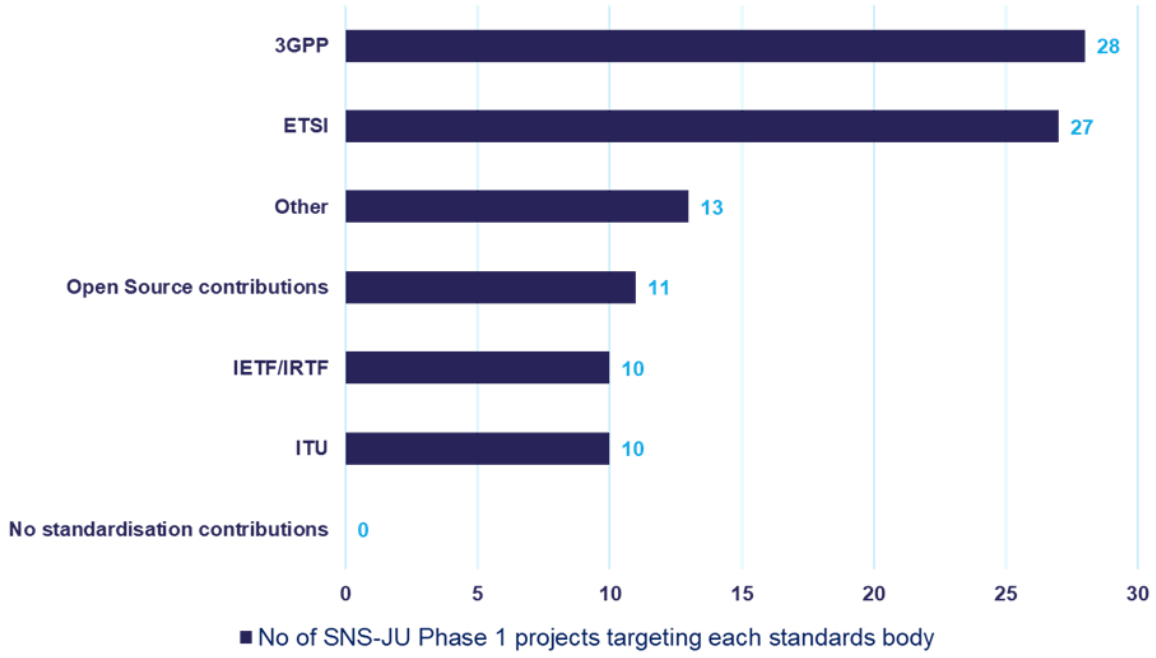

Figure 11: Targeted Standardization bodies by SNS projects

A more detailed analysis of the targeted working groups and sub-groups of each SDO, depicted in Figure 12, reveals that *ETSI ZSM* is the most popular group. This is followed by *3GPP RAN*, *3GPP SA1*, *3GPP SA2*, *ETSI ENI*, *ETSI OSM* and O-*RAN WG1*. All of the aforementioned groups seem to attract significant interest from the Phase 1 projects, while there are several others that are also well covered.

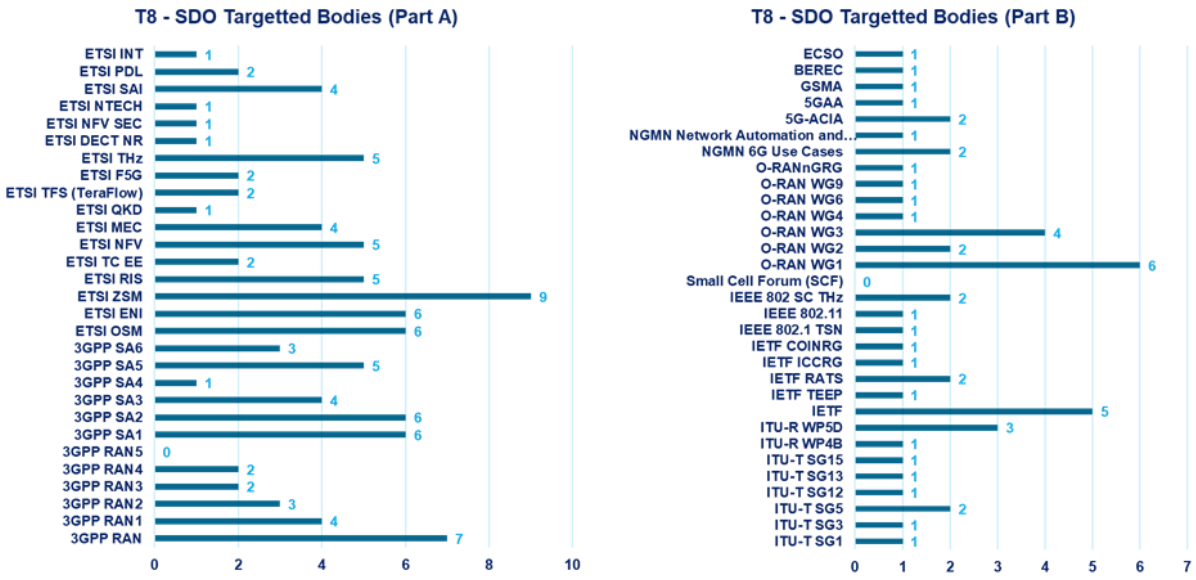

Figure 12: Targeted Standardization bodies by SNS Projects with sub domains

Key Insights

The following key insights may be extracted with regards to the targeted standardization groups of Phase 1 projects:

- **3GPP and ETSI** are by far the most targeted SDOs by SNS projects, which was expected due to the nature of the SNS programme. The fact that the vast majority of projects are planning active participations in these two bodies showcases that the Phase 1 projects have understood well the importance of impact creation via SNS R&I work.
- **Targeted early-phase contributions:** The most popular working groups / sub-groups indicate that there is a clear plan from the Phase 1 projects to influence early stage 6G standardization in terms of Use Case definition, architectural concepts and targeted RAN technologies. Open solutions also seem to offer early impact creation opportunities.
- **Broad coverage of standards groups:** The impressive standards related WG coverage by Phase 1 projects (targeting 58 different SDO groups) indicates that the SNS R&I work covers a broad range of related technologies and raises the ambitions with regards to EU stakeholder presence in the upcoming 6G developments and standards definitions.

4.1.7 Validation Methodology & Targeted Trials/Tests

Following question on standardisation, the questionnaire also included specific questions on targeted demonstration, trials and pilots. The question T9 addressed the validation method.

Question T9: Which methods will your project use to validate the technologies to be developed?

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 Tests*. Then it is followed by *Simulations* and *Advanced test*-beds. As it can be seen in Figure 13, those three validation methods are the main methodologies that are selected/preferred by the majority of the projects.

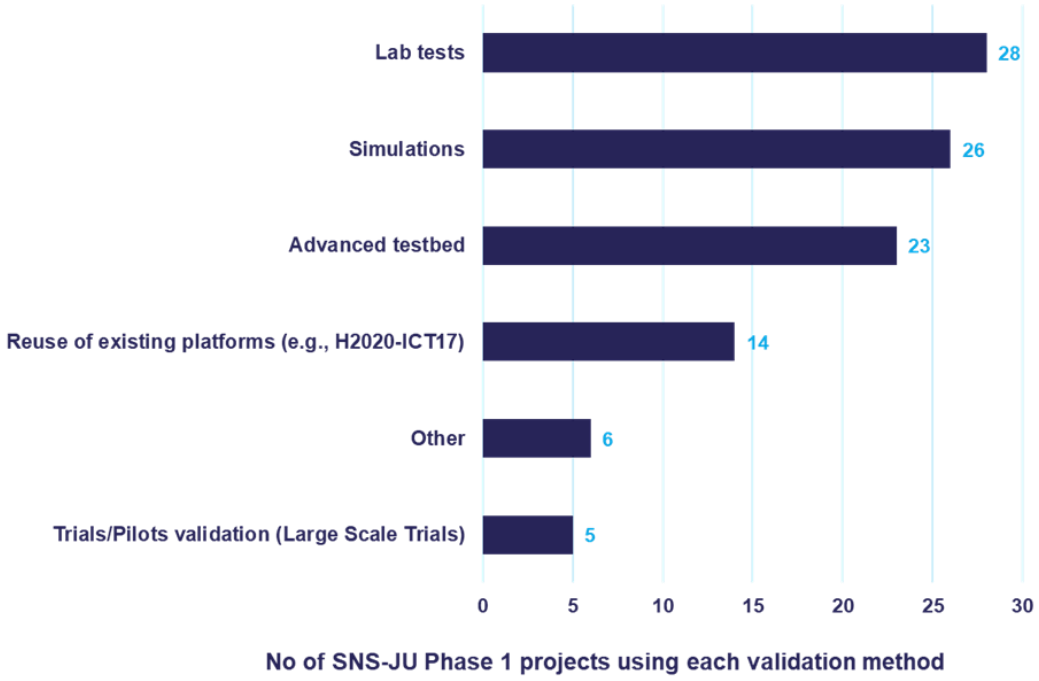

Figure 13: Validation methods of project for developed technologies

Simulations *Lab tests* are very popular due to early experimentation stage (Phase 1 projects – low TRL and early stage of research). Significant re-use and up-grade of existing experimentation facilities is important (e.g. from 5G Infrastructure PPP, National Platforms…with existing top R&I Platforms in EU). Phase 1 Stream D projects clearly target already first *Trials and Pilots*, also planning to implement their contractual Open Calls. More advanced *Trials and Pilots* are expected in the SNS follow-up phases / Calls (as also experienced in 5G Infrastructure PPP)

As depicted in Figure 14, Stream A and Stream B projects support relatively "simpler" validation methods while Stream C and Stream D projects support almost all validation methods and offer more advanced capabilities. This is directly aligned with the SNS Work Programme ambitions.

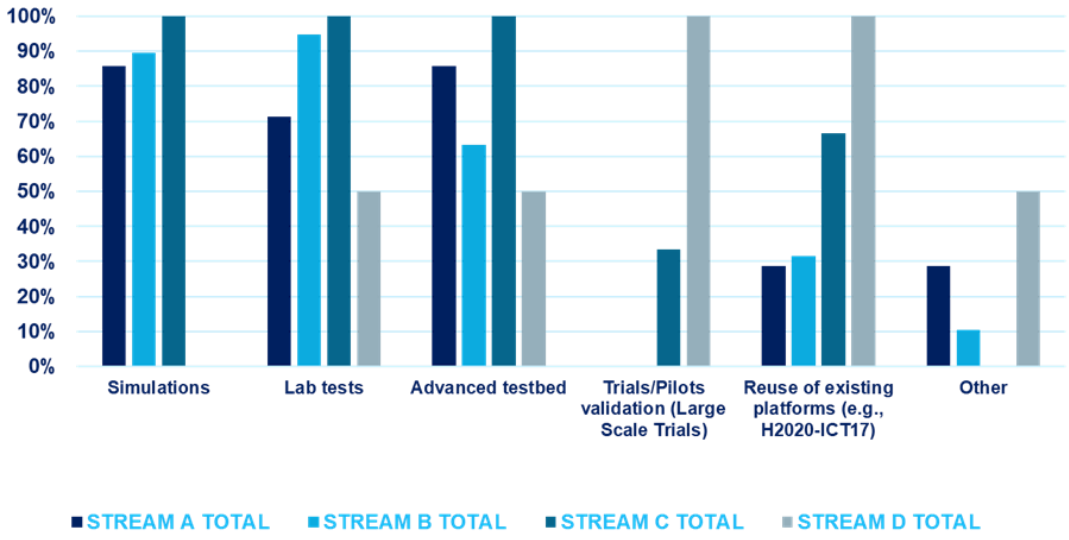

Figure 14: Validation methods of project for developed technologies per Stream

The questionnaire then addressed the test / end-user equipment to be used by the Phase 1 projects for testing and trialling.

Question T11: What type of (End User) Equipment will be used for testing/trialling in your project?

As depicted in Figure 15, the most popular devices are *Mobile phones*, closely followed by *IoT sensors* and *CPEs*. More specific devices like *Drones* or *Satellite receivers* targeting more specific use-cases will be also used, depending on the focus of the projects. A lot of other devices were also mentioned, including Smart glasses, XR user equipment, Robots/Cobots, Software Defined Radio, Smart Gateways. The answers showed a very great coverage of devices for targeted tests and trials.

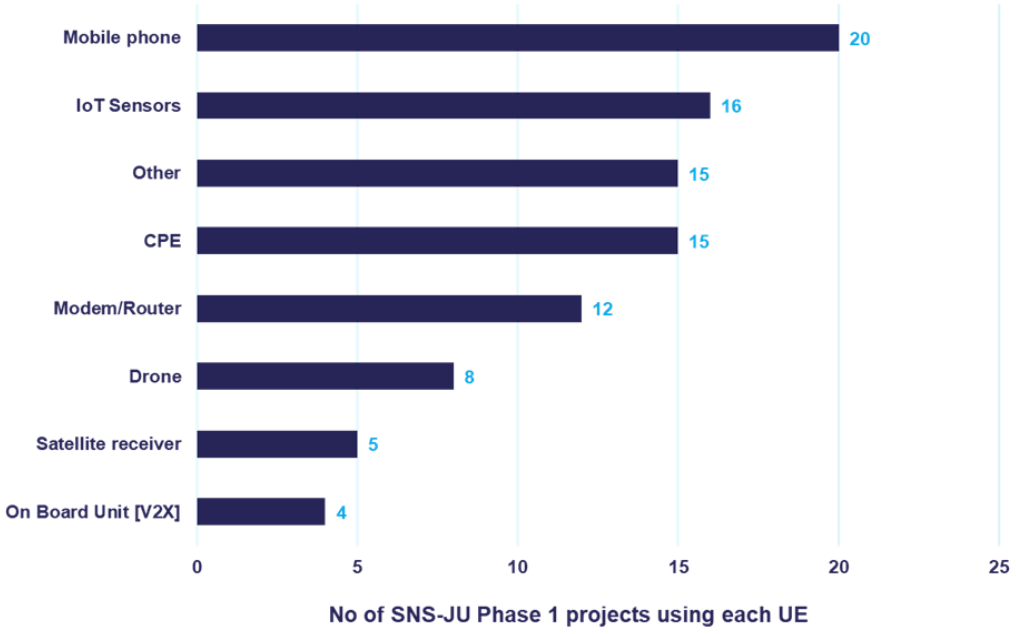

Figure 15: Use of end-user equipment in testing/trialling

As detailed in Figure 16, Stream C and Stream D projects offer a large variety of testing / trialling equipment, also knowing that those will expand their scope/use-cases and stakeholders through their

Open Calls. *On-Board Units* (OBU) have the lowest coverage as they target a specific technological area (Transport), that will be covered in Call 2023 Stream D project.

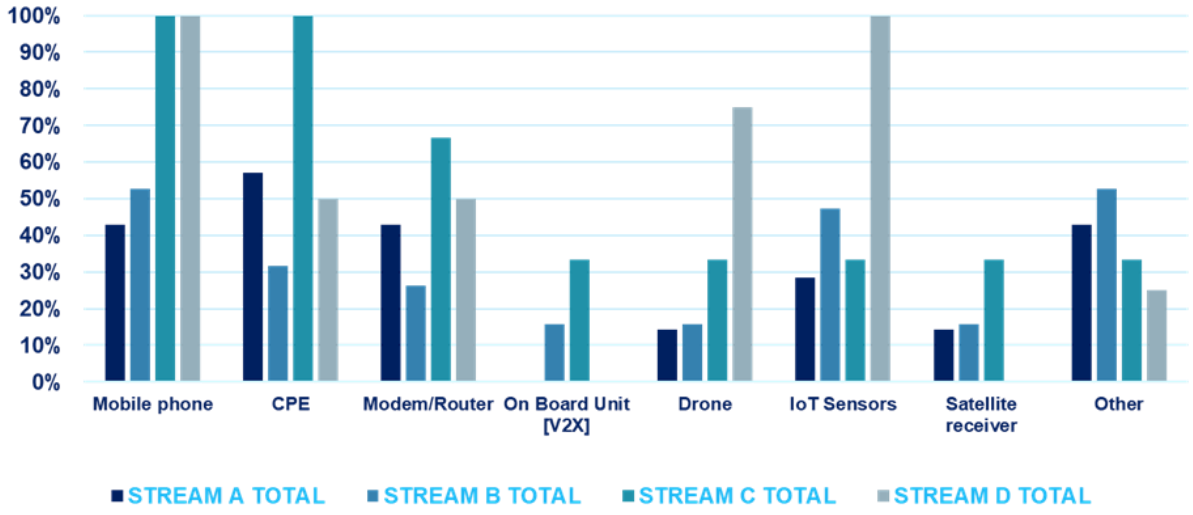

Figure 16: Use of end-user equipment in testing/trialling per Stream

Based on 5G Infrastructure PPP experience, the questionnaire then started to raise the question related to targeted Trials and Pilots (T&Ps), including possibly information on targeted use-cases, dates and locations.

Question T12: Please provide information regarding your planned Trials & Pilots including the focus of each trial?

As depicted in Figure 17, there were only few inputs already defined in detail by the Phase 1 projects, also considering that the Questionnaire was communicated in Spring 2023. Some Projects, e.g. in Stream D already provided detailed inputs on targeted use-cases. Due to the early stage of the projects, there was few information on dates and locations. As planned, the Stream C and Stream D Open Calls will result in additional Trials and Pilots.

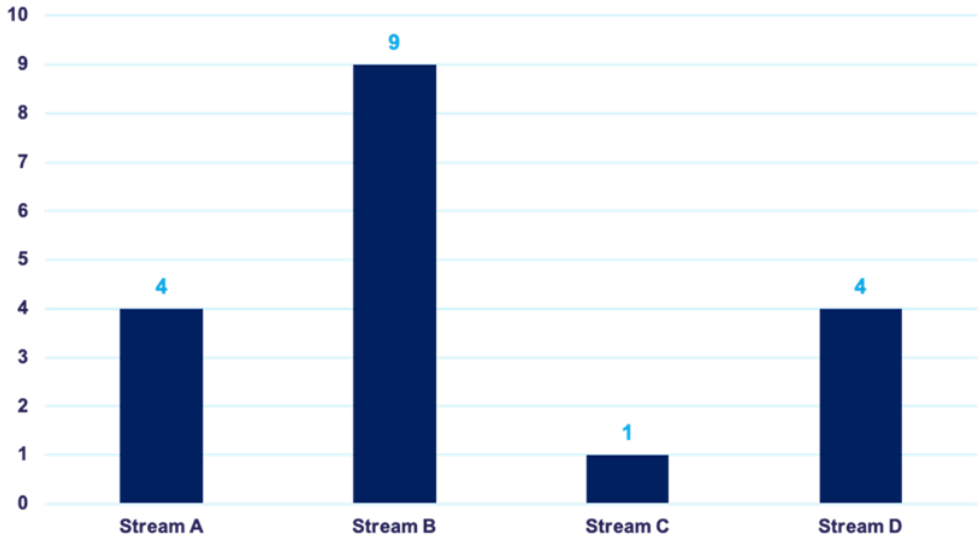

Figure 17: Planned Trials & Pilots (T&Ps)

Key Insights

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 first input to (1) Projects to be invited to make first contributions/presentation in the Trials WG online meetings, (2) Forthcoming

TB/Trials WG development of the T&Ps Summary document (also basis for forthcoming T&Ps Brochures – leveraging 5G Infrastructure PPP experience/documents) and (3) Forthcoming Verticals Cartography website/webpages development (also leveraging 5G Infrastructure PPP experience – related website[6]). There is a clear need to further synchronize with projects champions on the validation TRL [4], before any further detailed action/implementation, as answers included Validation, Lab Demonstrators, Demonstrations, Support to Experimenters (e g Open Calls), Trials, Testbeds and Pilots. This point is clearly taken into account for the Questionnaire Call 2023.

4.1.8 User Engagement by SNS Projects

One of the key targets of the SNS programme and related SNS projects is clearly related to the engagement of verticals sectors and SMEs. The questions T14 and T15 were specifically targeting the projects ambitions/plans related to Verticals and SMEs.

Question T13: How do you engage verticals in your project?

Requirement provisioning is the main engagement method employed by Phase 1 projects to engage vertical sectors with 22 projects targeting the identification, acquisition and managing of technological resources to meet specific vertical-related needs, as depicted in Figure 18. *Device adoption for trialling* and *end-user testing* are employed in 13 instances each, showcasing both a significant attention for existing vertical equipment in trial instances (especially relevant for Stream D projects) and *end-user experience*, an emerging value of SNS JU as a whole.

The *integration of vertical system with project-developed platform* appears in 11 instances, reflecting a central concern for Stream C projects. Interoperability is also in a central position, with the search for *common technology development for verticals* mentioned by 7 projects. Other vertical engagement methods are declared in 6 instances.

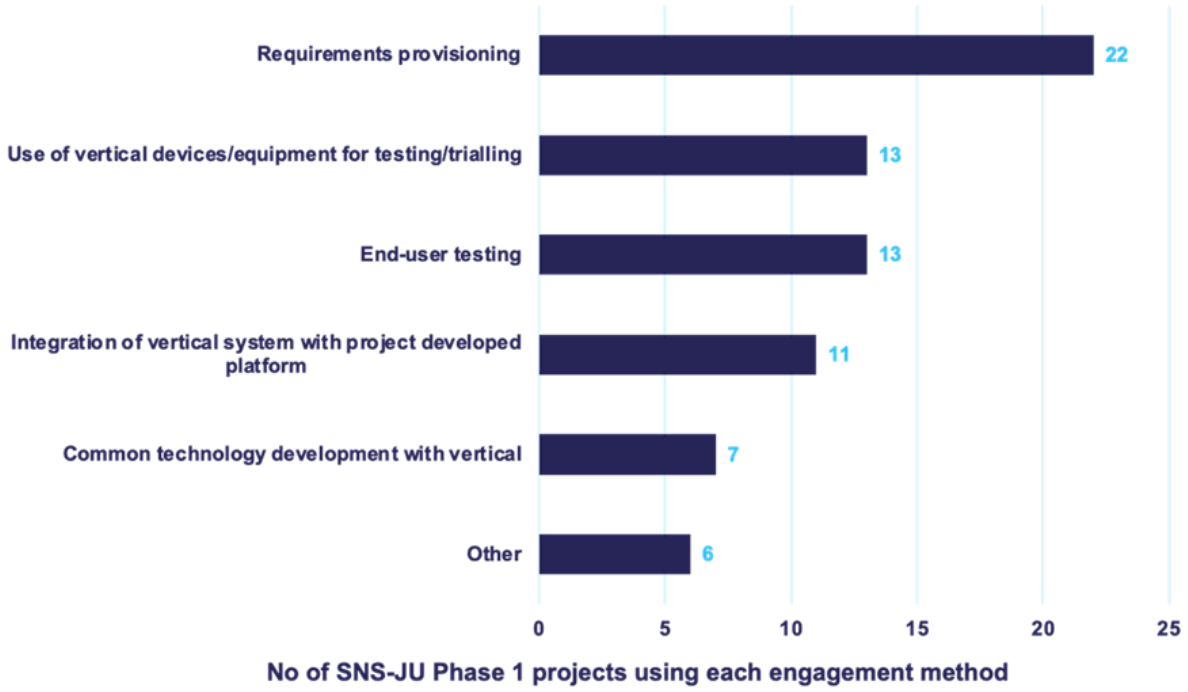

Figure 18: SNS JU Phase 1 projects vertical engagement method

Question T14: Does your project promote the participation of SMEs? How?

The exact nature of SME participation in the various projects was also investigated via the questionnaire as depicted in Figure 19. SMEs are mainly involved as *project consortium partners*. Some projects also

[6] https://global5g.eu/cartography

indicate that said SMEs are specifically *technology suppliers*, while others promote SME participation through *Open Calls*.

The 20% SME participation target set in the SNS Calls and the SNS projects *Open Calls* targeting SMEs have been critical to promote their involvement in the SNS JU. Naturally, the latter action can only be claimed by those SNS projects with such a mandate and which number is limited.

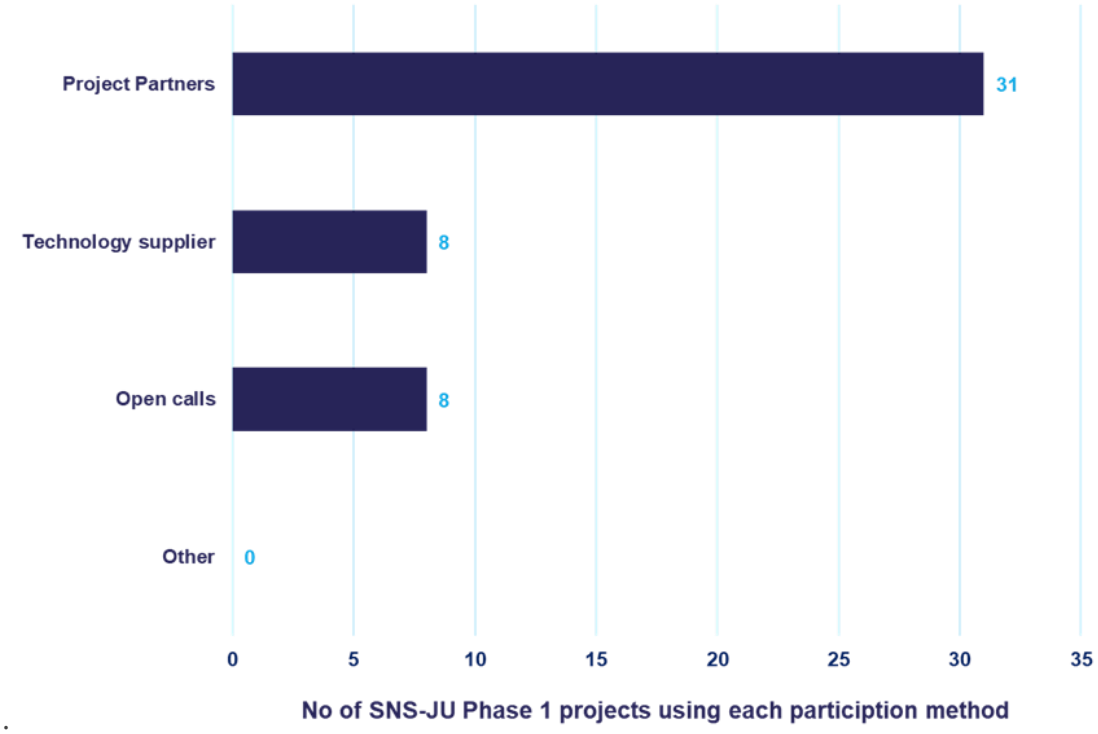

Figure 19: Projects SMEs participation

Key Insights

The different informative actions to raise awareness about the SNS JU have also contributed to grow the involvement of verticals and SMEs. Furthermore, the NetworldEurope SME WG has actively supported the dissemination of this information to the largest community of SMEs in the sector, facilitating the access to news and opportunities.

Yet, it is important to note that the relatively low number of SMEs as technology providers means that the participating SMEs are likely to fulfil other roles such as consulting or marketing. Therefore, efforts to boost the participation of SMEs in the SNS must continue to ensure all the available skills, expertise and potential, especially as the vertical sectors addressed are only expanding, is leveraged for a more competitive Europe.

4.1.9 Energy Efficiency within SNS Projects

Last but not least technical question in the Questionnaire, the focus and coverage related to energy efficiency.

Question T15: Does your project address energy efficiency, if so, how?

Based on the information depicted in Figure 20, most of the projects address energy efficiency. The majority of the projects focus on *Design of specific algorithms for energy efficiency*. This is followed by *Device side* and *RAN plane* options, indicating a healthy variability of application of energy efficiency mechanisms.

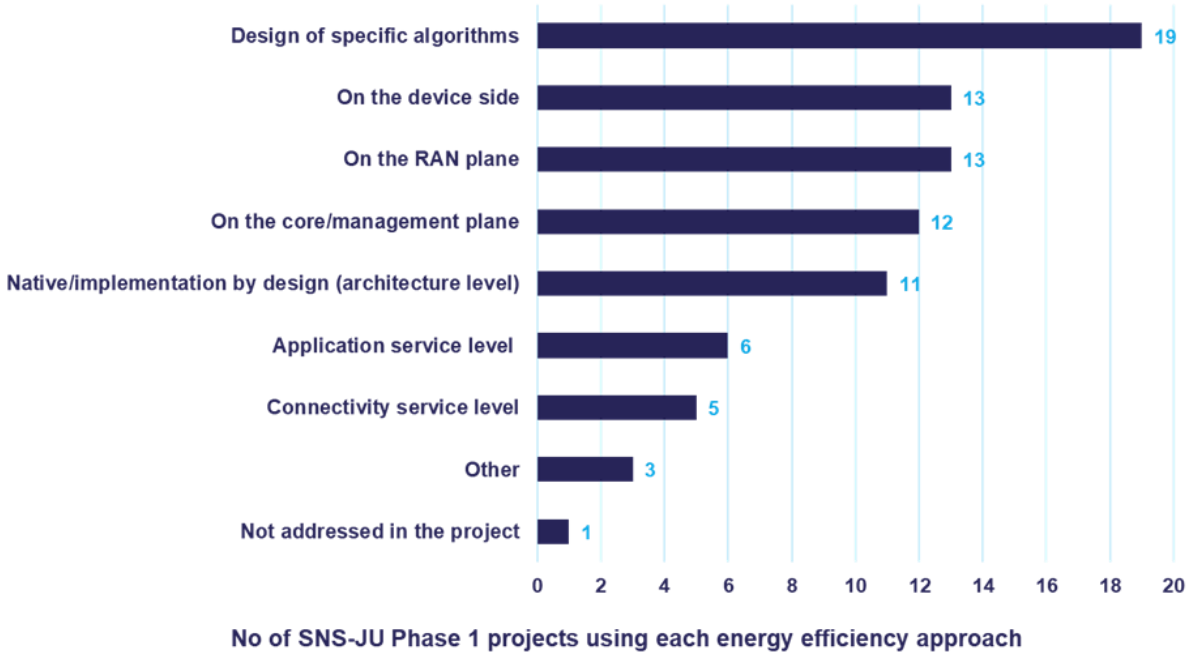

Figure 20: SNS JU Phase 1 projects using energy efficiency approach

When reviewing the Figure 21 which depicts the per stream analysis, it can be observed that Stream A projects mostly focus on *Design of specific algorithms* for energy efficiency. This is followed by *On the core/management plane* and *On the RAN plane*.

For the Stream B projects the focal point is on *Design of specific algorithms* and it is followed by *On the device side* and *Native/implementation by design (architecture level)*.

Stream C focuses *On the device side* which is very closely followed by *On the RAN plane*. Remaining energy efficiency approaches have nearly same score that are sharing the third place for the projects.

Finally, Stream D projects focus equally on *Design of specific algorithms*, *On the RAN plane*, *On the core/management plane* and *Application service level*.

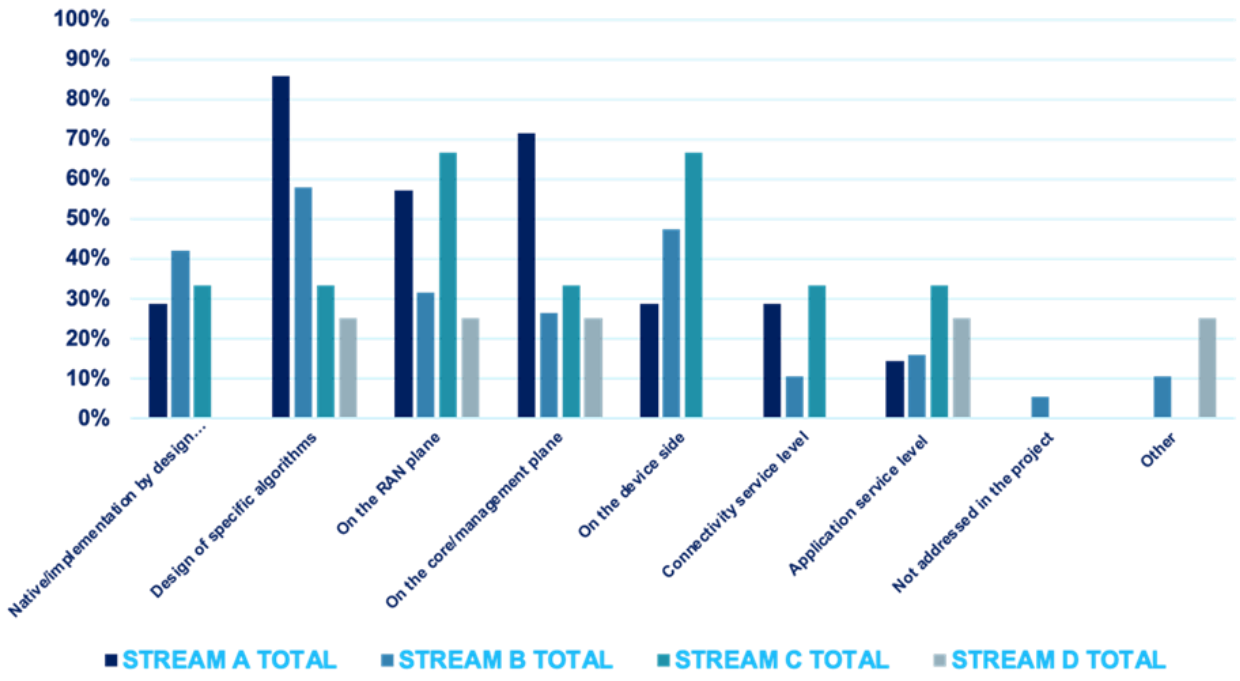

Figure 21: Energy efficiency focus per Stream

Key Insights

Sustainability is clearly broadly addressed by Phase 1 projects. When defining the scope and targeted outcomes of the Call 2024 B01-07 Sustainability Lighthouse Project (see Section 7), the answers to the Questionnaire were used to define a first 3 pages document from SNS OPS towards EC-SNSO as input to the preparation of the EC Stakeholders Workshop "Identifying common indicators for measuring the environmental footprint of electronic communications networks (ECNs) for the provision of electronic communications services (ECSs)" [5] organized on 10th of October 2023 in Brussels. The document summarized the key inputs provided by projects on Sustainability focus. This document was then shared from SNS OPS towards SNS TB as input to forthcoming actions, including then towards the SNS TB Sustainability Task Force.

4.2 SNS Roadmapping

As described in the previous sub-sections, the definition, design and annual up-date of the SNS OPS questionnaire, as well as the input collection and aggregation, analysis and extraction of insights and conclusions, is an effort-intensive and time-consuming process, that the SNS OPS partners have undertaken. This entire endeavour has been designed to enable the collection of critical data from the SNS community, combine it with additional sources of data and assist in the design and up-date of the SNS Roadmap, ensuring that the SNS will remain relevant in the global 6G arena and that EU stakeholders will continue to play a leading role in the technological developments of the future connectivity systems.

Task 1.2 of SNS OPS is mandated with collecting diversified input from the SNS OPS framework and other relevant sources (such as the other CSA project, SNS ICE and the 6G-IA), and utilizing it to perform a thorough Gap Analysis that will enable the up-date of the SNS Roadmap via the design of the follow-up SNS Work Programmes. The exact process that has been designed by SNS OPS partners to lead to the SNS roadmapping is depicted in Figure 22. Both Gap Analysis and Roadmap are input to the definition of the Work Programmes, complementing the other inputs (e.g. NetworldEurope SRIA 2024, 6G-IA Members Consultations…) considered by the Task Force / Core Team (TF/CT), as described in Section 7. Sections 4.2.1 and 4.2.2 explain how the input from the various sources is aggregated to enable the overall Gap Analysis, leading to the up-date of the SNS Roadmap and describe the collaboration with SNS ICE to obtain the relevant information, respectively.

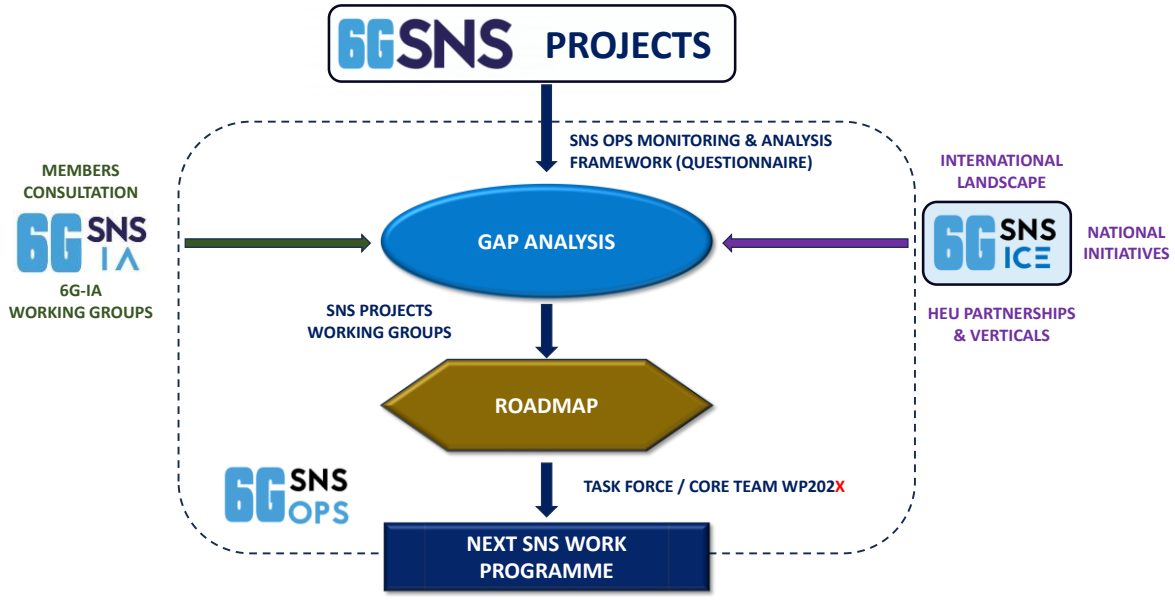

Figure 22: SNS OPS Gap Analysis & Road-mapping process

4.2.1 Input Aggregation & Gap Analysis

The Gap Analysis is an important process within SNS which allows for the comparison of the goals, addressed technologies and verticals of the selected projects of each Phase against the EC and SNS JU

high level goals. Such comparison offers insights with regards to the "adherence to the plan and strategy" of EC and the SNS JU and constitutes valuable feedback towards the Task Force / Core Team (TF/CT) of experts working on the follow-up SNS JU Work Programmes (see details in Section 7). The TF/CT may opt to make adjustments to the following Work Programmes to account for smaller or larger deviations from the agreed strategy based on the theme and technologies addressed by the selected projects (see details in Section 7). The TF/CT is also clearly taking into account the evolution of the overall 6G standardization plans, regulatory plans and policy framework and the overall global developments as reported by the CSA projects and the 6G-IA members and WGs. This feedback loop and available flexibility in the design of the annual Work Programmes ensures that the EU will not stay behind in the global Research and Innovation ecosystem in any of the important technological fields and that any potential gap will be quickly identified and addressed.

With the SNS OPS Monitoring and Reporting framework presented in D1.1 [1] and its first results presented in this D1.2, this "Gap Analysis" process becomes an annual standardised and automated process, which ensures the availability of the necessary data and the continuous feedback loop towards the Work Programme TF/CT. The insights highlighted in the previous section, paint a detailed picture with regards to the technologies, use-cases, enablers, KPIs and network aspects addressed by the existing SNS projects. These insights, along with the insights gained based on the reporting of global 6G R&I activities, the relevant partnership actions and the 6G-IA members priorities, may be combined with the targeted outcomes of the selected projects from Call 2023, to paint an even more broad picture with regards to the topics that will be addressed under the umbrella of the SNS JU. Such aggregated insights constitute critical input for the design of the follow up SNS JU Calls.

4.2.2 Related HEU Partnerships & EU National Initiatives

SNS OPS has been supporting both 6G-IA and NetworldEurope, helping the WGs management and supporting the ICT communication infrastructure. In parallel there has been a great effort regarding the establishment of synergies/liaison with other relevant partnerships and associations, e.g. with Chips JU (/former Key Digital Technologies (KDT) JU) for microelectronic and with ECSO (European Cyber Security Organization) concerning security. There are several other partnerships and associations with whom we have been in contact, among which are ERTICO (European Road Transport Telematics Implementation Coordination Organization) and AIOTI (Alliance for the Internet Of Things Innovation).

Furthermore, we are starting to see an increased concern in the establishment of communication with the national initiatives. Special attention has been given to the coordination with the German Hubs where we have participated in several events organized by the 6G Germany Hub [6]. Several other initiatives are being developed in Europe, with the French [7] and Dutch [8] initiatives having some presence in international events, where SNS OPS has also participated. Nevertheless, other countries have also developed their own 6G agendas, often associated with the national Recovery and Resilience Plans.

Also of mention, due to its dimension and importance, the efforts that have been made in having different meetings with Hexa-X and Hexa- X-II, in particular with components related with sustainability. As example, Hexa-X-II will organize on 13-14th of February 2024 the Event "The 6G series workshop by Hexa-X-II" [9], including presentations related to 6G German Initiative (6G-ANNA) and 6G International activities in US, Japan, South Korea, India…The SNS OPS partners have made use of the Impact Assessment and Facilitation Actions (IAFA) as organized by WP4, to engage with the various communities and stay in contact with multiple EU partnerships, national initiatives and other key stakeholders.

Besides the SNS OPS activities related to European Partnerships and National Initiatives, and in the context of the alignment of the CSA projects to avoid duplication of work and to maximize impact, a significant part of the activities regarding HEU Partnerships, National Initiatives and Vertical Associations has been assigned to SNS ICE. Within the context of the close collaboration of SNS OPS with SNS ICE, an active exchange of the necessary information regarding Partnerships, National Initiatives and Verticals, is taking place, ensuring early access for SNS OPS partners, contributing towards the project goals (Gap Analysis, events, Roadmapping, etc.). As such, and as depicted in Figure 22, SNS ICE reports on all the above aspects towards SNS OPS and the TF/CT team, to enable the overall gap analysis and design of the future Work Programmes.

The information exchange between the two projects for their first year of operation (2023), regarding these 3 groups of stakeholders, has focused on the following aspects:

- **EU Partnerships**: An overview of the relevant EU partnerships with which SNS ICE has established contacts, a description of the common activities and the key take-aways that are important from SNS JU perspective are provided in Deliverable D2.1 [10] of SNS ICE. More specifically, the relevant activities and insights from the following partnerships can be found in D2.2 [11] of SNS ICE
    - Chips JU (former KDT).
    - Photonics Europe.
    - HPC (High Performance Computing).
    - AI Data and Robotics.
    - CCAM (Cooperative, Connected and Automated Mobility).
- **National Initiatives**: In the same Deliverable of SNS ICE (D2.1 [10]) a major survey of the seven largest European National Initiative programmes is presented, detailing multiple aspects of the programmes, including, available budget, timelines, R&I scope, participating entities and technologies of interest. Through a timely process of p2p interviews, the SNS ICE partners have collected important information from each of these National Initiatives to better understand the commonalities and differences with the SNS JU targets, hence facilitating further collaboration in the future. This type of information is of particular interest for the update of the SNS roadmap. The seven Initiatives detailed in D2.1 [10] of SNS ICE are:
    - The Future Network Services (FNS) programme (The Netherlands).
    - UNICO 6G R&D (Spain).
    - RESTART: 'RESearch and innovation on future Telecommunications systems and networks, to make Italy more smART' (Italy).
    - France 2030 (France).
    - 6G Bridge (Finland).
    - 6G Flagship (Finland).
    - 6G Platform Germany (Germany).
- **Vertical Associations**: SNS ICE has also taken a leading role in the communication and collaboration with Vertical Associations, attempting to increase the participation of vertical stakeholders in the SNS calls and facilitating the exchange of information among the stakeholders. To that end an Initial trend analysis of nine key vertical sectors and their respective roadmaps has been performed and presented in the SNS ICE Deliverable D3.2 [12]. This type of analysis provides significant insights with regards to the expectations and requirements of the various sectors from future connectivity systems and may help the TF/CT working on the future SNS work programmes to design more attractive calls for vertical stakeholders. The vertical sectors analysed in deliverable D3.2 [12] of SNS ICE are:
    - Public Safety
    - Automotive
    - Transportation
    - Smart Manufacturing
    - Media
    - Agriculture
    - Health
    - Rail Transport
    - Non-Terrestrial Networks

5 SNS Vision & KVIs Insights

This section summarizes the responses and learnings from the Phase 1 projects regarding how the vision of the programme is addressed. Further it points forward to how SNS OPS can and will support and drive the work towards updating the SNS vision, which will be important for shaping the future SNS Work Programmes.

5.1 SNS OPS Questionnaire – Vision Section Analysis

The vision section of the questionnaire comprised six questions, of which four were multiple choice, and two were free text questions. One of the free text questions was specifically on how the projects address KVIs, which are introduced as a new metric in the SNS JU WP. The other question addresses the expectations and interest from the project in the SNS WGs. All questions were open for free text comments.

In the survey, the following topics were addressed:

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

The purpose of this section has been to understand how the projects from Phase 1 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 (A, B, C and D) 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.

5.1.1 Societal Challenges

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

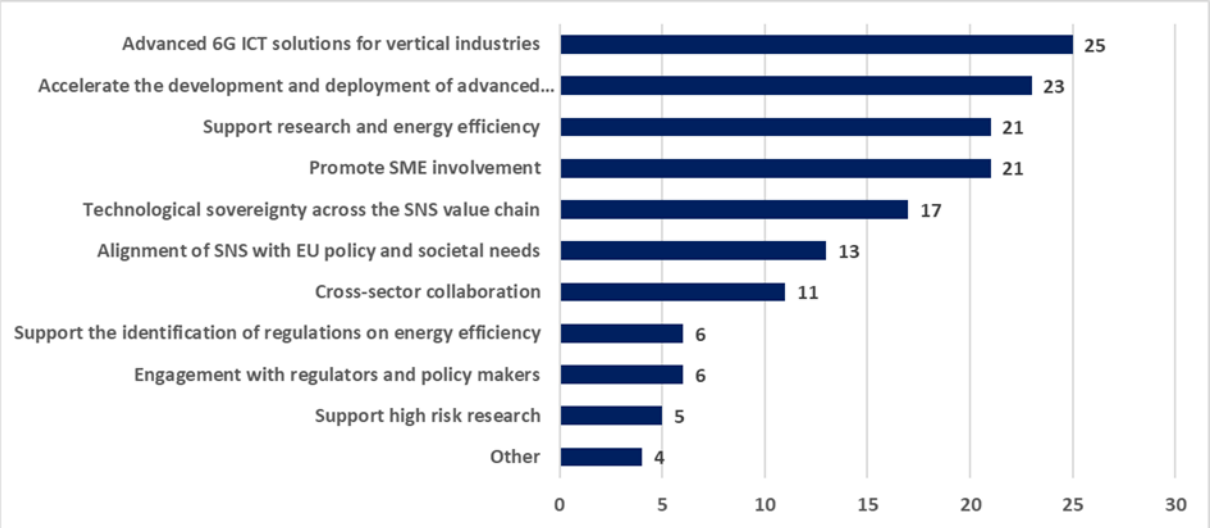

Figure 23: Contributions to societal challenges by SNS JU Phase 1 projects, aggregated over all Streams.

Figure 23 shows the responses received in total from all projects. The focus of the projects is strong on technology challenges, like *advanced 6G ICT solutions for vertical industries*, and to *accelerate the*

development and deployment of advanced infrastructures. This aligns well with the responses observed for the technical questions and with the scope of the SNS Work Programme. It is also interesting to see that many projects highly value the importance of *promoting SME involvement* and *the support of research and energy efficiency*. In the lower end we find *regulation and policy* issues.

These observations from the first wave of SNS projects is valuable for shaping the following Work Programmes of SNS where it can be ensured that also non-technical focus is covered across the multiple phases.

Further analysis of the responses for the different Streams is shown in Figure 24.

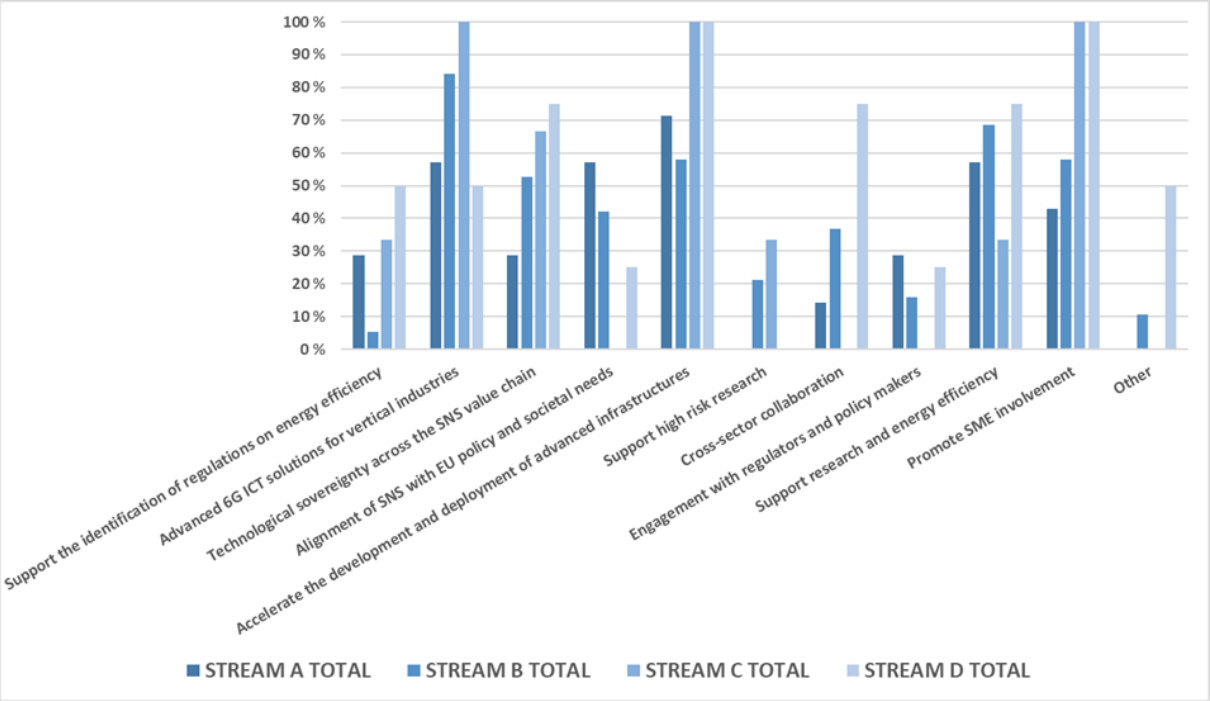

Figure 24: Contribution to societal challenges – per Stream analysis. The value given is the percentage of projects per Stream.

One observation is that Stream C and D projects report highest focus on societal challenges in total, i.e. that several issues are covered in the projects. Both Stream C and D projects are trials focused, being closer to investigating use and feasibility of technology for solving problems. Stream C on a longer time scale in developing trial platforms, while Stream D focussing on trials with verticals or stakeholders. Stream A projects being focused on the evolutionary path are showing some more interest in *Aligning SNS with EU policy and societal needs*. Stream B projects are addressing a number of challenges across the Work Programme, which makes sense due to the diversity in projects focus.

The free text responses basically support the multiple-choice responses. *Energy efficiency* is mentioned as central for both Stream A and B projects. Since Stream B projects outnumber the other ones, there is of course more diversity in the free text responses.

Key Insights

- Projects are mostly focused on technology challenges.
- Close followers are on research, energy efficiency, and SME involvement.
- Less focus on regulations and high-risk research.
- Stream C and D projects have the highest focus on societal challenges.

Further use should be primarily by the Vision and Societal Challenges WG, but also by the SNS Steering Board and Technology Board themselves.

5.1.2 Societal Values

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

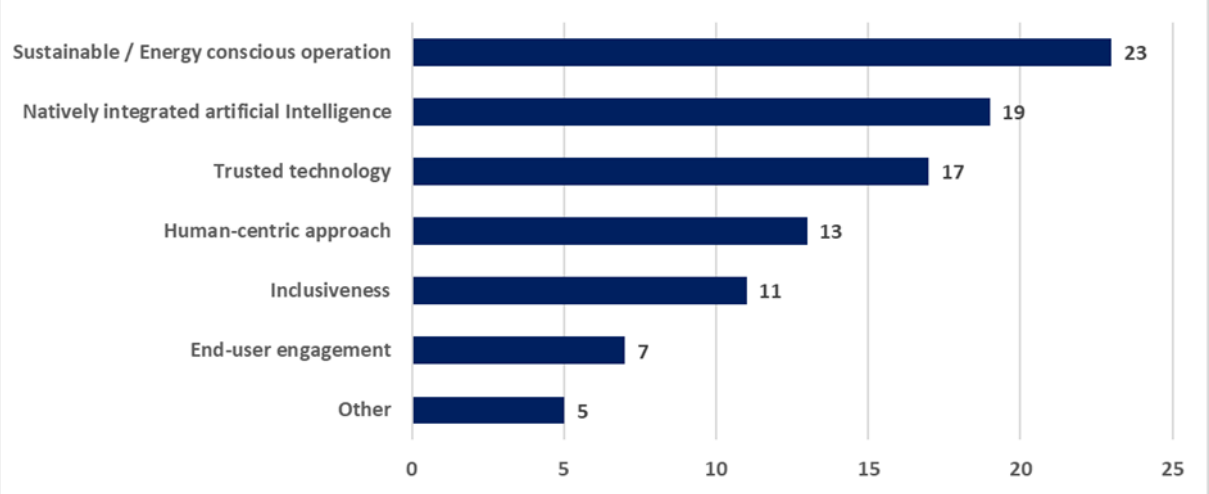

Figure 25: Societal values addressed by SNS JU Phase 1 project.

From Figure 25 it can be observed that *Sustainability and Energy consciousness* is on top of the societal values being addressed. *Native AI* and *Trusted technology* also have high scores. It shows that the first wave of SNS projects have adopted and understood the importance of having sustainability as a key value for shaping 6G. Societal acceptance of AI is a key issue and is connecting with both ethical and trust questions. Related to this is question V3 on KVIs which gives more insight to the understanding of societal values.

It is noticeable that *Inclusiveness* and *End-user engagement* is in the lower end of the list, and this is relevant input for the shaping of the future Work Programmes. Figure 26 shows the response to societal values per Stream.

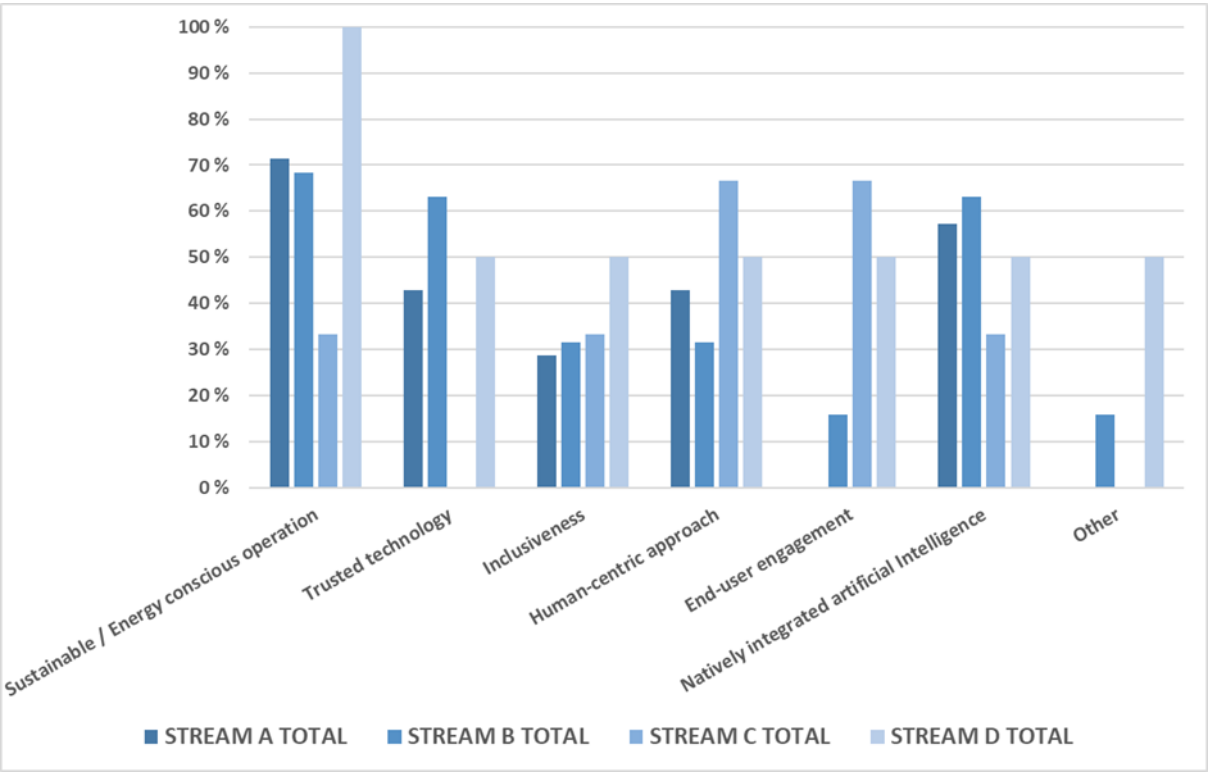

Figure 26: Societal values addressed by SNS JU Phase 1 project – per Stream

It can be observed that Stream D projects seem to have the highest attention to societal values. Stream D projects are large scale trials and pilots, and thus addresses the highest TRLs. This might explain that

they also focus most on these values. At least 50% of the Stream D projects address any of the values mentioned. Free text responses on the societal values support the multiple-choice responses by highlighting *sustainability* and *energy efficiency*.

Key Insights

- Sustainability and energy consciousness are claimed by many projects.
- Next comes natively integrated AI and trusted technology.
- Less focus on end-user engagement and inclusiveness.
- Stream D projects have the highest focus on societal values.
- Stream A projects have no end user focus.

These outputs will be useful for the work planning of the Vision and Societal Challenges WG, as well as the TB Sustainability TF.

5.1.3 Key Value Indicators (KVIs)

Question V3: Does your project address Key Value Indicators (KVIs)? If yes, which ones? Which use case/vertical do they address?

This was a free text question only, so the text inputs were matched with the Key Values (KVs) table proposed in the 6G-IA White Paper: "What societal values will 6G address?"[13]. A "direct" and "indirect" matching exercise was performed. Direct match means that the exact wording was used in the responses, while indirect means that an interpretation was done. Note that the total numbers exceed the number of projects, because several mentions were interpreted to match the KVs.

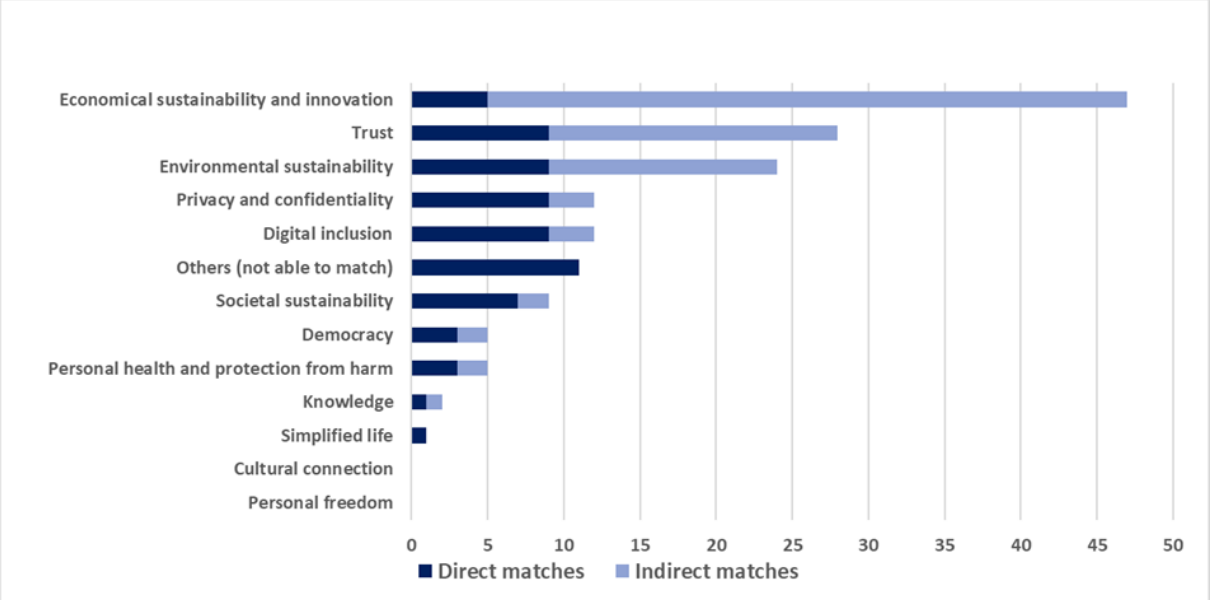

Figure 27: Key Values identified by SNS JU Phase 1 projects

From Figure 27, it can be seen that *Economical sustainability and innovation* is dominating above the others, while there is little match on *Cultural connection* (none), *Personal freedom* (none), *Knowledge*, and *Simplified life*.

Some projects have also provided feedback on the use-cases or verticals. No particular use-case group stands out, but the use of *extended reality* (XR), use cases for *eliminating transport* (living and working anywhere), seems to be mentioned by several projects. One Stream D project is actually listing the KPIs they will pursue in order to assess relevant KVIs.

The notion of KVIs is still difficult to grasp for many projects. Further insights and discussion are done in Sub-Section 5.3.

Key Insights

- The notion of KVIs is still difficult to grasp for many projects.
- Economical values are dominating above all other issues.
- Low match on Cultural connection and Personal freedom (none), Knowledge, and Simplified life.

Further use of this insight will most likely take place on the TB level, and maybe particularly for the Vision and Societal Challenges WG.

5.1.4 6G Vision

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

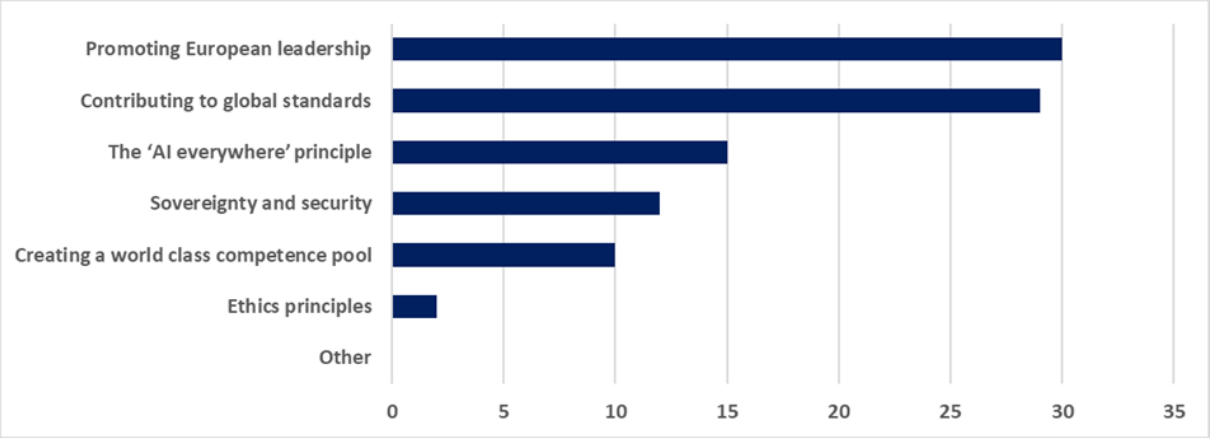

Figure 28: 6G Vision contributions as reported from the SNS JU projects

Figure 28 shows the multiple-choice responses. All projects are conscious about *European leadership* and *Contribution to standards*. Medium focus on *AI*, *Sovereignty and security*, and *Competence*, while little focus on *Ethics* principles.

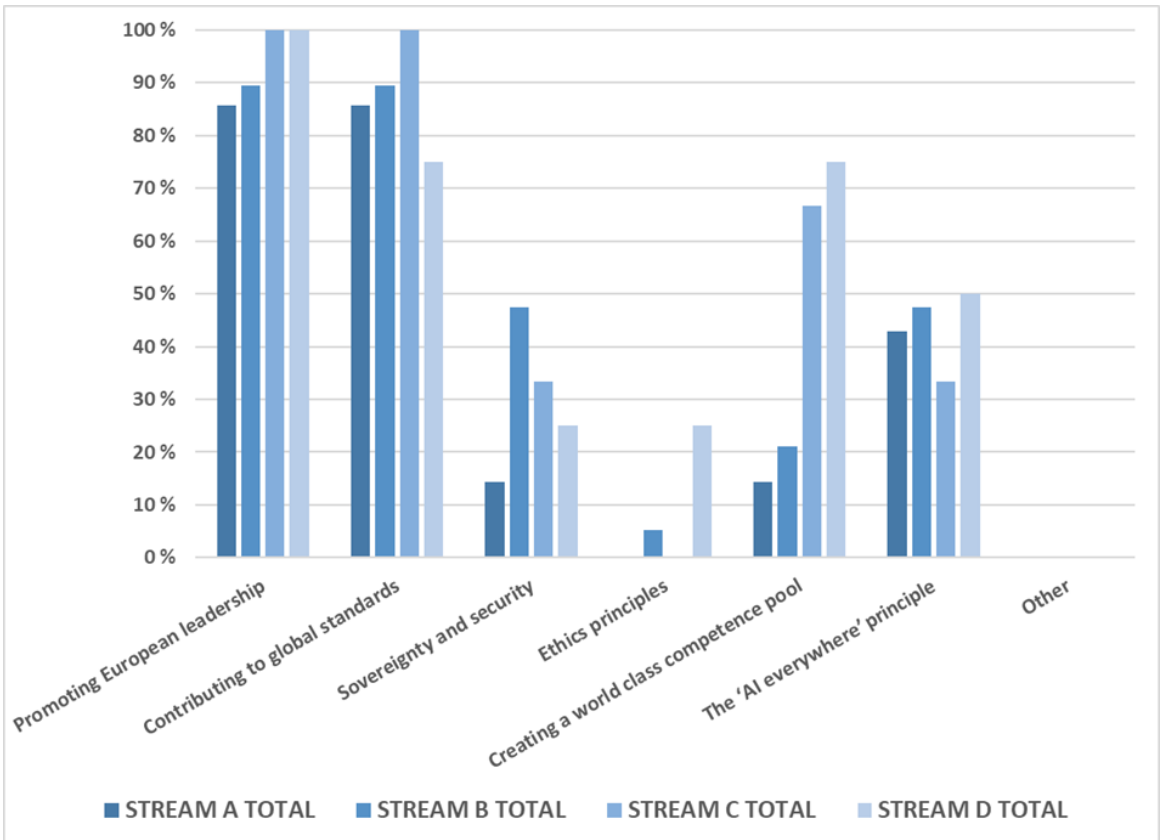

Figure 29: 6G Vision contributions as reported from the SNS JU projects – per Stream

Figure 29 shows the responses per Stream. *Promoting European leadership* and *global standardization* are important for all Streams. On the issue of creating a *world class Competence pool*, Stream C and D projects stand out significantly with a focus around 70% on this aspect.

Only Stream B projects had taken the opportunity to add free text responses to this question. Several projects emphasize *standardization* and *pre-standardization* contributions. Trust, reliability and resilience are mentioned, as well as European leadership. The answers reflect very much the different projects focus areas. No project, with the exception of one, has a broad focus on this respect.

Key Insights

- Projects are conscious about leadership and standards.
- Medium focus on AI, sovereignty and security, and competence.
- Little focus on ethic principles.

Further use of these insights will take place on the higher-level bodies such as the SNS SB and TB.

5.1.5 Sustainability

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

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)*.

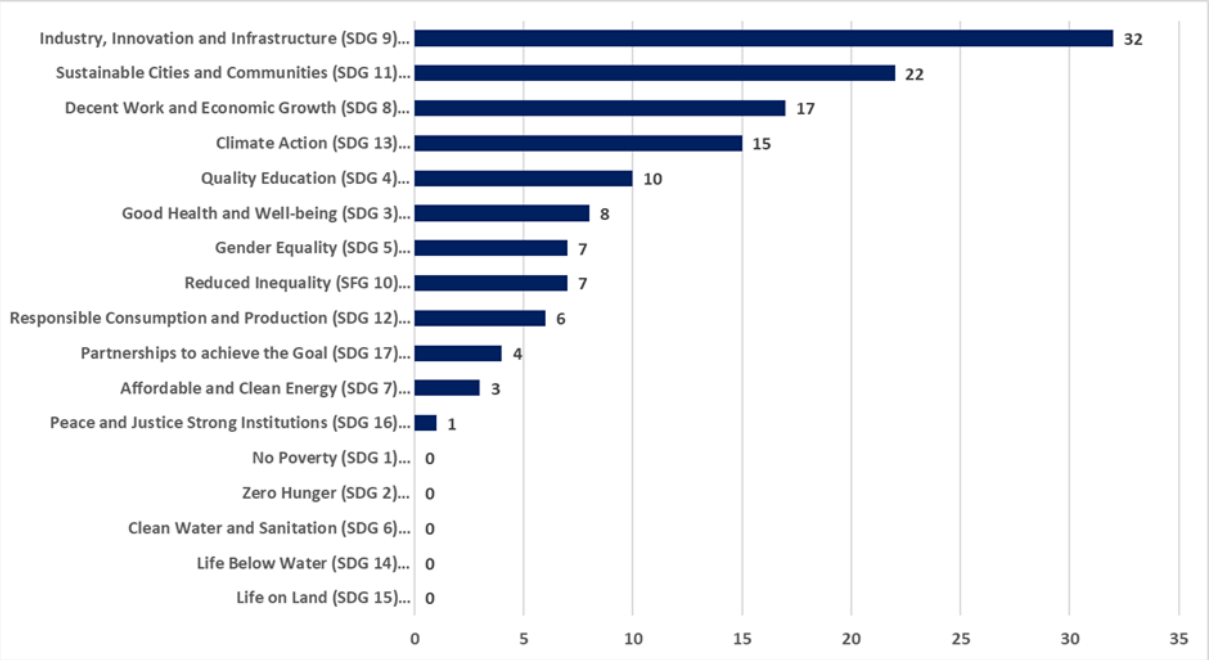

Figure 30: Contributions to UN SDGs by SNS JU Phase 1 projects

Investigating Figure 30, it becomes evident that the Phase 1 projects have these four SDGs on top of their priorities. Other SDGs which gain some attention are:

- Quality education (SDG#4).
- Good health and well-being (SDG#3).
- Gender equality (SDG#5).
- Reduced inequality (SDG#10).

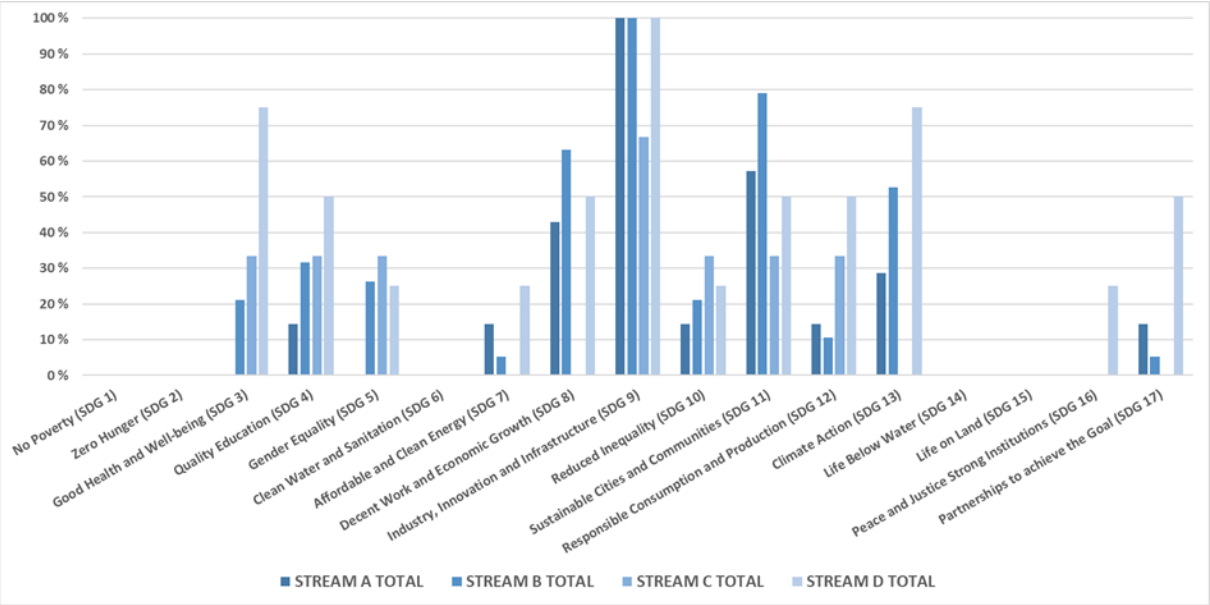

Figure 31: Contributions to UN SDGs by SNS JU Phase 1 projects – per Stream

Figure 31 depicts the focus on SDGs depending on the stream. Stream D projects have highest focus on SDGs in general. It is also observed that Stream B projects score well (almost 80%) on *Sustainable cities and communities* (SDG 11), while Stream D projects are standing out (75%) on *Good health and well-being* (SDG 3) and *Climate action* (SDG 13).

Some projects have given more in-depth explanation of their choices, and how they address these in the free-text field. One example from Stream A mentions innovative technologies for radio interface energy consumption to support SDG 8, 9 and 13. The Stream B project responses mentions sustainable industrialization, improved tele-health and tele-education, and digitization of the societies in general.

Key Insights

- The SNS Work Programme is specifically asking for contributions to 4 SDGs and the Phase 1 projects have indeed set these SDGs as their top priority.

Further use of these data is envisioned to take place in the Vision and Societal Challenges WG mainly.

5.1.6 Collaboration

Question V6: What type of thematic areas would be of interest to your project to commit resources and actively participate & contribute?

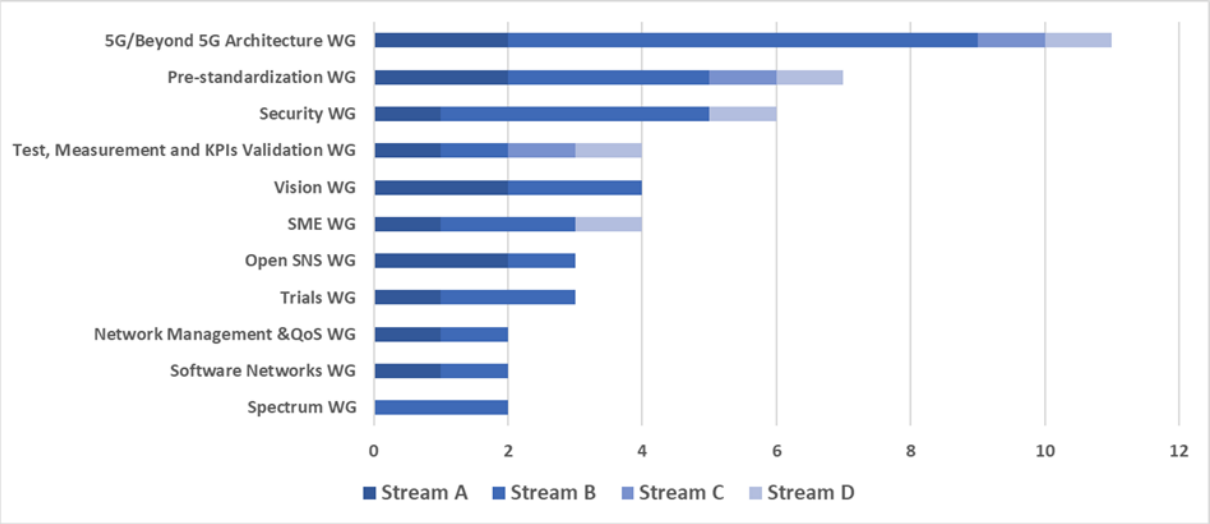

Figure 32: Attractive potential working groups as responded by the SNS JU Phase 1 projects.

At the time of the survey, the new SNS JU SB and TB had not been formed. Formally, no list of WGs existed. Thus, the intention of this question was to find out which areas was of interest for the projects to collaborate on. The projects were notified that the response is not binding and will only be treated as an indication. Since many project coordinators and partners have experience from the 5G-Infrastructure PPP programme, many projects referred to the existing and former WGs of the 5G Infrastructure PPP and 5G-IA. Since this was a free-text question, a match with the list found on PPP website[7] was performed.

Figure 32 shows the output from the matching process. It also distinguishes between the answers from the different Streams. The top three matches were.

- 5G/Beyond 5G Architecture WG.
- Pre-Standardization WG.
- Security WG.

A large number of thematic preferences were also put forward by the projects. A deeper analysis of these was not performed at this stage.

5.2 Shaping the SNS Vision

The initial EU stakeholders' vision of what 6G should be, led to the SNS programme creation. This initial vision, in general terms, is now being worked on in articulation with multiple projects that were contracted and are being led by the community. The community engagement and the natural priority separation that the community is performing, together with the technological innovation, is helping in the comprehension and in the improvement of this vision. In order to clearly assess this situation, there are several mechanisms that have been implemented in the project to improve the vision as time progresses, namely:

- The NetworldEurope Strategic Research Innovation Agenda (SRIA) that is released every 2 years with the involvement of all the community and respective actors. SNS OPS supports and helps this development via assistance in the NetworldEurope events and more.
- 6G-IA Vision and Societal Challenges WG and the up-dated version of the "European Vision for the 6G Network Ecosystem" white paper.
- SNS OPS questionnaires that allow us to assess what the community and the projects are working on and their respective vision.
- SNS OPS Vision retrospect / assessment based on the current and previous Work Programmes
- SNS online webinars which are used to provide explanations about the programme development, and also to receive informal feedback from the community.
- NetworldEurope technical events, supported by SNS OPS, and that are regularly organized as sessions on technological challenges, in order to help build a community vision on the future.

This is a cyclic process in which the community is involved and impacts the community and technical groups through the issued reports and results. They also impact the writing of the future Work Programmes and that can guide the SNS JU overall as well as serving as important input to the 6G-IA Board and the 6G-IA Vision and Societal Challenges WG ambitions (as well as the SNS projects Sustainability Task Force).

This vision is worked out as well in the creation of the Work Programme, where elements coming from the community work together with the EC in order to structure the mechanisms that will support the development of this vision (see Sub-Section 7.2). These actions go through an analysis of the existing actions inside the community, and the differential needed to build the pursued vision.

[7] https://5g-ppp.eu/5g-ppp-work-groups/

When considering the overall SNS JU proposal from a top-down perspective – considering e.g., the UN SDGs – the vision should be assessed and up-dated in terms of the overarching ambitions on matching and meeting the high-level European societal targets.

It was also observed that the Work Programmes (as in 5G Infrastructure PPP) and the SRIA focus are dominated by a technology research development. Indeed, the 5G Infrastructure PPP programme has succeeded to address vertical needs and business validation. However, 5G has not yet reached the anticipated new market growth and take-up for advanced 5G-enabled services.

Thus, it is anticipated that the SNS Vision should be enriched by:

- Reinforced focus on 5G smart services, business models and platform ecosystems, considering industry bottlenecks.
- Beyond the typical 5G business opportunities social, environmental and economic challenges and values must be addressed, mapping the relevant stakeholders in the extended ecosystems, e.g.:
    - NGOs.
    - Labour unions and professional associations.
    - Global emergency aid – PPDR in broader context together with the above.
    - Learning and education institutions.
    - Related academic institutes and think tanks addressing the above.

Both areas must engage the SNS JU community to reflect on maturity and develop roadmaps. A part of this will be to research and map industry bottlenecks and enablers and suggest mitigation. The SNS community should take care to engage with other relevant communities.

Based on the above presented information, this Deliverable can be seen as setting the context for and pointing into the SNS Vision up-date potential targets, which will be elaborated in Deliverable D1.3. Further activities should also be addressed by the relevant WGs, Subgroups, TFs, bodies and activities by e.g. the SB and TB and related activities to advance the vision in the before mentioned directions.

The anticipated updated SNS vision improves harmonizing all these aspects – top-down and bottom-up and the above suggested extensions. For this, we attempt to consider how the various roadmaps and "Vision – Roadmap" mappings might be conceived (to be reflected in e.g., the SNS phases). Deliverable D1.3 will elaborate on the anticipated SNS Vision and Roadmaps.

5.3 Key Value Indicator (KVI) Insight and Discussion

As was observed in the analysis of question V3 (see Sub-Section 5.1.3), the understanding of the notion of KVIs is not fully grasped by the SNS community. Even though the formulation of the question may have played a role here (pointing respondents towards Key Values), the lack of a clear understanding of what a KPIs is and how it could potentially be measured, is one of the key take-aways from this section of the questionnaire.

The 6G-IA White Paper "What societal values will 6G address" [13] explains the rationale behind KVIs and exemplifies the KVI analysis with 6 use-cases. This is brought further in the Hexa-X project Deliverable D1.4 [14] from June 2023.

Lesson learned from the first questionnaire is that a better introduction to KVIs is needed, especially for the new projects. In the revised questionnaire to be distributed among the new projects, it is natural to emphasize more on the KVI analysis process, instead of the KVIs themselves. Also, the link between KPIs and KVIs needs more attention. These aspects are expected to be further tackled by the ongoing work of the 6G-IA Vision WG.

This up-dated approach and methodology should consider the up-dated vision targets indicated and anticipated in Sub-Section 5.2.

6 SNS Market Outlook

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. This section summarizes the responses and learnings from the Phase 1 projects regarding how the market / economic of the programme is addressed.

6.1 SNS OPS Questionnaire – Market Section Analysis

The central objective of this section was to gain an in-depth understanding of the SNS Phase 1 projects projections and expectations regarding the evolution of the 6G market over the next years. The outcomes will help SNS 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 eight questions. Four questions were multiple choice and the other four were free text. Nonetheless, all questions included the possibility to elaborate on the response and, in the case of the multiple-choice ones, to provide additional answers to complement the options included in the pre-defined list.

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

- Key technologies and innovations for 6G.
- Main market trends in the advent of 6G.
- Vertical sectors expected to be impacted by 6G.
- Methods used in the validation of business opportunities.
- Main obstacles to the development of 6G.
- Novel markets for 6G development.
- Key exploitable results (KER) expected by the projects.

The analysis of each multiple-choice question showcases the aggregated responses of the 33 projects per option and the aggregated responses per option and per Stream, which are also expressed in percentages to reflect the different number of projects in each Stream and facilitate comparisons. For instance, Stream B, with 19 projects has more than all the other Streams together. Therefore, the overall responses will be largely determined by the opinions of Stream B.

The analysis of the free text questions followed a bottom-up approach. The answers were examined to find commonalities that would enable to group them and subsequently, to establish categories. Likewise, specific insights from the projects that would enrich the data obtained were highlighted.

This mixed approach provides robust evidence to identify trends and correlations, as well as to draw valuable conclusions about the key topics addressed.

6.1.1 Market Changes

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

This question was free text. Therefore, the information provided was analysed and then grouped around specific topics. As a result, three types of categories comprising all the responses, were identified:

Market trends

Two important trends, perhaps contradictory, refer to the evolution of the market in the next few years: market fragmentation versus rise of a few dominant industrial players. The fragmentation of the market would be mainly due to the modular architecture that would foster the emergence of new players covering the value chain. Contrariwise, the rise of a few globally dominant enterprises emerging from

current incumbents could be linked to the predominance of use-cases requiring the establishment of private networks in most vertical sectors, generating new business opportunities for MNOs.

The increased integration, enabling seamless connectivity, and the proliferation of wireless solutions, which allow for dynamic, environmentally friendly connectivity options are central to most projects and predicted to open new business opportunities. In this respect, new communication technologies, AI and advanced hardware are expected to accelerate the entry into markets that leverage massively scalable immersive environments. The openness of solutions is considered a driver for the adoption of 5G/6G.

AI-based solution and application providers will gain significant benefits, according to most SNS projects. The potential of AI is mentioned in relation to all innovations, technologies and sectors in the telecommunications market. Moreover, stricter and sophisticated security controls and privacy measures are necessary to guarantee the new services enabled by 6G are trustworthy. Similarly, the SNS focus on automation is highlighted across projects and Streams, whilst lowered technological barriers are anticipated to boost collaboration and interdisciplinarity.

VR/AR equipment, drones and UAVs, robots and sensors are expected to carve out benefits for vendors and original equipment manufacturers.

Market disrupters

The main technologies and innovations predicted to transform the market are Internet of Things, Digital Twins, Holographic technology, Internet of Senses, High Performance Computing, Quantum computing and TSNs.

Vertical markets

There are several vertical sectors and specific domains expected to grow with the development of 6G. Industry 4.0/manufacturing and Media and Entertainment are the main ones. Health, Transport & Logistics, PPDR and agriculture and forestry are also cited abundantly.

6.1.2 Technologies/Innovations Evolution

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

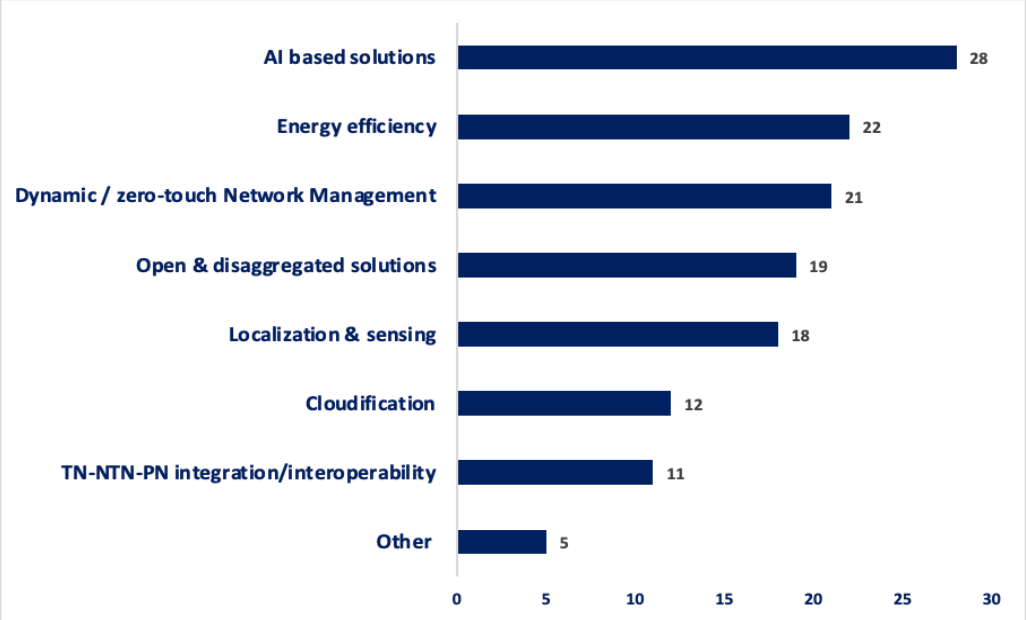

Figure 33. Technologies/innovations expected to play an important role according to all projects

AI-based solutions are predicted to be a game changer for the delivery of high-level and more efficient services in the telecommunications market, as shown in Figure 33. In fact, only two projects, one in Stream B and one in Stream D, did not mark this option.

Energy efficiency solutions and *Dynamic/zero-touch network management solutions* are also among the most anticipated innovations to disrupt the market in the coming years. The emphasis placed in *sustainability* is steering the development of more sophisticated solutions, including wireless systems, devices and networks, where *cloudification*, *zero-touch management* and *dynamic spectrum sharing* can make a difference. *Open and disaggregated solutions* and *location and sensing solutions* are also considered to have a remarkable potential to transform the telecommunications sector.

Other technologies and innovations mentioned are predictable networks. The integration of AI in all aspects of the communication networks is understood to be a game changer for all the ecosystem players. Deep network programmability and pervasive monitoring to support data-driven intelligence are also cited.

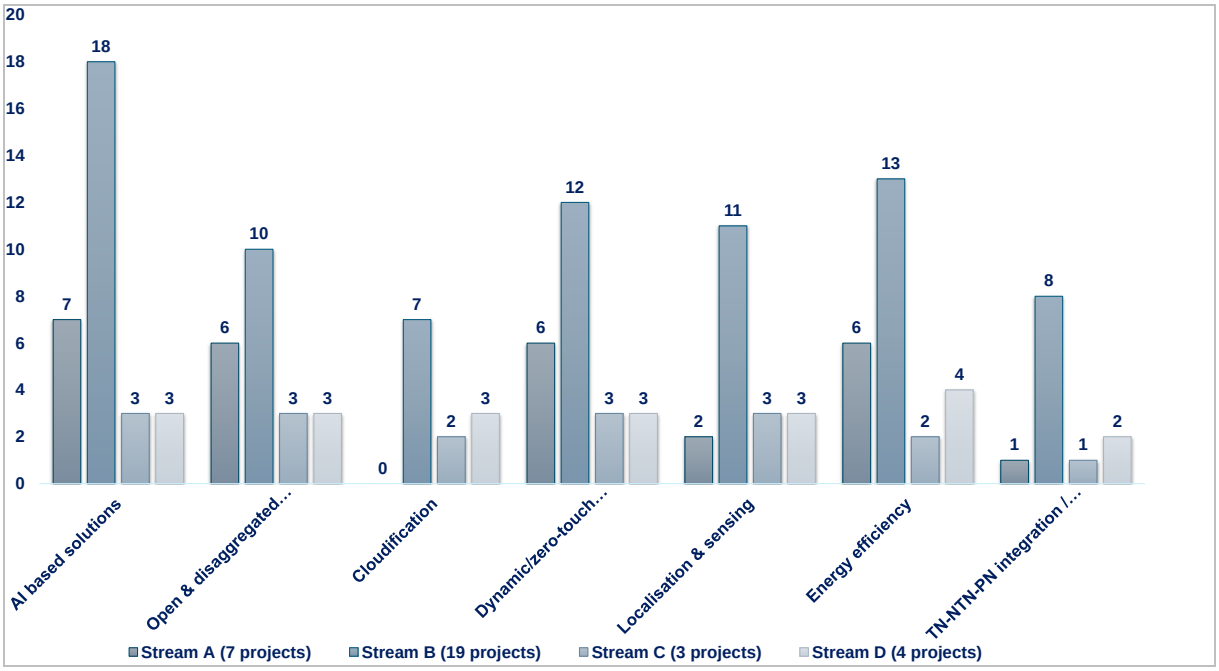

Figure 34. Technologies/innovations expected to play an important role per Stream

Key Insights

All Stream A projects expect *AI-based solutions* to have a notable impact in the market. Out of the seven projects in this Stream, six also predict *open and disaggregated solutions*, *dynamic/zero-touch network management solutions* and *energy efficiency* to contribute to change the market. None of the Stream A projects indicated *cloudification* as a market disrupter.

All Stream B projects except for one, foresee that *AI-based solutions* will radically change the market. Notwithstanding AI, the responses are rather varied, with almost all innovations and technologies considered to be highly relevant. For instance, AI coupled with sensing may drastically alter the interactions with digital services. Zero Trust security principal applications, which includes dynamic/continuous security and trust evaluation of the end-to-end network and services is also highlighted.

Similarly, Stream C projects consider most of the technologies and innovations listed to have a significant potential to change the telecommunications market. All three projects agreed that *AI-based solutions*, *open and disaggregated solutions*, *dynamic/zero-touch network management solutions* and *localisation and sensing solutions* will play key roles in the coming years. *Cloudification* and *energy efficiency* are mentioned by two out of three projects, whilst *TN-NTN-Public Network (PN) integration/interoperability* is only cited by one project.

Energy efficiency technologies and innovations are projected to have a remarkable influence in the market, according to Stream D projects. Yet, overall, Stream D follows the same pattern than that of Stream B and C. Some 75% (three out of four) projects consider AI-based solutions; open & disaggregated solutions; dynamic / zero-touch network management; and, localisation & sensing, as

noteworthy. Unlike in the previous cases, 75% of the projects also foresee cloudification to underpin important changes in the market.

6.1.3 Verticals Sector Impacts

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

Industry 4.0/Manufacturing and *Media/xR* are expected to be the verticals most impacted by the advent of 6G, as visible in Figure 35. The ultra-low latency and increased bandwidth in 6G networks, which enables high-speed data processing, coupled with wireless and mobile robotics, are deemed critical for industrial applications. In relation to media, the enhancements and innovations in VR, AR and xR technologies are anticipated to bring important changes to the entertainment and education sectors as well as more specific domains such as remote working. VR, AR and xR are also being utilised in manufacturing plants.

A remodelling of the *automotive and transport & logistics* sectors is also necessary to meet the Green Deal ambitions. The improved digital connectivity provided by 6G is intended to be exploited in various areas to build a more environmentally friendly industry.

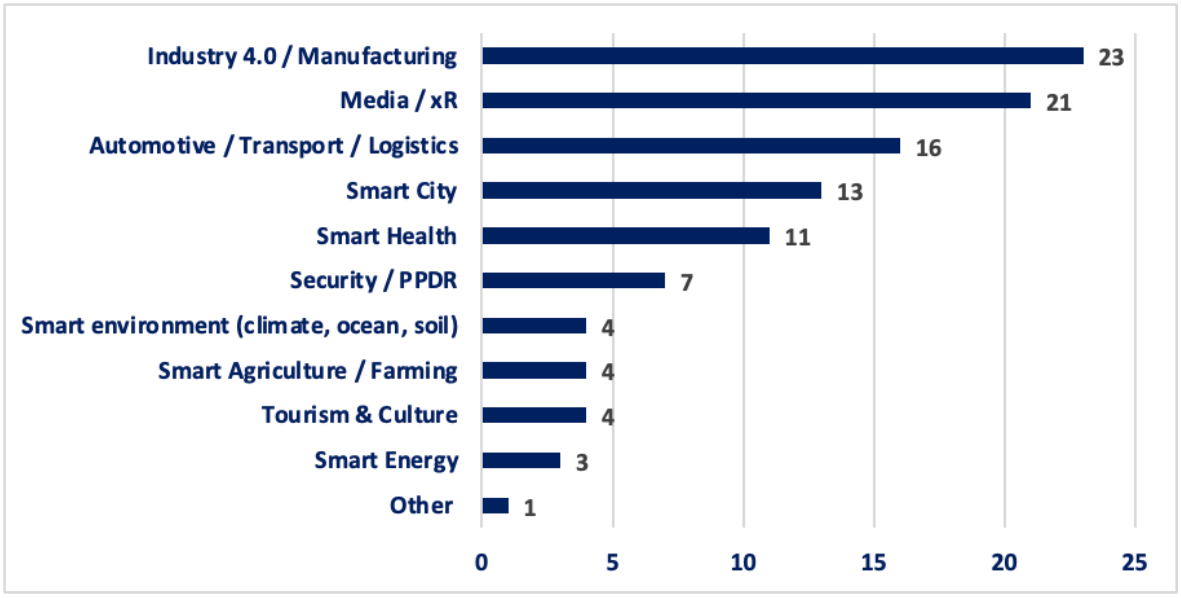

Figure 35. Vertical sectors expected to be affected the most with the advent of 6G according to all projects

Stream A and B anticipate *Industry 4.0/Manufacturing* to undergo the highest transformation with 6G, whereas Stream C and D do it in *Media/xR*, as shown in Figure 36.

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

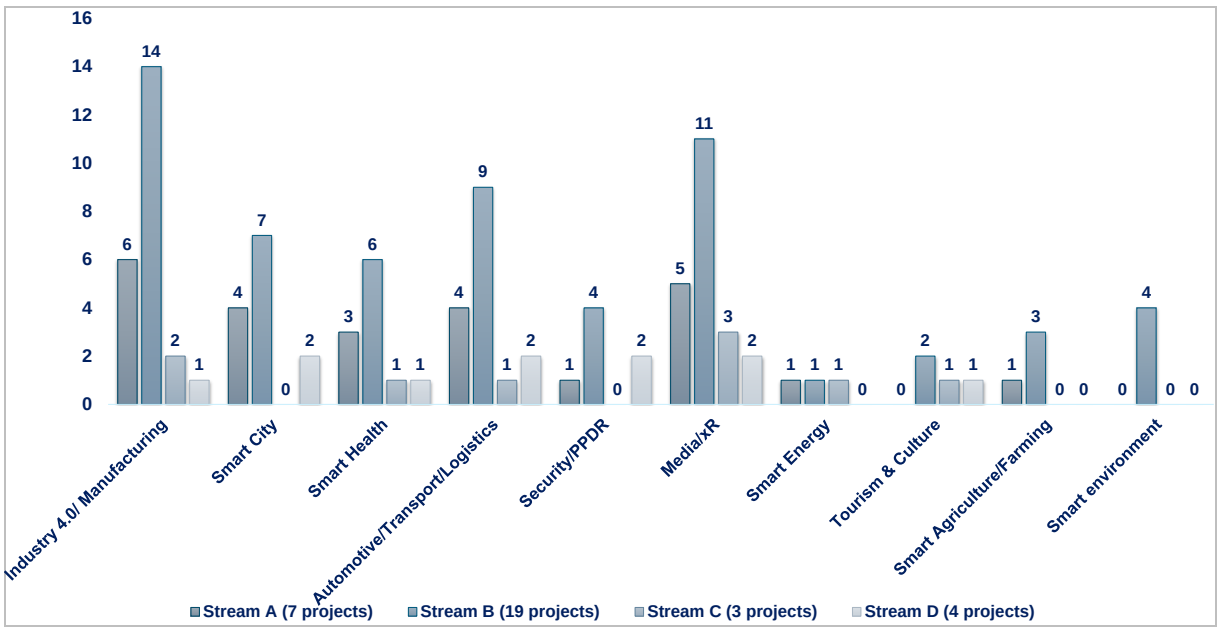

Figure 36. Vertical sectors expected to be affected the most with the advent of 6G per Stream

Key Insights

Out of the seven projects in Stream A, six indicated that *Industry 4.0/Manufacturing* is expected to be the sector to experience a significant transformation linked to the development of 6G, whilst five selected *Media/xR*. More than half of the Stream A projects also presume *Smart City* and *Automotive/Transport/Logistics* to undergo important changes connected to 6G, as shown in Figure 36.

According to Stream B and Stream C projects, *Industry 4.0/Manufacturing* and *Media/xR* are foreseen to experience the greatest impact by the advent of 6G. In fact, 100% of the Stream C projects mentioned *Media/xR*.

Smart City, *Automotive/Transport/Logistics*, *Security/PPDR* and *Media/xR* were the top verticals for Stream D projects. This departed slightly from the overall trends identified in the other Streams. Nevertheless, the opinions were very diverse, and these four sectors were only mentioned by 50% of the projects in Stream D.

Even though *Smart Energy* is expected to be the sector least impacted by 6G, it was considered by one project across all Streams except for D. However, none of the projects in Stream A, Stream C nor Stream D indicated *Smart Environment*. Moreover, no projects in Stream C and Stream D indicated *Smart Agriculture/Farming*.

It is also interesting to note that no Stream C projects marked *Security/PPDR* nor especially *Smart City*, which ranks fourth among the vertical sectors expected to be impacted by 6G in the overall count. Finally, no Stream A projects indicated *Tourism & Culture*.

6.1.4 Verticals Sectors Business Opportunities Validation

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

Some 70% of the projects validate their business opportunities in vertical sectors by working with *use-case owners*. The *development of hypotheses about the potential technology needs of vertical sectors* is rather common, with 45% of the projects selecting this option. Inversely, the *hypotheses about potential business models for the technology being developed* by the project nor the *application of the methods suggested by 6G-IA* are not widespread, as depicted in Figure 37.

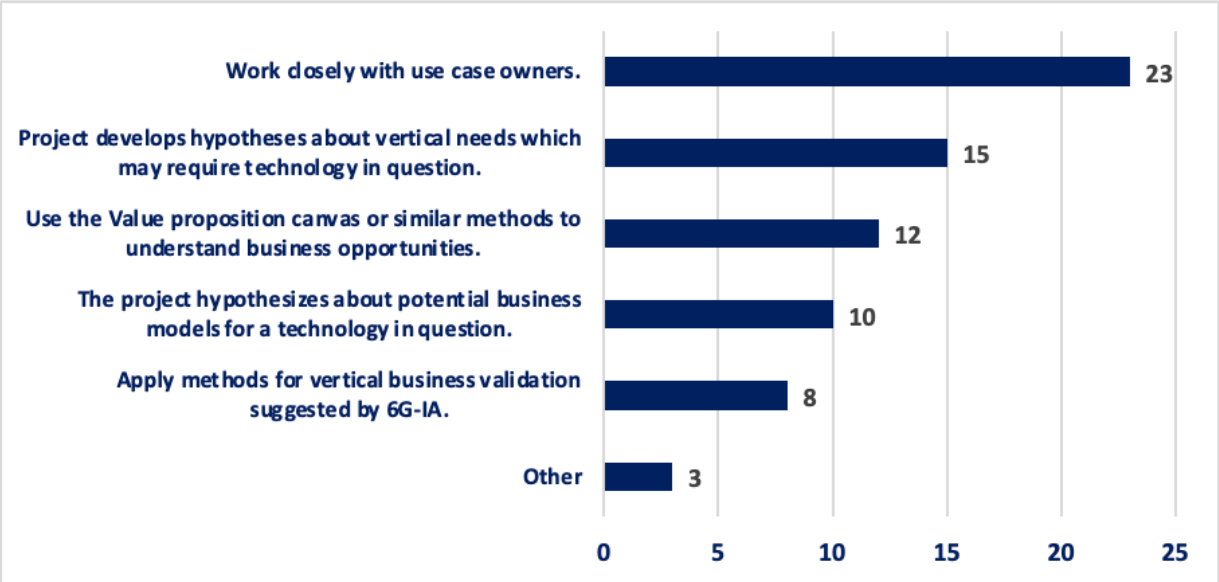

Figure 37. Validation of business opportunities in vertical sectors according to all projects

Figure 38 shows that the *work with use-case owners* is also the most common method across Streams.

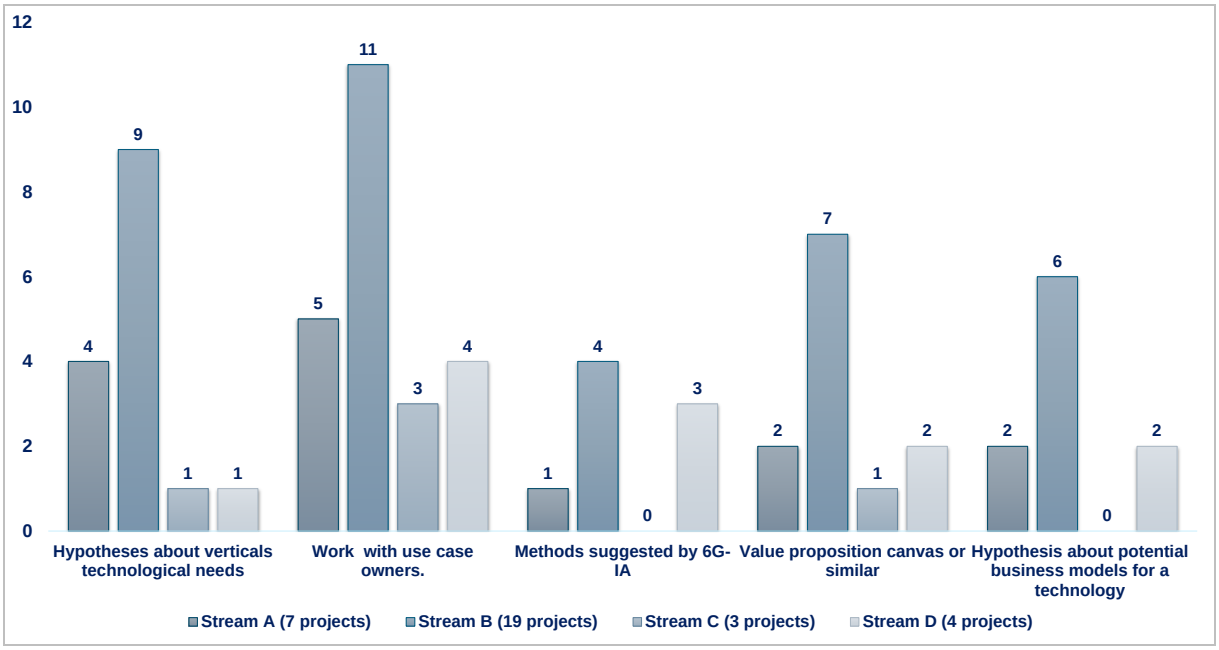

Figure 38. Validation of business opportunities in vertical sectors per Stream

Key Insights

The results showed that:

- The formulation of ***hypotheses about verticals technological needs*** is very common among Stream B projects.
- ¾ of the projects in **Stream D** projects choose the *application of* ***methods suggested by 6G-IA*** (the least popular response overall).
- No project in Stream C selected the *hypothesis about potential business models for a technology* nor the *methods suggested by 6G-AI*.

6.1.5 6G Networks Deployment Obstacles

M5. What do you consider to be the greatest obstacle for the deployment of 6G networks?

Deployment costs are seen as the main obstacle to the deployment of 6G. In particular, some projects indicate the lack of transparency regarding the Return of Investments (RoI). The *lack of demand for unique 6G service*s and *the lack of willingness to allow interoperability* are also seen as notable challenges by 48% and 42% of the projects. Regarding *interoperability*, anticipating complex applications and geopolitical challenges is key.

The *lack of trust in AI solutions* is also considered a remarkable obstacle. The current state of affairs, with policymakers and regulators trying to provide guidance to the different layers of AI-related implications and the general public concerns related to the potential impact of AI, are mentioned by projects as the main causes behind this obstacle, as shown in Figure 39.

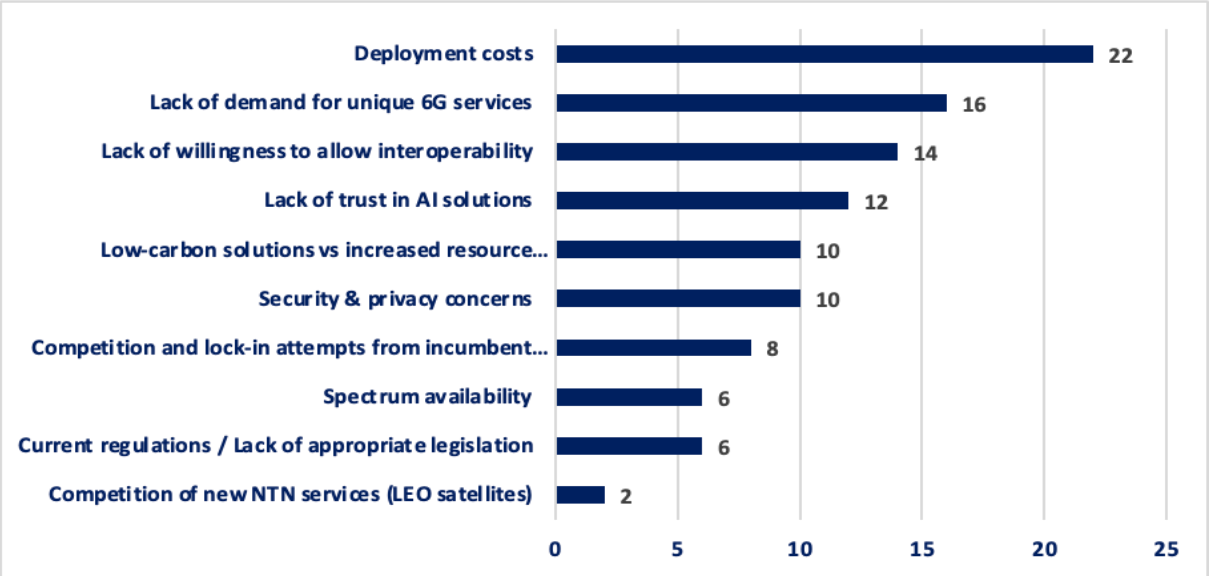

Figure 39. Main obstacles for the deployment of 6G networks according to all projects

The projects added some observations related to a few of the barriers listed. For instance, the large number of communication interfaces and the shared nature of the wireless environment will demand more sophisticated mechanisms to ensure security and privacy. Regarding the spectrum management, the main concerns refer to unlicensed bands in the mmWave and THz spectrum and the spectrum scarcity in the below 10 GHz region. Finally, the sustainability related issues stem from the contradiction between the heavily increase of energy consumption powered by the large amount of data needed in contrast to the slower improvement of solutions that increase efficiency.

Figure 40 illustrates the main obstacles to the deployment of 6G according to each Stream.

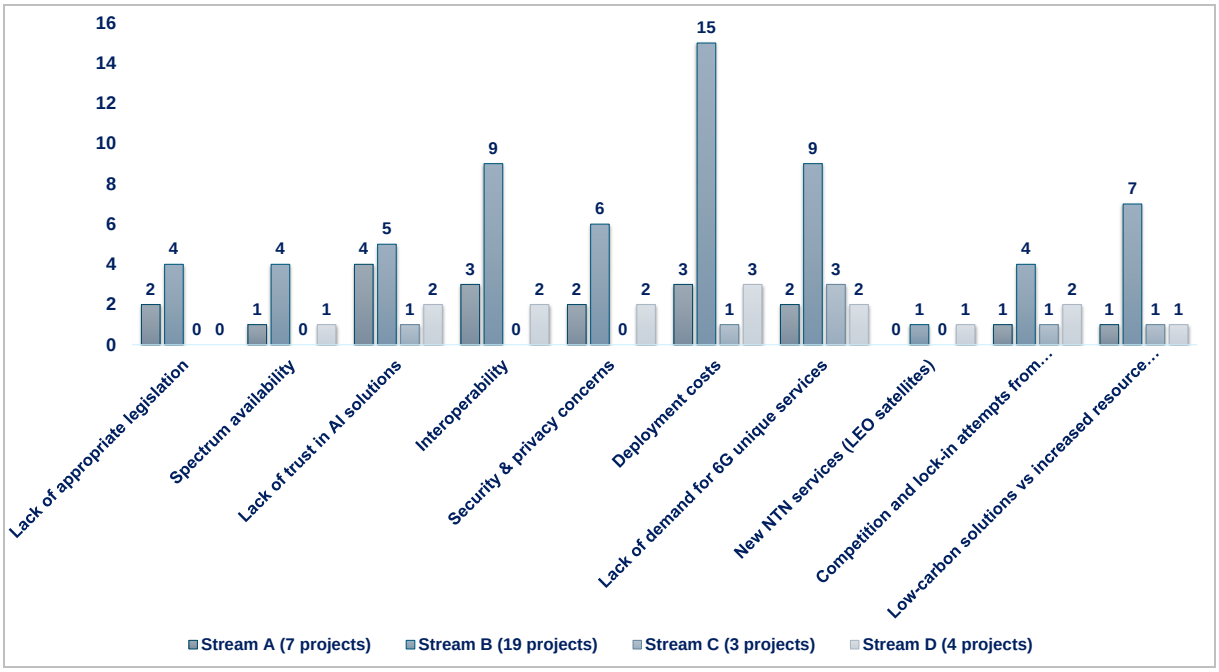

Figure 40. Main obstacles for the deployment of 6G networks per Stream

Key Insights

Almost 80% of the **Stream B projects and 75% (3/4) of the Stream D projects indicate *deployment costs* as the principal challenge** for deploying 6G networks.

The ***lack of trust in AI solutions* is the top obstacle for Stream A** projects, whereas **the *lack of demand for unique 6G services* is the main concern for Stream C** ones. In fact, all Stream C projects agree on that 5G may cover all the potential demands for services in the near future.

The issues related to ***interoperability***, which rank third amongst the main obstacles for the overall projects, are pointed out by some 40% of Stream A and Stream B projects, as well as 50% of Stream D ones. No Stream C projects indicate *interoperability* nor *security and privacy*, *lack of appropriate legislation*, and *spectrum availability* as an impediment.

6.1.6 App Ecosystem and Novel Market Section

M6. 4G enabled the "App ecosystem". Do you believe 6G can accomplish something similar? If yes, what would be your estimation as to the novel market section that 6G may enable?

Underpinned in 6G, large volumes of IoT data could be transformed using AI solutions into valuable and actionable knowledge, able to automate and optimise the decision-making process in multiple sectors ultimately, shaping a **"things ecosystem".**

Key Insights

6G high-speed and low latency coupled with holographic technology could enable significant immersive and realistic VR/AR/xR experiences, effectively accomplishing an **"immersive app/service ecosystem"** or **"metaverse ecosystem".** In fact, holographic representations are expected to become a key asset in a wide range of scenarios.

New services and produces such as advanced telemedicine, including real-time monitoring of patients and remote surgeries, or robots for the industry and general consumers, are also mentioned. Moreover, 6G is expected to boost sustainability by supporting the seamless interaction between several technologies, decreasing the processing time whilst increasing the energy efficiency, trust, stability, robustness and performance.

6.1.7 Key Exploitation Results (KERs) and Technology Readiness Levels (TRLs)

M7 . What are the Key Exploitable Results (KER) expected to be delivered by your project? At which Technology Readiness Level (TRL) is each of them expected to be delivered?

The number of KERs was widely different among projects. Moreover, each identified very specific results. Therefore, for this analysis, KERs were clustered in three main groups, namely: integration/network technologies (i.e., fully integrated NTN into 6G, Passive Optical Network (PON) solutions, waveform and radio protocol design, etc.), management (i.e., SLA-Driven E2E Slice Management, Deep Data Plane Programmability, Network Digital Twin, etc.), and security and privacy (i.e., security, privacy, confidential toolbox, distributed AI engine for services preassessment, threat detector, blockchain and attacks models, etc.). A fourth group contains KERs linked to sustainability and AI. A more detailed explanation is provided in the section below. Details are included in Appendix B.

To analyse the estimated TRLs per each KER as reported by the projects, the number of assigned TRLs per each KER was counted. For example, if a project mentions seven KERs each expected to reach TRL5 and other project mentions two KERs expected to reach TRL5, the result is nine KERs in TLR5. KERs that were assigned a range of TRLs (e.g., TRL3 to TRL5) by the projects were excluded from the count.

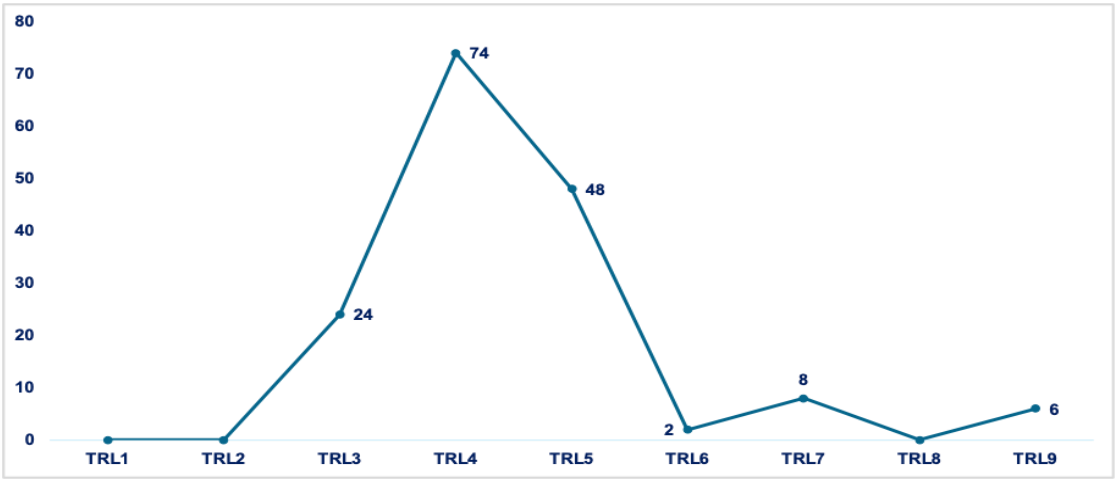

Figure 41. TLRs reported by all projects per each of the KERs listed.

Figure 41 illustrates that most projects defined medium TLRs, i.e., between 4 and 5. A steep drop can be observed for TLR6 followed by a slightly higher number of projects expecting their KERs to reach TRL7. Moreover, there are some 24 KERs expected to be delivered at TRL3. It is also remarkable that three KERs are anticipated to reach TRL9.

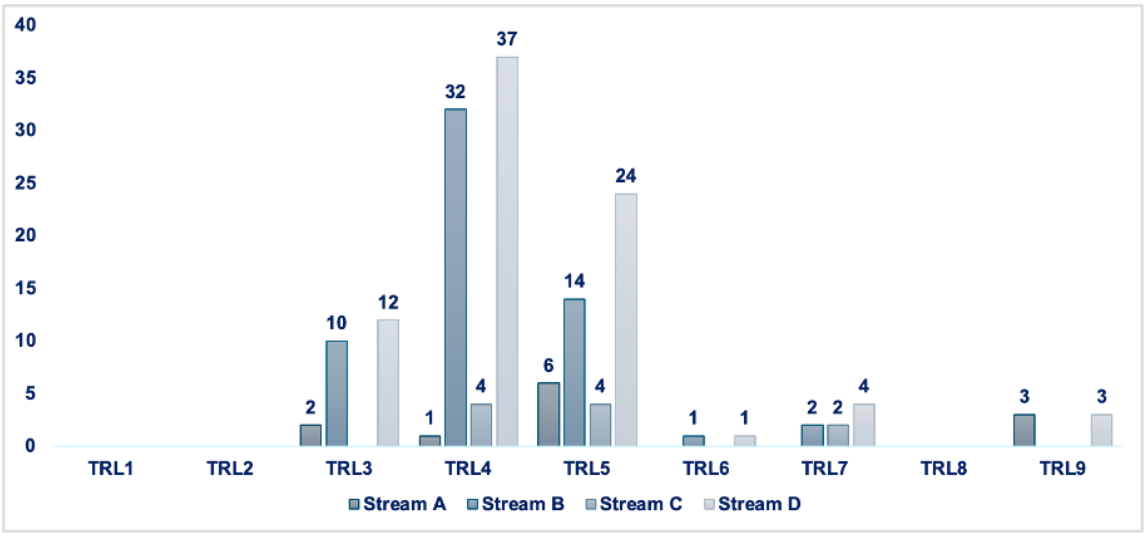

Figure 42. TLRs reported by all projects per each of the KERs listed per Stream

Key Insights

Most projects defined medium TLRs, i.e., between 4 and 5. Notable differences can be observed across Streams, as depicted in Figure 42:

- TRL3 is mainly reported by projects in Stream A and B.
- TRL7 is mostly reported by projects in Stream D, with some projects in Stream B and C.
- The highest TRL (9) is only reported by projects in Stream A and Stream D.
- No projects reported TRL1, TRL2 nor TR8.

6.2 Market Insights and Prospects

For this section, a top-down analysis with the respective grouping is carried out which helps with the understanding of the largest market opportunities for SNS stakeholders.

The SNS – OPS survey has asked the 33 SNS projects eight (8) individual free-text questions dealing with **Marketing related topics** envisaged with 6G.

The questions have resulted in significant information compiled, indeed from the vast majority of the SNS projects from all Streams, which are summarised below and analysed and consolidated further under a finer granulation of marketing topics for each question.

Based on the analysis of the questionnaire, various trends, sectors and technologies emerged as the most promising with the advent of 6G. Most technologies and innovations are expected to be enhanced by 6G and have a transversal impact across many vertical sectors, creating strong interlinks amongst them.

Early analysis points to sustainability and AI as key enablers of the future direction in 6G markets. Security, privacy and trust has also been identified as a core area due to the stricter and more sophisticated privacy controls demanded by the current 6G vision. Trust is a cornerstone in the new ecosystems.

There are remarkable expectations towards a renascence of Internet of Things. The standardisation and integration of the communication with the 6G rollout is projected to cause an explosion of the application of IoT devices, according to some projects. Furthermore, it is important to mention that the integration, proliferation and openness of solutions will be game changers in the new few years.

Industry 4.0 and Media and Entertainment are highlighted as the most auspicious vertical sectors with the introduction of 6G. The features of 6G and its integration with diverse technologies, including AI and AR, as well as high-performance computing and quantum computing, are meant to disrupt the current markets, opening new business avenues.

However, the deployment of 6G is not exempt of challenges. The lack of willingness for interoperability may pose the risk of losing a strong market position regarding UEs. Moreover, the high costs of devices may impact the proliferation in the mass market.

Trends, technological innovations and market disrupters

Sustainability

The green transition describes the shift towards economically sustainable growth. The Green Deal embeds all the principles to transform the European Union into a modern, resource-efficient and competitive economy. It aims to boost the economy through green technology, build a sustainable industry and transport, reduce pollution and create new opportunities whilst ensuring the transition is fair and inclusive for all.

The policies and incentives linked to the Green Deal goals are driving many of the technologies and innovations pursued by the SNS projects. The stop to planned obsolescence and the energy efficiency labels for household appliances are some of the examples mentioned.

The potential of 6G to advance energy efficient solutions is anticipated to carve an important part of the ICT market. The enhancements of 6G are expected to enable high wireless flexibility to systems, devices and networks. This will allow for dynamic, cost-effective, and environmentally friendly connectivity

options that can be applied to almost if not all vertical sectors, including industry and transport. The improvement of the hardware energy efficiency is also relevant.

Yet, 6G also poses some challenges. Even though 6G is expected to be more efficient, the heavily increase of energy consumption powered by the large amount of data needed contrasts the slower improvement of solutions that increase efficiency hence, the increasing Greenhouse Gas (GHG) emissions of the telecommunications sector.

Some of the sustainability related technologies include energy aware backpressure, which is a collection of HW-level energy consumption metrics and mapped onto tenants through adaptive AI-driven analytics, cloudification and zero-touch management to increase networks efficiency, TN/NTN integration enabling seamless connectivity at a lower cost with positive spillovers in remote areas and thus, the promotion of inclusiveness, Hardware Graphics Processing Unit (GPU) based acceleration offloading of energy intensive mMIMO RAN functions; energy efficient DSP, and, ultra-high rate and low-energy transmitters.

The seamless interaction among technologies supported by 6G is expected to lead to a shorter processing time and thus, lower energy consumption. In addition, 6G higher reliability will increase trust, stability, robustness and performance. The merits of power and energy efficiency in the context of 6G could be a driver of adoption that accomplishments of truly sustainable communication systems.

Artificial Intelligence

There is no question that AI will shape the ICT sector. The advances in 6G coupled with the evolution of the technology and its applications are predicted to be a game changer for the delivery of high-level and more efficient services in the telecommunications market. As a result, AI-based solutions and application providers are expected to gain significant benefits.

6G combined with AI and holographic, VR, AR and xR technology could accelerate the entry into markets that leverage massively scalable immersive environments effectively accomplishing an **“immersive app/service ecosystem”** or **“metaverse ecosystem”**. The accessibility and realism of these experiences are likely to enable a successful adoption in a broad range of sectors, including media, culture and education. High-performance computing and quantum computing are expected to also have a significant role powering the anytime, anywhere immersive experiences.

Ubiquitous 6G connectivity across a city-wide network enables massive high speed data collection and analysis by AI, yielding many benefits such as traffic management, emergency services, and environmental quality monitoring that will accelerate the transformation of smart cities. In this line, breakthrough innovations in healthcare and wellbeing services are also anticipated. Although smart agriculture was only tangentially addressed, it was highlighted how new types of sensing technology in 6G can augment smart farms with new types of sensor data combined with AI and increased data rates to improve crop quality, yields, and waste management.

It is important to note that the lack of trust in AI and its potential impact, especially powered by 6G, is one of the main concerns around this technology. The current state of affairs, with policymakers and regulators trying to provide guidance to the different layers of AI-related implications, the general public concerns related to the potential impact of AI must also be addressed from a technological perspective.

Security, privacy and trust

The new technology enablers expected with 6G will widen the threat landscape. Heterogeneous radio, RAN softwarisation, multi-vendor deployments, programmable platforms accessed by multi-stakeholders and tenants, applications and intelligence seamlessly and securely distributed end-to-end across heterogeneous domains, from the central clouds to edge clouds, and to smart devices, the emergence of new ultra-reliable and low-latency communications use cases or AI-driven network management are some examples of technologies and services that pose an increased risk, while offering numerous opportunities.

An increased demand for secure and trusted services is expected and consequently, an increased competition among service providers to offer the most secure and trusted services. Zero trust security principles, which include dynamic/continuous security and trust evaluation of the end-to-end network and services, are some of the solutions being explored. A projection indicates security and privacy may enable an OPEX reduction by at least 15% in detection, decision, mitigation and policy enforcement in

vertical sectors.

The security and privacy related KERs illustrate some of the ambitions in the field: a novel security and privacy toolbox, realistic blockchain and attacks models, confidential toolkit - a set of cryptographic or enablement libraries for confidential computing and confidential networking, distributed AI engine for services pre-assessment, threat detector and mitigation engine, eXplainable Artificial Intelligence (XAI) toolbox for decentralised security analytics, data anonymisation streaming pipelines software, and, AI-driven decision-making mitigation framework that allows to prioritise threats and design a mitigation plan, building a complete threat orchestration ecosystem.

The heterogeneity of the environment in which diverse network, devices and functions interact to offer services requires 6G to enable smarter security features to thrive and adapt to the changing environments.

Internet of Things

6G is predicted to enable higher levels of reliability, faster, cost-efficient and seamless connectivity and ubiquitous coverage. Therefore, it will support the transformation of large volumes of IoT data via AI-based solutions and big data technologies into valuable and actionable knowledge, which enables automating activities and optimising the decision-making process in multiple sectors, from smart city and autonomous driving to energy and transportation, ultimately shaping a "things ecosystem". It will also enable closed-loop control of a larger number of devices and appliances and will allow to connect devices not previously covered, opening new market avenues.

The two most impactful drivers that will dominate content generation and network traffic will be human augmentation – Internet of Senses - and digital-physical fusion - Internet of Things and Digital Twins.

This proliferation of new innovative applications and technologies such as light weight XR wearable devices is predicted to trigger the user demand for this type of services and others related to "Internet of Sense". This will lead to the involvement of knowledge-intensive small companies that will take advantage of the 6G network openness causing a broader distribution of the market share.

IoT, humans, and connected devices, vehicles, robots, and drones will generate zettabytes of digital information leading to applications such as holographic telepresence and immersive communication and meet far more stringent application requirements stemming along the edge-cloud continuum.

Some of the sectors that will benefit from 6G underpinning IoT are Industry 4.0, transport and logistics, or agriculture.

Integration, proliferation, and openness of solutions

Smooth **integration** of wireless and wired access technologies will allow new services to be introduced in several vertical domains i.e., Industrial IoT, manufacturing, logistics, autonomous driving and autonomous robots, and media and entertainment. Similarly, advances in integrated TN/NTN architectures will allow for seamless connectivity to diverse verticals.

Integrating new communication technologies such as reconfigurable intelligent surfaces and THz spectrum with AI and advanced hardware (e.g., high-computational devices) are predicted to accelerate the entry to markets that leverage massively scalable immersive environments, such as Public Protection & Disaster Relief (PPDR), automotive, energy, industrial manufacturing, health, media and entertainment, public safety and other ICT sectors, and introduce a new line of edge computing products in B5G/6G networks.

In this regard, edge computing continues to push intensive compute processes in which data is processed in a different place than its generated. 6G will be fundamental to meet the large demand for high-speed wireless networking to move all this data around at the edge. As of now, this is not possible with the current 5G and WiFi technologies.

KERs provide insights into the particular focus of the integration for SNS projects. In addition to fully integrated NTN networks into 6G, integration-related KERs include PON Solutions, Packet-Optical DPUs, Waveform and radio protocol design including mobility and multi connectivity, Latency-aware access in the unlicensed spectrum, centralized/distributed/hybrid radio resource management, Deterministic Wireless transmission, Wireless-friendly TSN and DetNet, photonic-based millimeter-wave/Terahertz antenna arrays, pursuing high-gain beamformed and beam-steerable RF beams;

Terahertz (THz) reconfigurable intelligent surfaces (reflective and transmissive), an OpenRU platform for Cell-Free mMIMO prototyping.

Overall, the potential of integration is expected attract more stakeholders in the different domains, but also to the industries originated on the new business models. For instance, the integration of these novel technologies can achieve high-precision in-body localisation capabilities thereby developing innovative, advanced, and more effective medical treatments. Additionally, the introduction of haptic communications can enable remote surgery scenarios.

The **proliferation** of wireless solutions for critical applications will cause a major leap from "mission critical" to "life critical" service support. This will largely build on the increased reliability and trustworthiness of solutions delivered by 6G. The ubiquitous coverage will open new market avenues.

The Software Defined Infrastructure trend continues from the advancements of software-defined networking in 5G and other sectors. This has a profound change on what companies supply the equipment necessary to operate 6G networks, and the commoditisation of 6G hardware changes the landscape and opens it to allow more companies to create products.

The greater coverage provided by 6G is expected to have a positive effect in the socioeconomic status of the population. The inequality caused by the lack of access to connectivity correlates with a poorer economy and a lower quality of life. 6G will deliver an evolution path for fixed and mobile broadband with more capacity, higher throughput, and lower latency. It will provide more pervasive access through higher-density connections and ubiquitous coverage, and it will expand mission-critical services through higher reliability and availability. The capacity to improve the accessibility to a network as well as the reliability of that access will help to reduce inequalities, irrespective of income level and geographical location.

The promotion of **open networks** will accelerate and ease the adoption by the industry beyond the ICT sector. Early proof has been gathered over the last few years in pre-5G advanced platforms that solidifies the projections regarding an increased willingness to adopt the platforms and utilise them for B2B and B2B2C business models to create economic growth through digital economy drivers. This is supported by use cases specified, controlled and owned by the industry sectors seeking to create and capture value in their ecosystem.

Other technological innovations and market disrupters

Automation will continue to be at the forefront. Some of the solutions targeted include automated network management and proliferation of federate testbeds to be made available for DevOps purposes, usage of virtualised and disaggregated network infrastructures facilitated by O-RAN and cell-less architectures, zero-touch automation or improved service orchestration through greater automation, network slicing, and open APIs. There will also be necessary unlocking reconfigurable networks, where the network capacity resources are continuously matching with the user demand.

The **evolution of RAN devices** is emphasised. Involving multi-antenna systems at both ends of the communication, RAN is the perfect context to deploy Joint Communication and Sensing (JCAS) schemes that improve the sensing capabilities of the network, allowing for reduced energy efficiency, and whose control can be delivered by Open-RAN solutions.

In fact, the **open-RAN ecosystem** is ideal for the incorporation of AI-based solutions related to high-level services, traffic and content management, whereas the localisation and sensing techniques will allow new services and application that will change the way objects and people move and interact in a mixed environment. Open-RAN is also favourable to radio resource management at RAN level to cope with the increased densification and therefore cumbersome interference levels. The advent of Open-RAN in 5G and beyond-5G networks will play an important role in the roll-out of next generation networks to rural areas and in developing regions.

AI-based solutions enable the **Orchestration and Management** of networks, improving the efficiency of services delivery. In addition, the following KERs were highlighted in relation to management: distributed domain orchestration platforms with Zero-Touch Provisioning (ZTP), explainable AI/Edge, system models for predicting performance of the dual carrier systems, SLA-Driven E2E Slice Management, Deep Reinforcement Learning (DRL)-based Zero-Touch Resource Management, Deep Data Plane Programmability, privacy-preserving pervasive monitoring, ultra-fast programmable high

capacity switching node architecture for the back-haul and Network Digital Twin.

Dynamic spectrum sharing with play a key role given the increased density of wireless networks and higher communication requirements. The exploitation of new areas of spectrum is critical to meet the massive data demand of future AI applications, along with localisation and sensing technologies for managing said spectrum and the overall network.

6G will enable higher throughputs and capacities and thus, the requirements from the transport network are expected to be increased accordingly. The need for **ultra-efficient fronthaul and midhaul** will become evident and new connectivity forms such "sidehaul" will appear, i.e., between nodes of the same level, for example, between Centralized Units (CUs) or between Decentralized Units (DUs) in disaggregated architectures. Further, a potential evolution of 5G Fixed Wireless Access (FWA) towards 6G KPIs and integration with future 6G network architecture, should be expected.

Finally, users can provide the computational capabilities of their devices to facilitate processing in multi-access edge computing environments. Examples include availability of industrial and consumer robots, "Network Applications ecosystem", "transparent network", contentarization, AIaaS, and Edge applications. The move towards human-centric networking instead of device-centric one is also notable.

The contribution and support of global **standardisation** action, such as coordinating the NTN initiatives, is emphasised.

The demand for private networks/PNI-NPN will increase, thus generating new business opportunities for MNOs. In addition, several use cases in sectors such as PPDR, media, agriculture, forestry, health, etc.., rely on VR/AR equipment, drones and UAVs, robots, sensors, therefore expected to carve out benefits for vendors and original equipment manufacturers in the different sectors in the near future.

Vertical sectors and novel markets

The global **Industry 4.0** market growth is expected to accelerate in the coming years. 6G will deliver ultra-low and deterministic latency, high flexibility at low costs, and a large increase in bandwidth. The predictability of the connection ensured by the broad introduction of Time-Sensitive Networks is also anticipated to be a game changer. These elements are critical, enabling dynamic, reliable, energy efficient, and automated industrial applications that can meet the specific needs of the industry and stakeholders.

The core of fully digital and interconnected value chains will be centred around the utilisation of sensor technologies and new laser systems for parameter monitoring. For instance, novel photonic-based systems will allow to sense the surrounding environment with high precision.

The larger bandwidth supports data intensive AI and virtual and augmented reality technologies processing, which combined with mobile robotics, can materialise fully mobile, autonomous and reconfigurable factory floors.

Media and entertainment are required to closely follow and adopt new technologies to remain competitive in a highly fragmented market. As abovementioned, 6G coupled with AI and holographic, VR, AR and xR technology is expected to materialise the **"immersive app/service ecosystem"** or **"metaverse ecosystem"**, which will go beyond media, education or culture to also benefit industry and manufacturing, smart cities, healthcare, and many more sectors. In fact, the holographic representations are expected to become a key asset in a wide range of scenarios including Protection & Disaster Relief (PPDR), automotive, or industry.

Smart health advancements will have a huge impact in the wellbeing and quality of life. Smart devices/sensors powered by 6G will enable a more efficient data collection and processing, enhancing the real-time monitoring of patients. 6G will also enable high-precision in-body localisation capabilities, thereby achieving novel, advanced, and more effective medical treatments. It can also be determinant in health crisis such as global pandemics. Remote surgeries, telemedicine and other areas can also largely benefit by the rollout of 6G. The ambition to build more compact devices and the AI-driven quality of life services for people services are also of great significance in this sector.

The improvement of the connectivity coverage in transport routes, zero-lag critical communication, or the move towards increasingly wireless functionalities in vehicles are expected to revolutionise the **automotive and transport** industries. The transformation of the mobility sector provides unique

opportunities for smarter, safer, and sustainable urban transportation systems, including applications towards the vision of a fully autonomous tram.

Ubiquitous 6G connectivity across a city-wide network enables massive high speed data collection and analysis by AI for many benefits such as traffic management, emergency services, and environmental quality monitoring. The confluence of consumer, enterprise and governance in **smart cities** offers the ideal context for the fastest pace of innovation towards 6G. Engendering the spatial internet, 6G can leverage on the accurate, precise real-time information about almost any facet of our environments, societies, and industries.

New types of sensing technology in 6G can augment smart farms with new types of sensor data combined with AI and increased data rates to improve crop quality, yields, and waste management. Advancements in **smart agriculture and farming** will have tremendous benefits for people in terms of availability of food in a cost-efficient way, which will greatly contribute to reducing hunger worldwide, as well as in terms of sustainability.

Smart devices/sensors for **environment** monitoring requiring ubiquitous wireless connectivity will profit from 6G for efficient data collection and processing. Moreover, novel photonic-based systems will allow to sense the surrounding environment with high precision.

Overall, solutions oriented towards resource optimisation will be highly demanded. Similarly, enabled infrastructures are anticipated to generate new service opportunities for the benefit of the broader community.

6.2.1 Biggest Market Challenges

In terms of the **biggest market changes** elaborated by the projects, the following were highlighted (not exhaustive):

- **Increased integration, proliferation, and openness of solutions** – Effective **integration** of NTN, hence allowing connectivity to very diverse verticals in a transparent manner to final users, i.e., not being aware as to whether communication happens over TN or NTN, new communication technologies such as holographic communications, reconfigurable intelligent surfaces, and THz spectrum, as well as leveraging Artificial Intelligence and advanced hardware (e.g., high-computational devices), new opportunities for various shareholders to expand their market options by enabling ML-based resource optimization and providing integrated computing and communication infrastructures. With advances within integrated TN/NTN architectures, it is expected to have more stakeholders being actively involved in the area and new industries being created based on new business models for such an integrated TN/NTN architecture. An increased **proliferation** of wireless solutions for critical applications, with a major leap of what initiated by 5G (eventually moving from ‘mission critical’ to ‘life critical’ service support). This would be enabled by a larger trust on wireless technologies, whose performance would finally be able to overcome the negative prejudice of wireless as an unreliable solution for communication. 6G will enable low-cost IoT solutions, which are currently served via non-cellular systems. It is envisaged to provide the connectivity necessary for truly enabling connected industries and automation, as well as autonomous vehicles and swarm systems. 6G will provide ubiquitous coverage, which will allow to connect devices not previously covered, opening new market avenues. Lack of access to connectivity is a factor in inequality and social economics. Connecting more people tends to reduce inequality and improve quality of life, so one goal of 6G should be to make connectivity more accessible, irrespective of income level or geography. Also, 6G will deliver an evolution path for fixed and mobile broadband with more capacity, higher throughput, and lower latency. It will provide more pervasive access through higher-density connections and ubiquitous coverage, and it will expand mission-critical services through higher reliability and availability. In terms of **openness**, the 5G-Advanced architecture has been specified to open the networks to easier adoption by industry sectors outside of telecoms. Early proof points have been gathered over the last few years in pre-5G-Adv platforms and we anticipate the greatest change will be the increased willingness to adopt the platforms and utilise them for B2B and B2B2C business models to create economic growth through digital economy drivers driven by use cases

specified, controlled and owned by the industry sectors as they seek value creation and capture in their ecosystem.

- **Automation and lowered technological barriers** – More room for solutions based on automated network management and proliferation of federate testbeds to be made available for DevOps purposes, Usage of virtualized and disaggregated network infrastructures facilitated by, e.g., O-RAN and cell-less architectures. Usage of virtualized and disaggregated network infrastructures facilitated by, e.g., O-RAN and cell-less architectures. Improve service orchestration through greater automation, network slicing, and open APIs. We expect an explosion of the application of IoT devices, especially when the communication is standardized an integrated with the 6G rollout. There will be a need for unlocking reconfigurable networks, where the network capacity resources are continuously matching with the user demand.
- **Exploitation in vertical markets** – integrating new communication technologies such as holographic communications, reconfigurable intelligent surfaces, and THz spectrum, as well as leveraging Artificial Intelligence and advanced hardware (e.g., high-computational devices) are expected to accelerate entering markets that leverage massively scalable immersive environments, like XR/VR and other markets and key vertical industries, such as Public Protection & Disaster Relief (PPDR), automotive, energy, industrial manufacturing, health, media/entertainment, public safety, and ICT sectors, and introduce a new line of edge computing products in B5G/6G networks. For example, the integration of these novel technologies can achieve high-precision in-body localization capabilities, thereby achieving novel, advanced, and more effective medical treatments. Additionally, the introduction of haptic communications can enable remote surgery scenarios. With respect to the industrial manufacturing domain, virtual and augmented reality technologies, combined with robotics, can facilitate the realization of fully autonomous factories. The global Industry 4.0 market size is expected accelerate within coming years. Communication through 6G technologies will enable and foster the development of technologies for industrial automation. Proliferation of new innovative applications and technologies such as light weight XR wearable devices that triggers the user demand for this type of services, and others related to “Internet of Sense”, and broader distribution of the market share, due to the involvement of knowledge-intensive small companies that will take advantage of network openness of 6G.
- **Larger scale markets and market disrupters** – Internet of Things, humans, and connected devices, vehicles, robots, and drones will generate Zettabytes of digital information leading to more challenging applications, e.g., holographic telepresence and immersive communication, and meet far more stringent application requirements stemming along the edge-cloud continuum. The two most impactful drivers that will dominate content generation and network traffic will be human augmentation (or the Internet of Senses) and digital-physical fusion (Internet of Things + Digital Twins). 6G will enable data collection and closed-loop control of larger number of devices and appliances through faster and lower-cost connectivity solutions. The increased focus on sustainable products will be supported by the expected improved energy efficiency of 6G. There will be an increased need for and greater accessibility to HPC and Quantum computing from connected anywhere, anytime to immersive experience anytime, anywhere along with an increased requirement for trustworthy confidential computing. It is expected there will be game-changing features that will disrupt some of the markets as we know them as of today. For instance, a smooth integration of wireless and wired access technologies will allow new services to be introduced in several vertical domains, among which Industrial IoT, manufacturing, logistics, autonomous driving / autonomous robots, and Media and Entertainment. Especially a broad introduction of Time-Sensitive Networks will allow for predictable connections, which in turn will decrease energy consumption and failures, finally delivering better, more energy efficient and faster production lines. The worldwide trend of edge computing continues to push intensive compute processes out to the location that the data is being generated, instead of being processed at the data centres. This results in a large demand for high-speed wireless networking to move all of this data around at the edge, a demand which is not met by current 5G and WiFi technologies. As 6G will require an order of magnitude higher throughputs and capacities, the requirements from the transport network are expected to be accordingly increased. Further, compared to traditional backhaul, the need for ultra-efficient

fronthaul/midhaul will be evident and even new forms of connectivity, like “sidehaul” will appear, i.e., between nodes of the same level, e.g., between CUs or between DUs in disaggregated architectures. Further, a potential evolution of 5G FWA towards 6G KPIs and integration with future 6G network architecture, should be expected. The Proliferation of Software Defined Infrastructure trend is continuing from the advancements of software-defined networking in 5G and other sectors. This has a profound change on what companies supply the equipment necessary to operate 6G networks, and the commoditization of 6G hardware changes the landscape and opens it to allow more companies to create products. Other expected market changes: Technology shift towards compactness of devices, Energy efficiency improvement of hardware, and Reduction of costs for industrialization feasibility.

- **Increased security, privacy and trust** – With a larger set of new technology enablers expected with 6G, this will widen the threat landscape further, by including aspects such as heterogeneous radio, RAN softwarisation, multi-vendor deployments, AI-driven network management. It is thus evident that the current vision for 6G calls for even stricter and more sophisticated security controls to guarantee trust in the new ecosystems. Significant advances are needed for applications and intelligence seamlessly and securely distributed end to end across heterogeneous domains, from the central clouds to edge clouds, and to smart devices. With the evolution in the telecommunications network and technology, more diverse network services, devices/functions from heterogeneous environment would interact to realize the overall 6G system and services; therefore, robust security and privacy becomes the key cornerstone of the 6G system which can be realized with the application of complete Zero trust security principles. So, it is expected that 6G system will enable smarter security features to thrive and adapt to modern day threats and adversaries. The following are some of the changes that are expected: Increased demand for secure and trusted services, Greater need for automation and intelligence, Emergence of new use cases such as ultra-reliable and low-latency communications, which will require a high level of security and privacy, and Increased competition among service providers to offer the most secure and trusted services.
- **Energy Efficiency** – 5G for industry was developed aiming at being very energy efficient, replacing cables and supporting a lot of different use cases. For 6G, the technology will be powerful and flexible enough to really deliver on the promise of high wireless flexibility at low costs. This could change the application possibilities and would enable a dynamic, environmentally friendly connectivity option that adapts to the needs of the industry and stakeholders.
- **Other market trends** – Two important trends, perhaps contradictory were highlighted: market fragmentation due to a more modular architecture and a few globally dominant enterprises, perhaps emerging from current incumbents. In most of the vertical sectors, the use cases involved require the establishment of private networks. Therefore, the demand for private networks/PNI-NPN will increase, thus generating new business opportunities for MNOs. In addition, several use cases in sectors such as PPDR, media, agriculture, forestry, health, etc.., rely on VR/AR equipment, drones and UAVs, robots, sensors, therefore expected to carve out benefits for vendors and original equipment manufacturers in the different sectors in the near future. Moreover, several use cases, such as industry 4.0, transport and logistics, agriculture, etc., require AI-based intelligent systems for the efficient automation of their activities and improvement of productivity. Thus, it expected that AI-based solution and application providers will have significant benefits.

6.2.2 Technological Innovations and Desired Markets

In terms of the **technological innovations and desired markets** elaborated by the projects, the following were highlighted (not exhaustive):

- **Evolution of the RAN devices** – involving multi-antenna systems at both ends of the communication, is the perfect context to deploy Joint Communication and Sensing (JCAS) schemes that improve the sensing capabilities of the network allowing for reduced energy efficiency and whose control can be delivered by Open-RAN solutions. Localization and sensing techniques, once properly deployed, will allow new services and application that will

change the way objects and people move and interact in a mixed environment. The advent of Open-RAN in 5G and beyond-5G networks will play an important role in the roll-out of next generation networks to rural areas and in developing regions.

- **Increase of AI based solutions** – The Open-RAN ecosystem is ideal for the incorporation of AI-based solutions; AI based solutions related to high-level services, traffic and content management but also down to radio resource management at RAN level, in order to cope with the increased densification and therefore cumbersome interference levels. AI-based solutions are in use to enable performant Orchestration and Management of networks and to improve the efficiency of services delivery.
- **Sustainability and energy efficiency** – Sustainability labels on end products like now is used for energy efficiency of household appliances. No longer end of life of electronic products due to the fact they are no longer upgradeable to current standards.
- **Dynamic spectrum sharing** – important given the increased density of wireless networks with demanding communication requirements. Predictable networks will change drastically the way goods are created, exchanged, and moved. Exploitation of new areas of spectrum is also a key in meeting the massive data requirements of future AI applications, along with localization and sensing technologies for management of that spectrum and the overall network.
- **Trust and Security** – Zero Trust security principal applications which includes dynamic/continuous security and trust evaluation of the end-to-end network and services.

6.2.3 Verticals Sectors Impacts

In terms of which **vertical sectors** affected the most with the advent of 6G, the following was reported:

- **Industry 4.0 / Manufacturing.** This enables fully mobile, automated, and reconfigurable factory floors. The core of fully digital and interconnected value chains will be centred around the utilization of sensor technologies and new laser systems for parameter monitoring. Provide low and deterministic latency communication critical for industrial applications.
- **Smart Health.** Smart devices/sensors for health monitoring will require 6G infrastructure for efficient data collection and processing. Smart health advancements will have a huge impact in people's lives. Sectors dealing with Pandemic related issues and crises.
- **Smart transport.** Transport routes and their successful digital connectivity will provide significant environmental and other benefits. Zero-lag critical communications in automotives. Increase of wireless installation in vehicles, to replace some of the wired functionalities. This would be a significant breakthrough given the conservative attitude of automotive industry. In the long term, this has the potential of reducing the wired harness in vehicles, translating in lower vehicle weight a therefore lower fuel consumption and CO_2 emissions.
- **Security, privacy and trust related sectors.** Availability of technologies ensuring secure, privacy preserving and trustworthy services in the context of a programmable platform accessed by multi-stakeholders and tenants including vertical industries as users.
- **Smart Cities**. Ubiquitous 6G connectivity across a city-wide network enables massive high speed data collection and analysis by AI for many benefits such as traffic management, emergency services, and environmental quality monitoring. Smart City has a unique confluence of consumer, enterprise and governance will create the context for the fastest pace of innovation towards 6G. Engendering the spatial internet, 6G can leverage on the accurate, precise real-time information about almost any facet of our environments, societies, and industries.
- **Smart Agriculture.** New types of sensing technology in 6G can augment smart farms with new types of sensor data combined with AI and increased data rates to improve crop quality, yields, and waste management. Advancements in smart agriculture and farming will have tremendous benefits for people in terms of availability of food in a cost-efficient way, which will greatly contribute to reducing hunger worldwide.

- **Smart Environments.** Smart devices/sensors for environment monitoring requiring ubiquitous wireless connectivity will profit from 6G for efficient data collection and processing. Novel photonic-based systems for sensing the surrounding environment with high precision.
- **Others:** Protection & Disaster Relief (PPDR), UAVs/robots and AI-based intelligent systems and the engagement of culture in the digital economy is likely to create accessible experiences to enable successful adoption.

6.2.4 Verticals Sectors Business Opportunities

In terms of the **business opportunities in vertical sectors** elaborated by the projects, the following were highlighted by the projects (not exhaustive):

- **Resource optimisation -** By providing a solution that enables these industries to optimize their resources and enhance their digitization.
- **New services -** Enabled infrastructure generates new service opportunities for the benefit of the broader community. Product design units in different locations around the globe can be enhanced by the utilisation of real-time AR/VR technologies. Transformation of the mobility sector provides unique opportunities for smarter, safer, and sustainable urban transportation systems, including applications towards the vision of a fully autonomous tram. Opportunities in air and space. Working directly with industry verticals in adapting new 6G THz technologies directly into use-cases.
- **Improved infrastructures -** Enabled 6G equipment manufacturers/vendors and network operators.
- **Security, privacy and trust -** Enabling OPEX reduction by at least 15% in detection, decision, mitigation and policy enforcement.

6.2.5 6G Networks Deployment Obstacles

In terms of the **greatest obstacle for deployment of 6G networks** elaborated by the projects, the following were highlighted (not exhaustive):

- **Cost -** the potential high cost of devices operating at such bands may negatively impact their proliferation in the mass market, requires a techno-economic analysis (CapEx and OpEx of the proposed solution).
- **Interoperability -** Lack of willingness for interoperability may imply the risk of losing a strong market position regarding UEs.

6.2.6 6G Deployment Novel Markets

In terms of the **novel markets for 6G deployments** elaborated by the projects, the following were highlighted (not exhaustive):

- **Reliable IOT -** the levels of reliability that 6G will now guarantee may finally help shaping a "Things ecosystem". Transforming large volumes of IoT data (via AI), into valuable and actionable knowledge, able to automate and optimize the decision-making process in multiple sectors.
- **AR/VR/XR -** 6G's high-speed connectivity and low latency could enable more immersive and realistic VR/AR experiences. Holographic representations are expected to become a key asset in a wide range of scenarios. Accomplish an "immersive app/service ecosystem" that will move beyond handheld devices and computer/tv screens. The realisation of the "metaverse ecosystem".
- **New services -** Users can provide the computational capabilities of their devices to facilitate processing in multi-access edge computing environments. Large number of examples provided including: Advanced telemedicine capabilities through remote-surgeries and real-time monitoring of patients. Availability of industrial and consumer robots, smart-city ecosystem, "Network Applications ecosystem", "transparent network", a new ecosystem is in the field of

autonomous vehicles and transportation, AI-driven quality of life services for people, Human-centric networking instead of device-centric one, Contentarization, zero-touch automation, AIaaS, and Edge applications.

- **Sustainability -** Seamless interaction between several technologies in a way that decreases energy consumption and processing time, and increases trust, stability, robustness and performance. The merits of power and energy efficiency in the context of 6G could be a driver of adoption.

6.2.7 Projects Key Exploitable Results (KERs)

In terms of the **key exploitable results (KERs) expected to be delivered by projects and their TRL levels (if known)**, the projects highlighted the following (not exhaustive):

- **Integration -** Fully integrated NTN networks into 6G; PON Solutions, Packet-Optical DPUs, Waveform and radio protocol design including mobility and multi connectivity, Latency-aware access in the unlicensed spectrum, centralized/distributed/hybrid radio resource management, Deterministic Wireless transmission, Wireless-friendly TSN and DetNet, photonic-based millimeter-wave/Terahertz antenna arrays, pursuing high-gain beamformed and beam-steerable RF beams, Terahertz (THz) reconfigurable intelligent surfaces (reflective and transmissive), An OpenRU platform for Cell-Free mMIMO prototyping.
- **Management -** Distributed domain orchestration platforms with ZTP, explainable AI/Edge, system models for predicting performance of the dual carrier systems, SLA-Driven E2E Slice Management, DRL-based Zero-Touch Resource Management, Deep Data Plane Programmability, Privacy-preserving pervasive monitoring, ultra-fast programmable high capacity switching node architecture for the back-haul, Network Digital Twin.
- **Sustainability -** Hardware GPU based acceleration offloading of energy intensive mMIMO RAN functions, Energy Efficient DSP, ultra-high rate and low-energy transmitters.
- **Security and Privacy -** A novel security and privacy toolbox, realistic blockchain and attacks models, confidential toolkit, a set of cryptographic or enablement libraries, for confidential computing and confidential networking, distributed AI Engine for Services Pre-assessment, Threat Detector and Mitigation Engine, XAI toolbox for decentralised security analytics, Data anonymization streaming pipelines Software, AI-driven Decision-Making mitigation framework that allows to prioritize threats, and come up with a mitigation plan and create a complete threat orchestration ecosystem.
- **AI -** Intelligent and trustworthy edge computing platform supporting highly demanding XR applications.

In terms of the **other important aspect that projects are addressing (technical, vision or market related) not included in the previous questions,** the following were highlighted: (not exhaustive):

- **Sustainability -** Energy-Aware Backpressure is a collection of HW-level energy consumption metrics and mapped onto tenants through adaptive AI-driven analytics. The creation of truly sustainable communication systems.
- **Standards -** Contribution and support of global standardization actions such as coordination of NTN initiatives.
- **Experimentation -** Automate the process of creating ad-hoc experimental end to end 6G networks for experimenters. A repository service will be implemented incorporating Application / Use Case requirements, KPIs, KVIs, lessons learned, open-source tools.

7 6G SNS Momentum

This Section is detailing the Work Programme CT/TF actions and related SNS OPS support related to the development of the SNS Work Programmes, 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 contributing to / engaging with the SNS definition and implementation.

7.1 SNS Work Programme & Future Calls

The SNS Work Programme definition is relaying on the overall set of stakeholders and inputs summarized in Figure 43 [15].

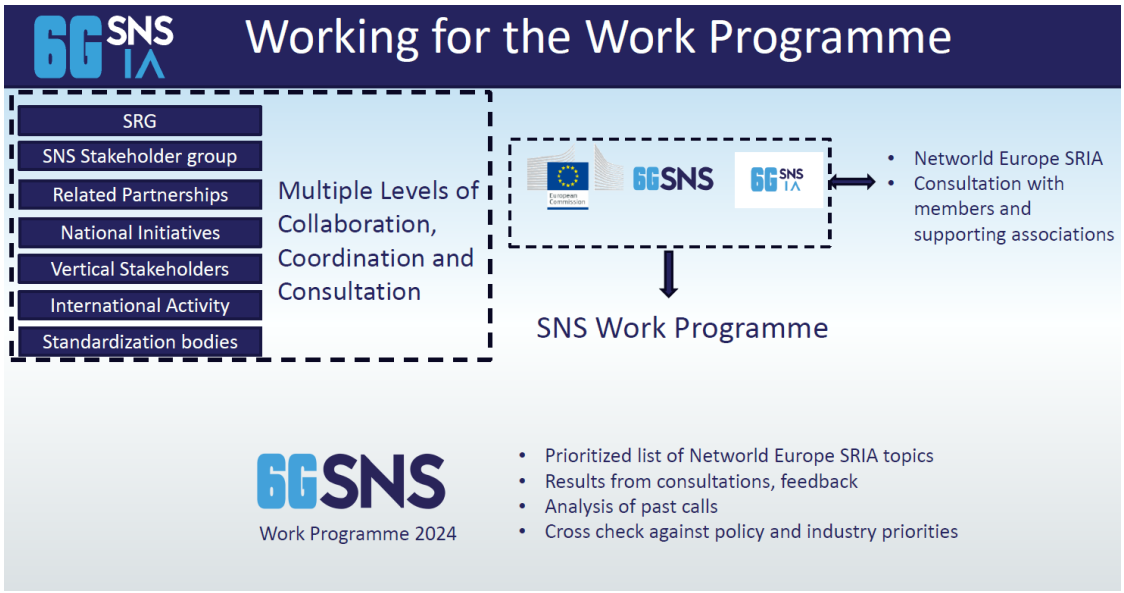

Figure 43. SNS Work Programme definition – Overall perspectives and stakeholders

Leveraging SNS Phase 1 and Call 2023 Work Programme definition experience, the WP 2024 definition started on the 24th of March 2023 with the organization of the first 6G-IA Board – Task Force (TF) / Core Team (CT) online meeting. The overall draft WP2023 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 11th of April 2023. The overall definition represented a huge effort, spanning from March 2023 to November 2023, including 27 TC/CT online meetings, 16 TF/CT – EC-SNSO online meetings, 2 6G-IA Consultations with 6G-IA Members and 2 meetings between EC-SNSO and SNS States Representatives Group (SRG).

Over the complete period March-November 2023, the TF/CT included the participation from the following persons, as detailed in Table 9.

Table 9: Participants to the TF/CT, from March-November 2023

6G-IA Board TF/CT Participants	
Didier Bourse	Chairman - Nokia
Alexandros Kaloxylos	6G-IA Executive Director
Werner Mohr	6G-IA
Bernard Barani	6G-IA

Carles Anton	6G-IA Board Member – CTTC
Rui Aguiar	NetworldEurope Chairman - IT Aveiro
Raffaele de Peppe	6G-IA Board Member – Telecom Italia
Jean Schwoerer	6G-IA Board Member – Orange
Emmanuel Dotaro	6G-IA Board Member – Thales
Egon Schulz	6G-IA Board Member – Huawei
Jesus Alonso Zarate	6G-IA Board Member – I2CAT
Nicola Ciulli	6G-IA Board Member – Nextworks
Damir Filipovic	6G-IA Board Member – AIOTI
David Lund	6G-IA Board Member – PSCE
EC-SNSO Participants	
Mario Scillia	EC
Pertti Jauhiainen	EC
Anna-Caterina Carli	EC
Remy Bayou	EC
Pavlos Fournogerakis	SNSO
Oana Radu	SNSO
Odysseas Pyrovolakis	SNSO
Chiara Mazzone	SNSO
Javier Albares Bueno	SNSO.

The WP 2024 definition started from the high-level pre-definition, worked out in 2022 in the context of the WP 2023-24 definition [16]. The following Table 10 shows the Streams and Strands initially pre-defined.

Table 10: Streams and Strands initially pre-defined

SNS WP2024 Streams and Strands	Targeted EC Funding (ME)	Projects
HORIZON-JU-SNS-2024-STREAM-B-01-01: System Architecture - Standardisation and Follow-up/PoCs	16	2
HORIZON-JU-SNS-2024-STREAM-B-01-02: Wireless Communication Technologies and Signal Processing – Standardisation and Follow-up/PoCs	16	2
HORIZON-JU-SNS-2024-STREAM-B-01-03: Communication Infrastructure Technologies and Devices – Standardisation and Follow-up/PoCs	16	2
HORIZON-JU-SNS-2024-STREAM-B-01-04: Reliable Services and Smart Security–Standardisation and Follow-up/PoCs	16	2
HORIZON-JU-SNS-2024-STREAM-B-01-05: International Collaboration – EU-JP	3	1
HORIZON-JU-SNS-2024-STREAM-B-01-06: International Collaboration – EU-SK	3	1
HORIZON-JU-SNS-2024-STREAM-B-01-07: Sustainability Lighthouse	10	1
HORIZON-JU-SNS-2024-STREAM-C-01-01: SNS Microelectronics Lighthouse	10	1
HORIZON-JU-SNS-2024-STREAM-D-01-01: SNS Large Scale Trials and Pilots (LST&Ps) with Verticals	26	2

The initial draft WP2024 pre-definition was including the major components of the WP, the overall target was to define before October 2023 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 2023), (2) the step by step mature SNS Phase 1

projects portfolio understanding (March-October 2023), (3) the first awareness of the SNS Call 2023 selected proposals portfolio understanding and respective gap analysis (August-October 2023) and (4) the technical inputs from the NetworldEurope SRIA 2022.

The draft WP2024 definition was progressed step by step during April-May 2023 with multiple consecutive versions (10+) until Version V1.0, regularly enriched with new inputs and proposed updates/grades from TF/CT and EC-SNSO. The first draft WP2024 6G-IA Members Consultation was implemented as a specific part of a wide 6G-IA Members Consultation including also (1) Proposed 6G-IA Statutes modifications (4 questions), (2) Re-organization of 6G-IA WGs (5 questions) and (3) 6G-IA strategic position (8 questions). This first Consultation was launched on the 6th of April 2023 with a deadline for input set on the 28th of April 2023. The TF/CT Members defined a set of questions for the draft WP2024 definition, as highlighted in Table 13 in Appendix C.

The TF/CT Members analysed the overall set of 6G-IA Members inputs (57 inputs). A dedicated 6G-IA Webinar was organized on the 31st of May 2023, 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 draft short-listed Scope Topics for B01-01/02/03/04 as summarized in Table 11.

Table 11: Scope Topics for B01-01/02/03/04

Topic/Strand	Short listed scope
B01-01 – Architecture	o New design approaches for 6G system architecture systems o Native and trustworthy integration of AI for telecommunications o Network exposure to vertical application developers. o Mechanisms, leading to partial or complete Digital network twinning, applied in 6G. o Integrated and dependable sensing & actuation networks. o New Data Transfer Paradigms
B01-02 - Wireless Communications	o Novel techniques for integrated sensing and communication. o Machine learning empowered physical layer evolutions. o Cell-free and extreme exploitation of MIMO technologies potentially including reconfigurable surfaces. o Key functionalities and technologies for 6G RAN system design. o Seamless integration of multiple frequency bands.
B01-03 - Infrastructure and Devices	o Ultra-high energy efficiency especially in optical networks. o 3D networking for 6G networks. o Development of low-energy communication solutions. o New IoT components and devices. o Integrated NTN service provision. o Integration of Optical and Wireless Technologies.
B01-04 - Security and Services	o Exploitation of (distributed) trusted AI/ML for 6G infrastructures. o Cooperative holistic E2E security and privacy solutions for 6G architectures. o Smart and trustworthy service. o Efficient security and privacy enablers. o Zero-touch integrated security deployment. o Quantum key distribution and post-quantum cryptography support for secured 6G communications. o Timing sensitive, and time responsive software technologies for distributed, multi-stakeholder service provision. o Service frameworks.

The Webinar also confirmed the following orientations discussed in TF/CT – EC-SNSO and validated through this first Consultation:

- Further investigation/definition of a potential B01-08 project on Reliable AI.
- Further definition of the C01-01 Microelectronic Lighthouse project.

- Further definition of the D01-01 LST&P projects, without prioritizing Verticals Sectors but targeting to contribute to / impact SNS on Sustainability (Energy or/and Societal or/and Economic).

The draft WP2024 Version 1.0 was released on 25th of May 2023 and communicated as input to the EC-SNSO – SRG meeting n°1 organized on 06th of June 2023 in Goteborg collocated with EuCNC & 6G Summit 2023. 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.

The draft WP2024 definition was then further progressed step by step during June-July 2023 with multiple consecutive versions (9) 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 20th of July 2023 as input to the second 6G-IA Members Consultation (document attached to the Consultation). The second draft WP2024 6G-IA Members Consultation "2nd Consultation on the 6G-IA orientations for the SNS Work Programme 2024" was defined in July 2023. The second Consultation was launched on 20th of July 2023 with the initial deadline set for the 28th of August 23, which was later extended to the 1st of September 2023. The TF/CT Members defined the detailed questions listed in Table 14 in Appendix C.

The TF/CT Members analysed the overall set of 6G-IA Members inputs (41 inputs). A dedicated 6G-IA Webinar was organized on 19th of September 2023, to present the overall analysis and engage into further interactions with 6G-IA Members, including live Q/As. 6G-IA presented summarized the Consultation outcomes and analysis, including the following points:

- Very positive feedbacks on the raised questions with Yes scores spanning from 84.2% up to 95%.
- Positive feedbacks on the 6 Topics to be potentially included in the Environmental Sustainability project, spanning from 70.3% to 97.4%
- 16 positive answers on the possibility to bring "Real-world datasets for training/testing" and 36 positive answers on the possibility to bring "Synthetic datasets for training/testings".
- Very great set of inputs in the free text answers.

The following status was also shared with 6G-IA Members

- Further fine tuning on the orientations based on:
  - In-depth analysis of the projects selected during the 2022 call.
  - A first quick analysis of the retained projects from the 2023 call.
  - The consultation results.
- Further input expected:
  - Feedback from the SRG is also expected.
- Next steps:
  - DG-CNECT, SNS JU Office and 6G-IA working hard to have the final version prepared as soon as possible.
  - Activities to further improve the text for the sustainability lighthouse, the dedicated project on AI/ML, expectations from the Stream D projects (sustainability).
  - There are planned activities for the 6G-IA members to be able to present to other members their vision and competences (new 6G-IA Forum WG).

In addition to the 6G-IA Members Consultations, the TF/CT Members also defined, as was the case for the draft WP2023 definition with the SNS Phase 1 PMs Survey, the SNS Call 2023 PMs Survey. The SNS Call 2023 Projects Assessment Questionnaire was targeting to assess the technical coverage of the Call 2023 projects (predecessor of the SNS OPS Monitoring and Analysis framework to assist with the gap analysis).

The questions raised to SNS Call 2023 B01-01/02/03/04/05/06, C01-01 and D01-01 projects Coordinators were addressing the following core basis:

- The list below contains a set of topics under scope in this Stream. Please distribute a total of 20 points (cumulative total) according to the relevance your proposal plans to give to that specific topic. The higher the number, the more work your proposal plans to do here

  - Specific B01-01/02/03/04/05/06, C01-01 and D01-01 list (see details in Table 14 and Table 15 below).
- What are the main planned technology outcomes, or the key improvements targeted by your proposal?
  - C1. What are the top (two) KPIs for your project?
  - C2. What are the top (two) KVIs for your project?
- Which technological enablers will your proposal work on/make use of?
- Is your proposal using AI/ML as an enabler? If yes please provide a summary of the keys areas you focus upon.
- If your proposal is using AI/ML as an enabler, please briefly explain if it uses real data or synthetic data to train the AI models.
- Is your proposal covering sustainability aspects? If yes please provide a summary of the project targeted outcomes related to sustainability.
- Final comments: Please provide any final comments you think are important for the work of your proposal.

In addition, specific questions were addressing B01-01/02/03/04/05/06 Strands as detailed in Table 15 in Appendix C and C01-01 and D01-01 Strands as detailed in Table 16 in Appendix C. One additional question was raised towards C01-01 and D01-01 concerning the Verticals addressed Energy, Automotive, Industrial IoT, Construction/Building, PPDR / security and safety, eHealth, Smart Cities, Tourism and culture, Media & xR communications, Gaming, Metaverse, Smart Farming and Other.

The SNS Call 2023 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 2023 projects portfolio scope and coverage, clearly highlighting the well covered topics, e.g. B01-02 Joint communication and sensing and the topics of low or no coverage, e.g. B01-03 Nano-Things Networking and Troposphere Networking. This Coordinators Survey laid the foundation for the overall SNS OPS Questionnaire detailed in this Deliverable, and provided the necessary input to perform the required Gap Analysis.

The draft mature WP2024 definition was then further progressed and converged in September-October 2023, with multiple consecutive versions (15+) until Version V3.0, still further regularly enriched with new inputs and proposed up-dates/grades from TF/CT and EC-SNSO. The draft Version 3.0 was released on the 23rd of October 2023, following the latest remaining 6G-IA Board Members up-dates/grades and the introduction of the EC-SNSO targeted Strand "HORIZON-ER-JU-2024-FAR2-SNS" developing synergies between SNS and Rail JUs. This version 3.0 was communicated as input to the second SRG online meeting organized on the 6th of November 2023. Again, the draft Version was very positively received / discussed during the SRG meeting. The final version [17] was officially published on 11th of December 2023 and it included the following Summary depicted in *Figure 44*.

Streams / Topics	Call 2024 Topic Budget (in M€)
HORIZON-JU-SNS-2024-STREAM-B (RIA)	
01-01: System Architecture	16.0
01-02: Wireless Communication Technologies and Signal Processing	16.0
01-03: Communication Infrastructure Technologies and Devices	16.0
01-04: Reliable Services and Smart Security	16.0
01-05: International Collaboration – EU-JP	3.0
01-06: International Collaboration – EU-KOR	3.0
01-07: Sustainability Lighthouse	13.0
01-08: Reliable AI for Reliable Communications Systems and Services	6.0
HORIZON-JU-SNS-2024-STREAM-C (RIA)	
01-01: SNS Microelectronics Lighthouse	10.0
HORIZON-JU-SNS-2024-STREAM-D (IA, with FSTP)	
01-01: SNS Large Scale Trials and Pilots (LST&Ps) with Verticals (IA)	25.0
HORIZON-JU-SNS-2024-STREAM-CSA (CSA)	
01-01: SNS Operations and Output optimisation	4.0
HORIZON-ER-JU-2024-FA2-SNS	
EU-RAIL – SNS SYNERGY: Digital & Automated testing and operational validation of the next EU rail communication system	1.0[39]
Total (M€)	**129**

Figure 44: SNS Call 2024 Streams and Strands summary

Following the completion of the WP2024 definition, the TF/CT organized a dedicated post-mortem analysis, addressing the key take away points / lessons learnt, to be further considered for the forthcoming draft WP2025-26-27 definition. The dedicated TF/CT post-mortem online meeting addressed the following points (1) Top 3 positive points, (2) Top 3 negative points and (3) Top 3-5 points to be considered/recommended for forthcoming draft WP2025-26-27 definition. The analysis is carefully considered in the current initial steps for the draft WP2025-26-27 pre-definition, before engaging the detailed WP2025 definition in January-September 2024.

7.2 SNS Momentum & Community Building

6G-IA, EC-SNSO, SNS OPS, SNS ICE and 6GStart CSAs 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 7.1, the SNS momentum is also 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. In the context of the draft WP2023 / Call 2023 definition (in 2022), 6G-IA Members were also consulted (before the start of SNS OPS). The definition of the Call 2023 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. As presented during the 6G-IA General Assembly meeting organized on 14th of December 2023, the 6G-IA Membership has now increased to 310 Members, with clear boost in 2022 and 2023, in direct connection to the SNS Phase 1 Call and Call 2023 (Figure 45).

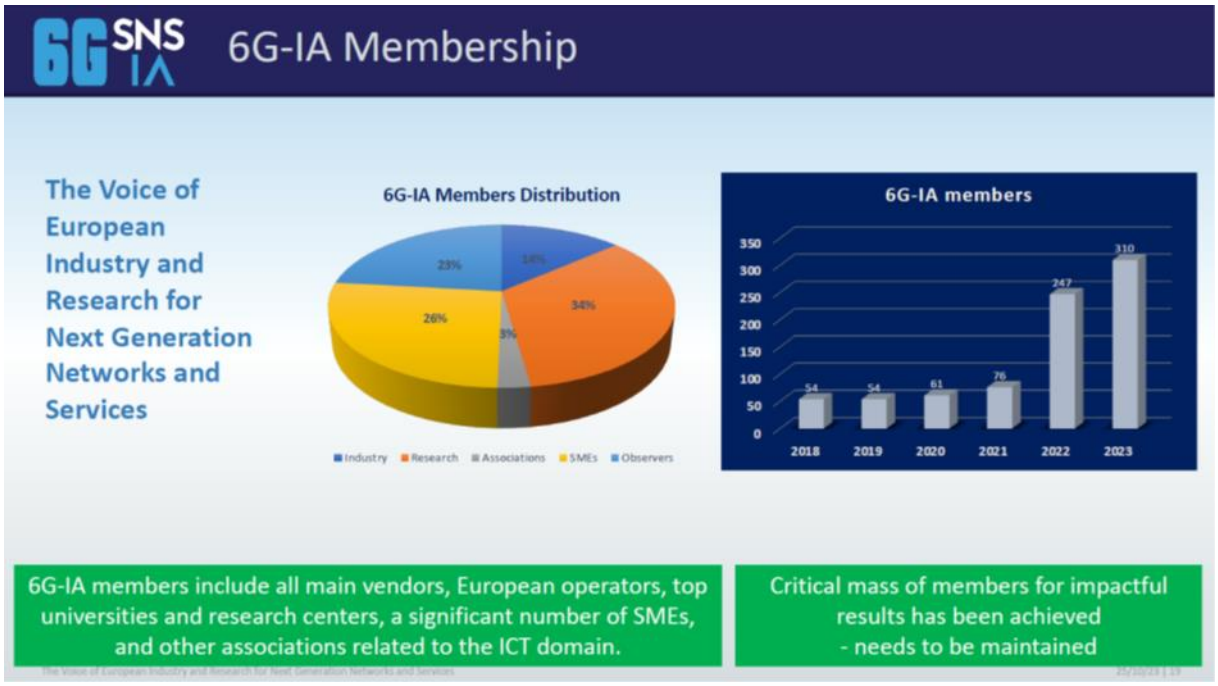

Figure 45: 6G-IA Membership – 6G-IA General Assembly Meeting (14.12.23)

Concerning the SNS WP2023 / Call 2023 definition and implementation, the SNS Call 2023 Information Day [18] organized on the 23rd of January 2023 was one key event to develop the SNS Momentum.

The NetworldEurope SRIA Webinar [19] organized on the 12th and 13th of January 2023, presenting the latest up-dates related to the SRIA 2022 and related R&I priorities/challenges [20], also broadened the overall SNS / NetworldEurope Community and further raised awareness of the SRIA / SNS WPs development. The Webinar presented a condensed overview of the challenges, visions, and discussions pertaining to a variety of technological domains deemed highly relevant for European R&I, as covered in the SRIA 2022. The presentations highlighted technologies indicative of the innovations being sought for upcoming SNS Calls, based on the technical content of the SRIA 2022.

The recent NetworldEurope Vision for Future Communications Summit (VFCS) 2023 [21] which took place on 7th and 8th of November 2023 in Lisbon, launched the definition of the NetworldEurope SRIA 2024, that will be the official technical foundation for the forthcoming SNS draft WP 2025-26-27. The Summit covered multiple research lines, such as system and architecture, radio technologies, quantum technologies, communication technologies, security and software enablement, 6G networks among others. All sessions were organized as panels of distinguished speakers from academia, industry and high-level EC officials presenting their viewpoints on a subarea within each track. Panels were enriched with contributions from an open call to the community, and with sessions presenting long-term visions from different stakeholders. The Summit gathered around 50 participants. The Workshop GPAINS [22] "Towards Realistic Usage of AI in 6G Networks" took place in the same location on the previous day and gathered around 30 participants. This Workshop on Realistic AI Usage in Networks addressed the challenges and constraints associated with implementation and deployment of AI and ML methods in current and next generation networks. Both Summit and Workshop were very useful to engage active discussions and brainstorming on current and future R&I challenges.

Concerning the SNS WP2024, the first 6G-IA – EC-SNSO Briefing Session [23]organized on 11th of December 2023 gathered 310 participants, clearly highlighting the strong interest from 6G-IA Members / Community. The 6G-IA Members Brokerage Event organized on 13th of December 2023 included 95+ participants with 39 6G-IA Members presentations/pitches. The 6G-IA – EC-SNSO Events organized in January 2024 (1) SNS R&I WP 2024 Information Day [24] and (2) SNS WP2024 Brokerage event [25] are also clearly targeting to reinforce and develop the SNS momentum from 6G-IA Members and Community. 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.

Last but not least, the SNS Brokerage Platform[9] 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.

As a summary, the SNS momentum has been steadily growing and there is a clear plan/path for further growth 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 (first version of which was presented in this deliverable) play a pivotal role in better understanding the current work and scope 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 CT/TF 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.

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

8 Conclusions and Way Forward

One of the objectives of the SNS OPS CSA is to monitor, evaluate and report the progress of the SNS JU projects. SNS OPS developed and regularly up-dates the comprehensive monitoring and analysis framework that is and will be used to systematically monitor, analyse and document the technological Key Performance Indicators (KPIs) and societal Key Value Indicators (KVIs), as well as other relevant work aspects of the SNS projects. The regular monitoring of KPIs and KVIs of the SNS projects, the clarification of the scope and the exact technological enablers being used, as well as the main UCs addressed, the vision of each project and their market prospects, were the basis to build the framework. Moreover, this framework will also act as the main tool for collecting the necessary SNS JU metrics (programme KPIs) to assist with the tracking of progress of the SNS JU programme as a whole.

Section 2 detailed the SNS OPS monitoring and analysis framework and its on-going evolution, while Section 3 explained how the projects achievements will be qualified and quantified, detailing the targeted SNS metrics methodologies and data collection.

The first questionnaire communicated to the 33 Phase 1 projects included 29 questions and was structured in three sections (technical, vision and market). All answers were analysed and a dedicated 6G-IA / SNS OPS webinar was organized to present the key findings and insights. Sections 4, 5 and 6 provided the detailed analysis, conclusions and plans concerning the first assessment of the Phase 1 projects scope and coverage addressing respectively the technical, vision and market perspectives.

One key action in 2023 for the development of the SNS programme was the definition of the SNS Work Programme 2024. Section 7 detailed the work process followed, including key actions and achievements.

The monitoring and analysis framework, related gap analysis and roadmap definition constitute an important process within SNS which allows for the comparison of the goals, addressed technologies and verticals of the selected projects of each Phase against the EU and SNS-JU high level goals. Such comparison offers insights with regards to the “adherence to the plan and strategy” of EC and the SNS JU and constitutes valuable feedback towards the Task Force / Core Team (TF/CT) of experts working on the follow-up SNS JU Work Programmes (as detailed in Section 7). The TF/CT may opt to make adjustments to the following Work Programmes to account for smaller or larger deviations from the agreed strategy based on the theme and technologies addressed by the selected projects. The TF/CT is also clearly taking into account the evolution of the overall 6G standardization plans, regulatory plans and policy framework. This feedback loop and available flexibility in the design of the annual Work Programmes ensures that the EU will not stay behind in the global Research and Innovation ecosystem in any of the important technological fields and that any potential gap will be quickly identified and addressed.

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Appendix A Specific Objectives (SOs) of SNS Work Programme 2021-22 [26]

Stream A. Smart Communication Components, Systems and Networks for 5G Evolution Systems
A-SO1. Prepare for new advanced user services (e.g., immersive communication, holographic telepresence & Augmented Reality / Virtual Reality etc.), as well as new vertical industry challenges (e.g., connected and automated mobility, environment surveillance, personalized medicine, etc.) which require significant improvements from existing connectivity and service platforms.

A-SO2. Support the European vision for societal challenges such as digital inclusion and accessibility, unlocking rural economic values and opportunities, under a Green Deal overarching objective (see KVIs explained in the 'Context and Objectives' above). It requires addressing high energy efficiency solutions. It also aims at an open connectivity and service platform evolution with reduced energy consumption and lower operational and ecological costs, able to meet KPI requirements identified in the NetworldEurope's SRIA for mid-term objectives.

A-SO3. Define and establish system level interfaces to be able to realize a unified vision of pre- 6G systems, with the support of the Coordination and Support Actions (CSAs).

A-SO4. AI techniques are expected to be widely explored across Stream A projects. The data sets to be used for the training and the evaluation of the mechanisms to be developed are key for open innovation strategies. Such open data sets (e.g., date of release, its scope, and the dimension and diversity of data) will be considered as part of the impact evaluation criteria for relevant projects that aim to explore AI techniques.

Stream B. Research for Revolutionary 6G Technology and systems

B-SO1. Significant contributions to the establishment of a globally accepted set of KVI's and KPI's framing future 6G developments.

B-SO2. Dynamic end-to-end distributed security for connectivity, devices and service infrastructures. This security "lifecycle" should be provisioned to account for distributed systems (e.g., asset orchestration and data aggregation), operational security (e.g., a dedicated SOC), security quantification, and a strategy for ongoing security threat assessment.

B-SO3. A comprehensive zero-touch open end-to-end resource management system with drastic OPEX reduction and innovation support.

B-SO4. Trustworthy and energy-efficient device, network, and service infrastructures, delivering critical services as well as a dynamic multi-vendor supply market, through new open network and service paradigms.

B-SO5. Increased spectrum efficiency and dynamic spectrum sharing across multiple (and potentially new) frequency bands (potentially above 100GHz), covering technologies and architectures enabling optimized co-existence with the most difficult spectrum environments, enabling long-term opening of new frequency bands for mobile communication usage with better energy consumption performance, innovative sharing concepts, spectrum re-farming capabilities, and also addressing citizen concerns like low EMF exposure.

B-SO6. Foster European capabilities in key technologies and notably AI/ML, advanced signal processing and microelectronics, paving the way towards advanced systems realizing visual vanishing (e.g., making the infrastructure imperceptible to the end-users) by fusion with physical environment. Insofar as AI techniques are concerned, the data sets to be used for the training and the evaluation of the mechanisms are expected to be open results from projects.

B-SO7. Provide a set of technologies and architectures to reinforce the European industry position during the 6G standardisation phase expected to start around 2025.

Stream C. SNS experimental Infrastructure

C-SO1. To develop EU wide experimentation platforms that can incorporate candidate 6G technologies for their further validation.

C-SO2. To make such an experimentation platform capable of hosting advanced pilot “6G” use cases as targeted under Stream D during the subsequent SNS implementation phase.

C-SO3. Reusability and evolvability of the experimental platforms over the lifetime of the SNS programme.

C-SO4. Accessibility and openness.

C-SO5. Directionality and optimisation of previous and related investments in Europe.

C-SO6. Disruption friendly: capable of hosting possible upcoming 6G disruption and hence guarantee their future-proofness.

C-SO7. End-to-end: demonstrating E2E service capabilities and include a full value chain including IoT devices, connectivity, and service provision.

Stream D. SNS Large Scale Trials and Pilots (LST&Ps) with Verticals

D-SO1. The validation of SNS KVI and KPI’s and in the context of very advanced digital use cases implemented through Large-Scale Trials and Pilots (LST&P).

D-SO2. The identification of use case specific KVI and KPI’s and how they may be matched by SNS platform KVI and KPI’s.

D-SO3. A structured feedback loop from vertical users towards SNS stakeholders, in view of ensuring the best match between beyond 5G/ 6G systems capabilities and users.

D-SO4. Accessibility and openness: use of the infrastructures/platforms in further phases of the SNS by any consortium, requires using modular implementation methodology, potentially open-source solutions with well-defined technological and business interfaces clearly documented.

Appendix B SNS Questionnaire – Markets KERs

Table 12: SNS Questionnaire – Markets KERs

Integration	Management	Security & Privacy	Others
STREAM A			
• Fully integrated NTN networks into 6G. • Convergence of NTNs and terrestrial networks for 6G. • Unified radio interface leveraging on user-centric beamforming and resource optimisation. • PON Solutions. • Packet-Optical DPUs for 5G+/6G access and functional split implementations closer to cell-sites for low latency services. • Latency-aware access in the unlicensed spectrum.	• Distributed domain orchestration platforms with ZTP, trust & intelligent event management features. • Explainable AI/Edge framework.	• Novel security and privacy toolbox. • Realistic blockchain and attacks models.	*Sustainability* • Hardware GPU based acceleration offloading of energy intensive mMIMO RAN functions embedded in O-RAN DU. • Physical layer network enhancements, based on JCAS and RIS, for improving energy efficiency. • P2MP solutions. • Energy Efficient DSP. *AI* • Intelligent and trustworthy edge computing platform supporting highly demanding XR applications running on a heterogeneous cloud continuum.
STREAM B			
• Waveform and radio protocol design incl. mobility and multi connectivity. • Centralised/distributed/hybrid radio resource management. • Photonic-based mm-wave/THz antenna arrays, pursuing high-gain beamformed and beam-steerable RF beams. • THz reconfigurable intelligent surfaces (reflective and transmissive. • Latency-aware access in the unlicensed spectrum. • Deterministic wireless transmission. • Wireless-friendly TSN and DetNet.	• System models for predicting performance of the dual carrier systems. • SLA-Driven E2E Slice Management. • DRL-based Zero-Touch Resource Management. • Deep Data Plane Programmability. • Privacy-preserving pervasive monitoring. • Ultra-fast programmable high capacity switching node architecture for the backhaul. • Network Digital Twin.	• Confidential Toolkit, a set of cryptographic or enablement libraries, SDKs and for confidential computing and confidential networking. • Secure encrypted transmission systems. • Distributed AI Engine for services pre-assessment. • Threat Detector and Mitigation Engine. • XAI toolbox for decentralised security analytics. • AI-driven Decision-Making mitigation framework. • Data anonymization streaming pipelines Software.	*Sustainability* • Ultra-high rate and low-energy transmitters. *AI* • AI-based network control-plane framework.

Integration	Management	Security & Privacy	Others
STREAM C			
• OpenRU platform for Cell-Free mMIMO prototyping. • 6G platform with native integration for XR services.	• System models for predicting performance of the dual carrier systems.	• XAI/MR driven orchestration framework.	• Joint Communication and Sensing. • Internet of Senses applications.
Stream D			
5G and TSN integration for industrial LAN.		• Zero Touch Management and Testing as a Service.	• Device-agnostic Precise 5G positioning • 5G enabled edge device for energy measurement.

Appendix C Draft WP2024 – Consultations and Survey

This Appendix includes the detailed Tables related to draft WP2024 definition and 6G-IA Members consultations highlighted in Section 7.

Table 13: Draft WP2024 – First 6G-IA members consultation questions

Q1: Please suggest the top ranked 5 topics from the list below related to HORIZON-JU-SNS-2024-STREAM-B-01-01: System Architecture. This strand aims in 2024 solutions that may have been investigated in Call 2022 but now target a higher TRL and/or clear standardization opportunities. You may also add up to 3 topics that may not have been included in the list:

1. 6G system architecture structure and enablers covering simplification, sustainability, energy-efficiency, robustness and security.
2. Technologies for scaling inter-compute systems in dynamic multi-tenant environments.
3. New Data Transfer Paradigms, including enhanced data plane techniques with deep Edge integration.
4. Network exposure to vertical application developers.
5. Native integration of AI for telecommunications, including edge cloud continuum.
6. Pervasive Resilient Autonomic Control in Virtualised Systems.
7. Integrated and dependable sensing & actuation networks.
8. Deterministic Networking.
9. 6G Broadcasting.
10. Digital network twinning applied in 6G.

- *[Priority 1]*
- *[Priority 2]*
- *[Priority 3]*
- *[Priority 4]*
- *[Priority 5]*

Also, please select up to three topics that you consider that have not been included in the above list

- *[Topic]*
- *[Topic]*
- *[Topic]*

Q2: Please suggest the top 5 ranked topics from the list below related to HORIZON-JU-SNS-2024-STREAM-B-01-02: Wireless Communication Technologies and Signal Processing. This strand aims in 2024 solutions that may have been investigated in Call 2022 call but now target a higher TRL and/or clear standardization opportunities. You may also add up to 3 topics that may not have been included in the list:

1. New Waveforms, Random and Multiple Access and Enhanced Modulation and Coding for sustainable and efficient radio systems.
2. Human-friendly Radio systems.
3. Spectrum Re-farming and Reutilisation.
4. Cell-free and Extreme exploitation of MIMO technologies.
5. Seamless integration of multiple frequency bands.
6. Machine learning empowered physical layer evolutions.
7. Optimal usage of wireless edge caching.
8. Novel techniques for integrated sensing and communication.
9. Reconfigurable Intelligent Surfaces.
10. Joint Communication and Sensing.

- *[Priority 1]*
- *[Priority 2]*
- *[Priority 3]*
- *[Priority 4]*
- *[Priority 5]*

Also, please select up to three topics that you consider that have not been included in the above list

- *[Topic]*
- *[Topic]*
- *[Topic]*

Q3: Please suggest the top 5 ranked topics from the list below related to HORIZON-JU-SNS-2024-STREAM-B-01-03: Communication Infrastructure Technologies and Devices. This strand aims in 2024 solutions that may have been investigated in Call 2022 call but now target a higher TRL and/or clear standardization opportunities. You may also add up to 3 topics that may not have been included in the list

1. Flexible Capacity Scaling.
2. Ultra-high Energy Efficiency.
3. Integration of Optical and Wireless Technologies.

4. NTN infrastructures.
5. Integrated NTN service provision.
6. New IoT components and devices.
7. New Physical Layers and associated protocols.
8. Development of low-energy communication solutions.
9. Deterministic packet optical x-haul networks and technologies for 6G radio networks.
10. Open and disaggregated packet-optical systems for x-haul networks.

- *[Priority 1]*
- *[Priority 2]*
- *[Priority 3]*
- *[Priority 4]*
- *[Priority 5]*

Also, please select up to three topics that you consider that have not been included in the above list
- *[Topic]*
- *[Topic]*
- *[Topic]*

Q4: Please suggest the top 5 topics from the list below related to HORIZON-JU-SNS-2024-STREAM-B-01-04: Reliable Services and Smart Security. This strand aims in 2024 solutions that may have been investigated in Call 2022 call but now target a higher TRL and/or clear standardization opportunities. You may also add up to 3 topics that may not have been included in the list

1. Smart Service frameworks, including secure lifecycle management.
2. Efficient security enablers.
3. Service deployment for complex services.
4. Cooperative holistic E2E security for 6G architectures.
5. Zero-touch integrated security deployment.
6. Exploitation of (distributed) trusted AI/ML for 6G Infrastructures.
7. Developments on service technologies for secure time-sensitive and computation intensive applications.
8. Physical layer security.
9. Integration of operational security including third-party Security as a Service.
10. Quantum key distribution for secured 6G communications.

- *[Priority 1]*
- *[Priority 2]*
- *[Priority 3]*
- *[Priority 4]*
- *[Priority 5]*

Also, please select up to three topics that you consider that have not been included in the above list
- *[Topic]*
- *[Topic]*
- *[Topic]*

Q5: Do you believe that for 2025/2026 (expected EC funded budget of around 130 M€ per year) a similar distribution for resources as in 2022, 2023 and 2024 should take place between Stream B, C, D (e.g., > 60% for Stream B)?
Yes:
No:

Q6: Do you believe that for 2025/2026 the same Strands structure for Stream B should be followed? [e.g., Architecture, Wireless Communication and Signal Processing, Communication Infrastructure Technologies and Devices, Reliable Services and Smart Security]?
Yes:
No:

Q7: Do you believe that a SNS lighthouse project for AI/ML to combine results from existing SNS projects as well as create an overall framework for testing and evaluation is needed?
Yes:
No:

Q8: Please provide any additional comment you may have for the WP2024 or/and WP2025/26.
[max 500 words]

Table 14: Draft WP2024 – Second 6G-IA members consultation questions

Q1: Do you consider that the text describing the strand HORIZON-JU-SNS-2024-STREAM-B-01-01: System Architecture (Targeted Outcome and Scope), also considering the results of the previous consultation, is consistent with SNS program objectives?
Yes:
No:
Please provide some rationale for your answer [text….. 300 char]

Q2: Do you consider that the text describing the strand HORIZON-JU-SNS-2024-STREAM-B-01-02: Wireless Communication Technologies and Signal Processing (Targeted Outcome and Scope) is consistent with SNS program objectives?
Yes:
No:
Please provide some rationale for your answer [text….. 300 char]

Q3: Do you consider that the text describing the strand HORIZON-JU-SNS-2024-STREAM-B-01-03: Communication Infrastructure Technologies and Devices (Targeted Outcome and Scope) is consistent with SNS program objectives?
Yes:
No:
Please provide some rationale for your answer [text….. 300 char]

Q4: Do you consider that the text describing the strand HORIZON-JU-SNS-2024-STREAM-B-01-04: Reliable Services and Smart Security (Targeted Outcome and Scope) is consistent with SNS program objectives?
Yes:
No:
Please provide some rationale for your answer [text….. 300 char]

Q5a: Do you consider that the text describing the strand HORIZON-JU-SNS-2024-STREAM-B-01-07: Sustainability Lighthouse (Targeted Outcome and Scope) is consistent with SNS program objectives?
Yes:
No:
Please provide some rationale for your answer [text….. 300 char]

Q5b: Under the understanding that sustainability has three pillars (i.e., environment, societal and economic sustainability) would your organization consider that the following topics would be in scope of the Environmental Sustainability?

- Improving energy efficiency and total energy consumption (network and device side) Yes/No.
- Investigating network performance vs energy consumption trade-offs Yes/No.
- Improving materials efficiency and circularity Yes/No.
- Evaluating from a system and life cycle perspective, using environmental metrics Yes/No.
- Developing strategies to ensure that AI/ML techniques to be used in future 6G networks are environmentally sustainable Yes/No.
- Awareness of service users by exposition of sustainability attributes Yes/No.

Q6a: Do you consider that the text describing the strand HORIZON-JU-SNS-2024-STREAM-B-01-08: Reliable AI for Reliable Communications Systems and Services (Targeted Outcome and Scope) is consistent with SNS program objectives?
Yes:
No:
Please provide some rationale for your answer [text….. 300 char]

Q6b: As the main issue in AI/ML R&I activities, the existence of data sets is of paramount importance to achieve impactful results, we would like to investigate if the expectation to have such data sets for SNS R&I projects is a realistic ambition or not. Under this context, do you consider realistic that if your organization participates in this or future calls, it could provide:

- Real-world datasets for training/testing Yes/No.
- Synthetic datasets for training/testings: Yes/No.
- No datasets for training/testing: Yes/No.

Q7: Do you consider that the text describing the strand HORIZON-JU-SNS-2024-STREAM-C-01-01: SNS Microelectronics Lighthouse (Targeted Outcome and Scope) is consistent with SNS program objectives?
Yes:
No:
Please provide some rationale for your answer [text….. 300 char]

Q10: Do you consider that the text describing the strand HORIZON-JU-SNS-2024-STREAM-D-01-01: SNS Large Scale Trials and Pilots (LST&Ps) with Verticals? (Targeted Outcome and Scope) is consistent with SNS program objectives?
Yes:
No:
Please provide some rationale for your answer [text….. 300 char]

Q11: Do you agree to target tangible sustainability results from the Stream HORIZON-JU-SNS-2024-STREAM-D-01-01: SNS Large Scale Trials and Pilots (LST&Ps) with Verticals?
Yes:
No:
Please provide some rationale for your answer [text….. 300 char]

Table 15: Specific B01-01/02/03/04/05/06 Strands questions

Topic/Strand	
B01-01 - System Architecture	○ AI powered edge cloud continuum. ○ Technologies for efficient Network and Service Resource Management in dynamic multi-tenant environments. ○ Energy efficiency enablers. ○ Pervasive Resilient Autonomic Resource Control in Virtualised Systems. ○ Integrated and dependable sensing & actuation networks. ○ Digital network twinning applied in 6G. ○ New Communication Paradigms with enhanced intelligence.
B01-02 - Wireless Communication Technologies and Signal Processing	○ New physical layer technologies up to millimeter wave. ○ Extreme exploitation of MIMO technologies up to millimeter wave range. ○ Human-friendly Radio systems. ○ Spectrum Re-farming and Reutilisation. ○ Seamless integration of multiple frequency bands across a unified energy, EMF, and spectrum efficient framework. ○ Machine learning empowered physical layer evolutions. ○ Optimal usage of wireless edge caching. ○ Novel techniques for integrated sensing and communication.
B01-03 - Communication Infrastructure Technologies and Devices	○ Troposphere Networking. ○ Integration of Optical and Wireless Technologies of advanced light related technologies. ○ Nano-Things Networking. ○ Development of low-energy communication solutions. ○ Packet optical technologies for 6G radio networks.
B01-04 – Reliable Services and Smart Security	○ Service deployment for complex services. ○ Cooperative holistic E2E security for 6G architectures. ○ Zero-touch integrated security deployment. ○ Exploitation of (distributed) AI/ML for 6G Infrastructures. ○ Developments on service technologies for secure time-sensitive and computation intensive applications. ○ Physical layer security. ○ Human Centric methods that give the control to the user to guarantee privacy and confidentiality.
B01-05 – Microelectronic-based Solutions for 6G Networks	○ Topic 1: Energy and Cost-Efficient Radio Hardware for 6G RAN Solutions ▪ Very wideband transceivers. ▪ Joint communication and sensing. ▪ Full-duplex RF frontends for massive MIMO. ▪ Reconfigurable surfaces. ▪ Multi-band or multi-octave transceivers. ▪ NTN environments requirements for low/medium earth orbit. ▪ Other (please state what). ○ Topic 2: Beamforming and Multi-User Technologies ○ Wideband beamforming. ○ True time delay. ○ Solutions for beam squint.

	○ Run-time calibration. ○ Hybrid beamforming and MIMO. ○ THz antenna systems. ○ Other (please state what). ○ Topic 3: Antenna and Packaging Technologies and Materials for 6G RAN Solutions ▪ On-chip antennas. ▪ Lens-integrated antennas. ▪ Planar and conformal antenna arrays. ▪ Integrated waveguides. ▪ Low loss distribution networks. ▪ Beamforming and MIMO. ▪ Meta-materials and meta-surfaces. ▪ human friendly radio systems. ▪ Other (please state what).
B01-06 – EU-US 6G R&I Cooperation	○ Topic 1: 6G Technologies and Architectures Powered by Artificial Intelligence. ▪ Lower layer radio aspects. ▪ Higher layers targeting intelligent function placement. ▪ Network self-configuration. ▪ Security and resilience. ▪ AI based support of user applications. ○ Topic 2: Reference Framework for AI Usage ▪ Methodologies. ▪ Reference use cases. ▪ Data acquisition and generation. ▪ Repositories. ▪ Curated training and evaluation data. ▪ Functionalities needed to use it as a benchmarking platform. ○ Topic 3: Contributing to 6G Human Centricity and Societal Acceptance ▪ Availability on data sets.

Table 16: Specific C01-01 and D01-01 Strands questions

Topic/Strand	
C01-01 – Complementary SNS Experimental pan-EU Federated Infrastructure	○ Validate a representative end-to-end 6G architecture: ▪ A. disaggregated and open architectures. ▪ B. secure end-to-end service provisioning with slicing capabilities. ▪ C. architectures beyond the 5G SBA, notably the AI native architecture. ▪ D. cloud continuum including operational multi-access edge computing. ○ European federated open platforms: ▪ A. capability extension towards US. ▪ B. synergies with 6G platforms developed in EU Member States or associated countries. ○ Assess 6G KPIs & demonstrate the operational performance of 6G candidate technologies. ○ Integrate full value chain experiments covering IoT/devices, connectivity, and service delivery. ○ Support innovative use cases and applications for the large-scale trials and pilots. ○ Assess 6G KPIs & demonstrate the operational performance of 6G candidate technologies. ○ Support the demonstration of the technological operational feasibility of key societal requirements and objectives. ○ Validate management functions. ○ Support integration of key 6G related KDT developments.
D01-01- SNS Large Scale Trials and Pilots with Verticals	○ Integrate vertical use cases specific performance/KPI requirements, as applicable also across public and non-public networks and services. ○ Validated infrastructure core technologies and architectures in the context of vertical large-scale pilot use-case implementations and relevant deployment scenarios.

	○ Validated core technologies and architectures across the value chain (IoT, connectivity, services) for differentiated performance requirements. ○ Viable business models for innovative digital use cases tested and validated across a multiplicity of industrial sectors. ○ Support to impactful contributions towards standardisation bodies. ○ Repository of requirements from verticals and of "lessons learned" to prepare for subsequent phases of the SNS programme. ○ Contribution to a repository of open-source tools and modules. ○ Collection of new requirements that are needed in subsequent phases.

